Build Homework – Semester 1

Fortnight 3 CECS8001 – 2021

External Conditions Influence on the Refrigerator's Temperature

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Abstract

This report's main aim is to see how the refrigerator's temperatures have changed over time with the influence of external conditions such as the refrigerator volume and the frequency of door opening in comparison to the outside room temperature. Temperatures were recorded at the refrigerator compartment's middle level using a Circuit Playground Express (CPE) from Adafruit. The main sample refrigerators were on average 6.5 °C, a minimum of 4.5 °C and a maximum of 8.6 °C. I found that the temperature fluctuated inside the refrigerator and seemed dependent on the external condition that I experimented with. This report shows the influence of the external conditions on the temperature.

Introduction

Refrigerator is becoming one of the "must-have" appliances in our household these days. According to the U.S. FDA (2014), the refrigerator temperature needs to be kept at or below 40° F (4° C), and the freezer temperature should be 0° F (-18° C). Refrigerator temperatures play a crucial role in minimizing food spoilage and waste and the growth of microorganisms that can be added for further research but not included in this report. Laguerre et al. (2002) mentioned that for highly perishable food such as meat and meat products (Figure 1), the preservation temperature should not exceed 2–4 °C, also different optimum temperature depending on the type of product.

Temperature	Foodstuffs
0–2 °C	Fish and seafood
+ 2 °C	Ground meat
+ 4 °C	Various types of meat and meat preparations, sausage, chicken, fresh milk, cheese
+ 5 °C	Eggs
+ 8 °C	Stable meat products, dairy products

Figure 1 Optimum Temperature for Different Type of Food

Sometimes when I buy the fresh fruit and vegetables after a couple of days, they usually go soft and not fresh or crunchy anymore. So, I want to see if the temperature inside is constant or fluctuated every day. And I wonder if the temperature fluctuation will affect the quality of the food stored inside. I also want to know the temperature average inside the refrigerator when it's full or empty, the highest and lowest temperature, how the temperature changed over time between weekdays and weekends, what cause the inside temperature to change. How frequent door opening/closing affects the temperature and the implications of frequent door opening/closing to the overall refrigerator temperature average concerning food quality.

I'm interested in finding out about those because I have two young children who often open and close the refrigerator door to get some snacks and drinks who occasionally didn't shut the door properly. So, I would like to know if those behaviours will influence the average temperature inside and negatively impact the fresh food's quality and longevity inside the refrigerator. I assume the steady temperature can prolong the use-by date for fresh food, therefore, reduces the food waste ultimately.

To answer those questions, I need to understand the refrigerator system how it works to start with. What the relationship between the refrigerator structure and its temperature sensor behaviour in particular, what influence the sensor to produce specific reading patterns and results. I can use system thinking to help identify the root causes of problems and see new opportunities,

Meadows (2008) mentioned that a system is a set of interconnected "things" in such a way that they produce their pattern of behaviour over time. Outside forces can influence the design, and the system's response to these forces is simply unique. My aim in creating this model is to help explore and answer my research question, perhaps finding a new way to keep fresh food longer and save energy power consumption in the long run.

Methods

I use the circuit python playground to measure the refrigerator's temperature because it has the temperature sensor built into the circuit. I could use the standard thermometer, but the temperature will have to be checked and recorded manually. The circuit playground can measure and record the temperature over a set time and the number of readings that I can set/program using the Mu Editor application. After I activated the circuit python playground following the instruction from Memunat Ibrahim and updated it to the latest version, I tried to run it and measured the room temperature few times and saved the data each time.

1. In the first experiment, I wanted to measure the average refrigerator temperature to see if there's fluctuation with the temperature over time. I set up the number of readings to 500 with an interval of 10 minutes (time.sleep = 600 seconds). I went back to Sydney that weekend, and I was hoping to see the circuit can measure the temperature over the weekend (~3.5 days) without any interruption from me opening and closing the door at all. Unfortunately, the reading stopped at 288, not 500, which was only 48 hours (2 days).
2. In the second experiment, I wanted to measure the temperature with different external condition factors, such as when the refrigerator is empty or full when the refrigerator is open for a long time. I set up the number of readings to a lower number (60) with an interval of 1 minute (time.sleep = 60 seconds) because I want to compare the shorter period. Also, because if I take out the food from the refrigerator (to run the experiment for empty refrigerator temperature) and leave them outside for too long, they will go off and become food waste.

This method can address my initial assumption that the more often you open the refrigerator door, the higher the refrigerator's inside temperature because you let the outside temperature in therefore adjust the equilibrium of the temperature overall. The impact on fresh food inside the refrigerator could also be significant to the degree of increasing food waste.

But this method has some limitations to consider with some other factors such as the humidity, time of the day, and the experiment's duration. Also, I used the mini-sized bar refrigerator with a small freezer section integrated on the top, which can also affect the overall temperature. This refrigerator that I used has a relatively low energy start rating (only 2 out of 5). To draw a more accurate conclusion, the experiment will need a longer duration (more than 7 days). I need to use a better or bigger refrigerator with an energy rating of more than 2 and use a different device to measure the temperature and use more state variables to be measured, not only temperature but also humidity and air quality.

Those limitations constrain what I can or cannot do, and I have to adjust my experimentation and adapt my conclusion. For example, with the time constraints and limited option for device availability for this experiment, I will only monitor a particular refrigerator aspect, which is the temperature. I'm aware that the conclusion that I draw from the assumptions I made can be pretty narrow and limited to my constraints. So, it may not be accurate and need further improvements in the future. But my assumptions are made reasonable enough because I believe that my refrigerator was in excellent condition; therefore, the thermostat should be working correctly and not too many fluctuations. As mentioned before, I use a much smaller refrigerator (bar size bridge) in my accommodation room here in Canberra compare to the refrigerator that I have back in Sydney. So, the result can be the model to predict the bigger version.

Methods that I do to measure is mixed between qualitative and quantitative. Although I am taking a range of actual measurement data quantitatively to gain insights on system properties, I compare the system insight or aspect more qualitatively due to my limitations and constraints.

From the first session on fortnight 3, I learnt that the refrigerator system diagram could be illustrated as shown in Figure 2, where one system can have open or closed-loop either positive or negative feedback to the next connected system.

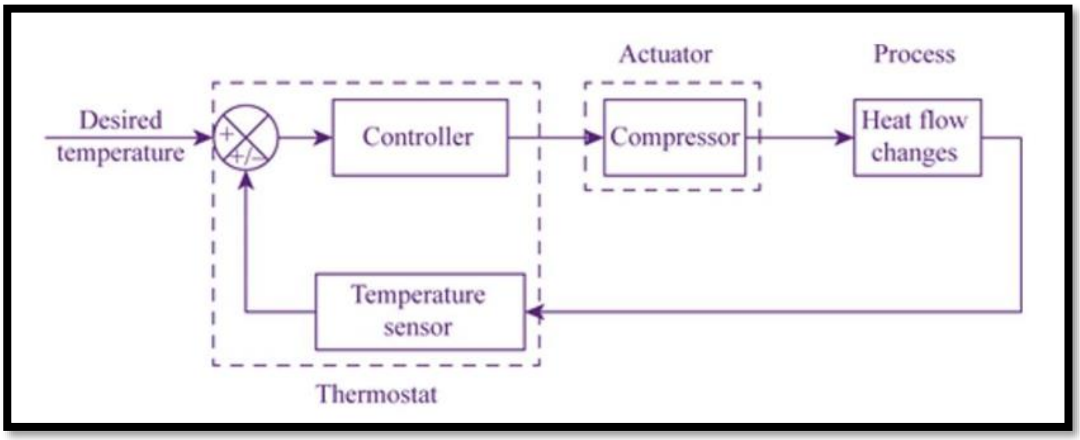


Figure 2 Refrigerator System Diagram

Based on the example on "Constructing an Influence Diagram" that Proust & Newell (2020) illustrated, I created my causal loop diagram using step by step as shown in Figure 3.

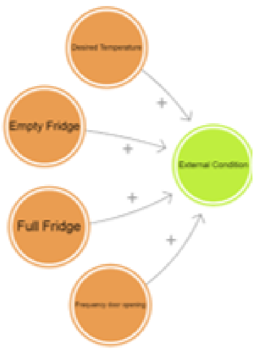
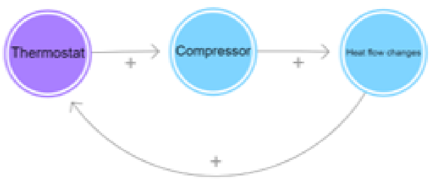
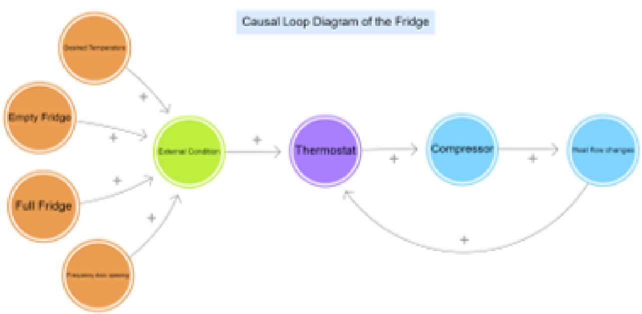
Step 1 Think about the problem situation, list some variables, do some rough sketches of links.	
Thermostat	**Step 2** Identify a focus variable X whose level you believe plays a key role in the system-of-interest or problem situation.
	**Step 3** Add driver variables. Changes in the level (size, magnitude, value) of any of these variables can affect the level of X. Draw arrows to indicate your statement that the driver variables can influence (have an effect on) X. Try to keep the number of driver variables small, about 3 or 4. This will help you to select the most important variables.
	**Step 4** Add affected variables. These are variables whose levels can be affected by changes in the level of X. Draw arrows to indicate your statement that the affected variables can be influenced by X. Keep the number of affected variables small, about 3 or 4.
	**Step 5** Draw additional influence links to describe possible feedback loops. Add a few variables, if needed, to help build the feedback loops and capture your view of the dominant cause-effect structure. But keep the total number of variables as small as possible (≤ 10). When feedback loops are constructed the distinction between driver variables and affected variables becomes meaningless. Changes in the level of any variable in a feedback loop are both cause and effect.

Figure 3 Refrigerator Causal Loop Diagram

Using the Loopy diagram, I tried to illustrate this causal loop diagram of my refrigerator as shown in Figure 4, and the feedbacks were all positive or reinforcing feedback.

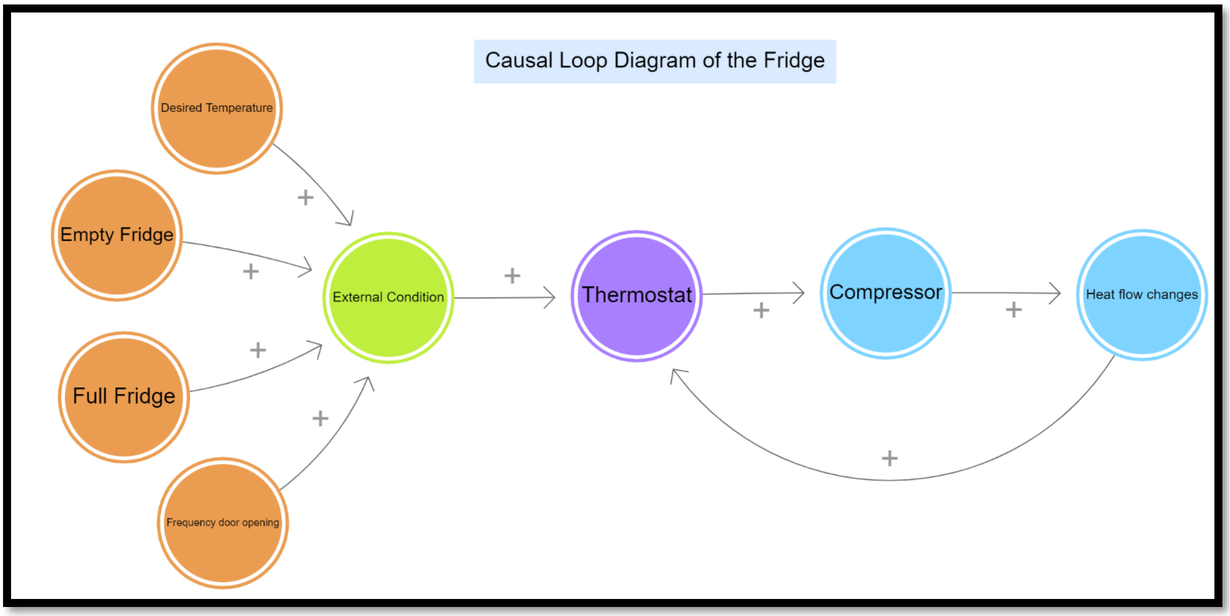


Figure 4 Reinforcing Feedback Loop

For my experiment, I collected the measurement from the middle of the refrigerator section, storage shelf number 4 from the appliance diagram as shown in Figure 5, which I thought can be the perfect spot to measure the inside temperature overall, instead of inside the temperature regulator house or the thermostat system from the diagram which is the freezer part on this mini refrigerator unit.

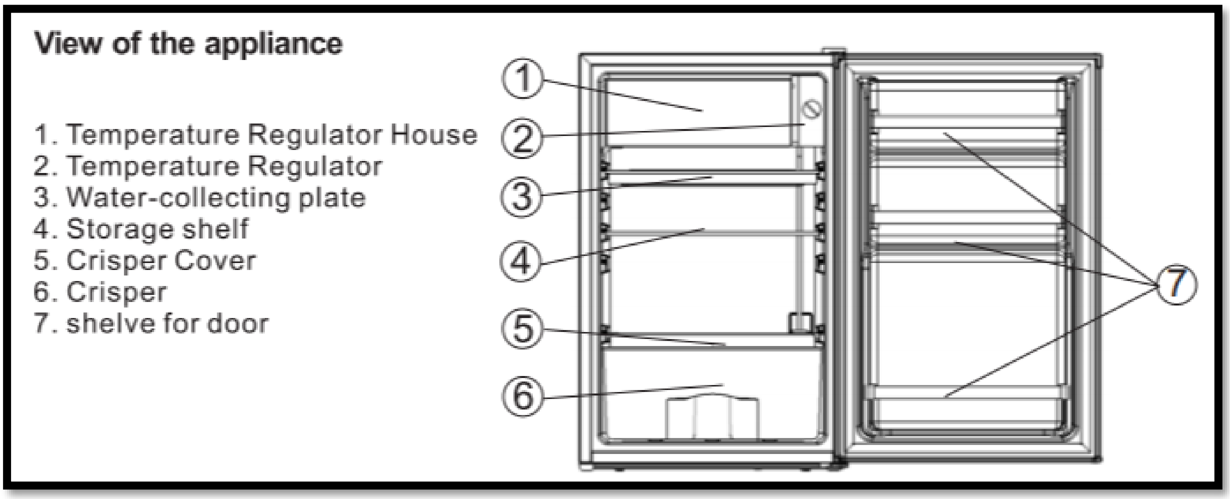


Figure 5 Hisense Refrigerator View of the Appliance[1]

[1] https://hisense.com.au/wp-content/uploads/2015/11/HR6BF121-FINAL.pdf

Analysis

The dataset that I gathered from the readings is extracted as a CSV excel file with the interval times every 600 seconds that I set up at the beginning. But I noticed that on every 9th dataset, I got an extra one second added (in red), as shown in Figure 6. By the end of my readings, I have more than 30 seconds added to the total. So, this could be one of the measurement problems if you want a higher accuracy. From the seconds, I have to convert them into the hour for the ease of plotting the dataset in a line chart style, as shown in Figure 7.

Time (s) (start = 10:45 pm)	Temp (C)
0	8.3
600	5.9
1200	5.7
1800	6.2
2400	6.8
3000	7.5
3600	8.1
4200	8.1
4801	6.9
5401	5.4
6001	5
6601	5.4
7201	6.1
7801	6.9
8401	7.4
9001	8
9601	7.5
10202	6.1
10802	4.9
11402	5
12002	5.5
12602	6.3
13202	6.9
13802	7.5
14402	7.8
15003	6.9
15603	5.4
16203	4.7

Figure 6 Extra One Second for Every Ninth Reading

The first set of data that I gathered over the first-weekend present the constant reading with the average temperature around 6.5 °C when I draw the linear trendline for the line chart, as shown in Figure 7. There are some highs and lows temperature between 4.5 - 8.6 °C in a pretty consistent zigzag pattern (more details on Table 1). So, this indicated that the thermostat system in the refrigerator is fluctuating every hour in general.

Weekend Temperature.xlsx

Table 1 Weekend Temperature

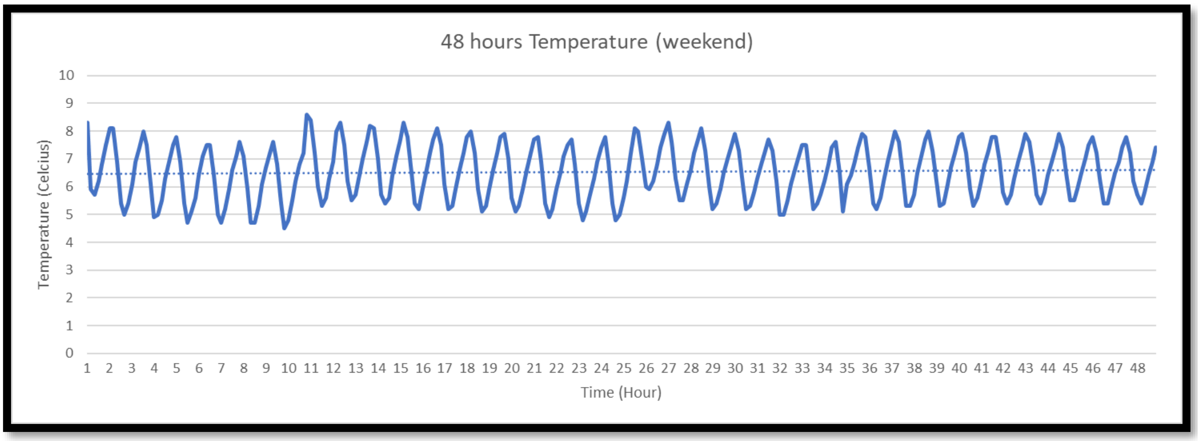


Figure 7 Weekend Temperature Chart

Then I tried to measure the temperature influenced by different external conditions such as the refrigerator's volume (full and empty) and the door opening frequency. First, I measure the room temperature per minute for 60 minutes. However, I only use the last 30 minutes to get more accurate readings as the first 10 readings usually still influenced by the previous condition (room temperature) and can cause the anomaly or skewed line on the chart. Then follow by empty the refrigerator as shown in Figure 8. After that, I put all the food back inside the refrigerator again (full refrigerator) and measured the temperature per minute for 60 minutes, as shown in Figure 9.

Figure 8 Empty Refrigerator

Figure 9 Full Refrigerator

Lastly, I keep the refrigerator door open for 60 minutes while it's full and measure the temperature per minute. I was a bit worried if this will damage the food I have, but fortunately, everything is fine. Nothing goes to waste because Canberra weather is relatively much cool compared to Sydney, so there is no significant damage to the food I can see. However, the conclusion that I make can be very bias because I only look at one small refrigerator, which is not representative of all the refrigerator in general. From all four experiments, I compare the temperatures as shown the Figure 10.

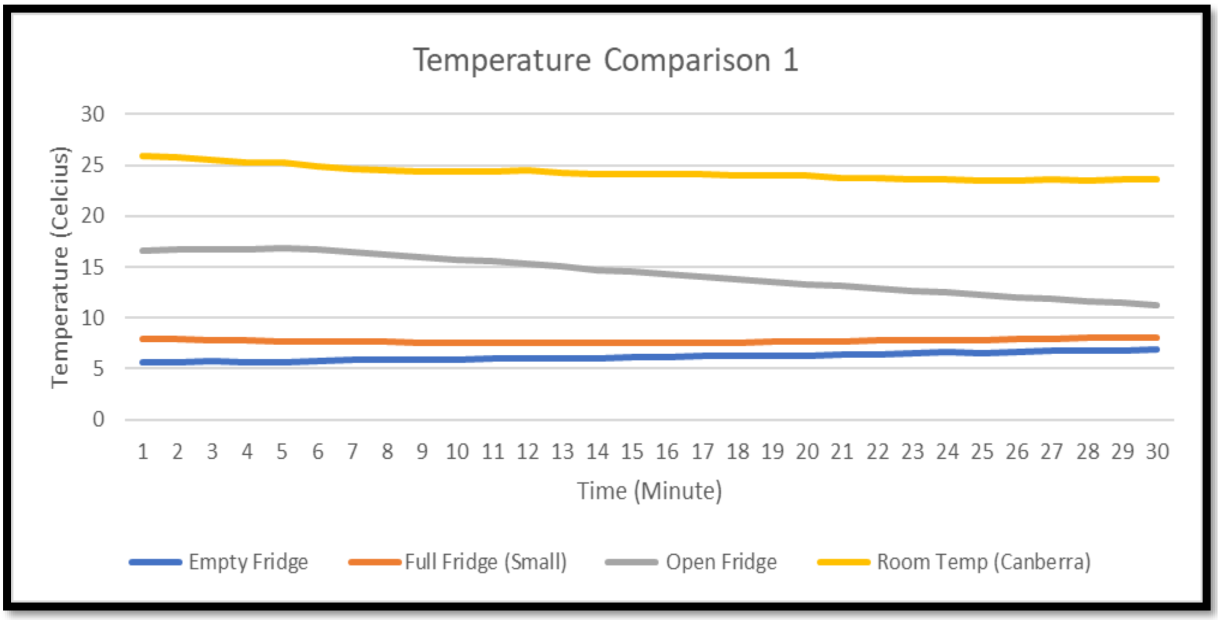


Figure 10 Temperature Comparison 1

We can see that the full refrigerator average temperature is higher than when it's empty because the more volume inside the refrigerator, the higher the average temperature inside and more energy it requires to cool down the temperature, and the thermostat takes time to balance this. Furthermore, when you put some hot food inside the refrigerator, this can cause the thermostat to work even more complex and more protracted, resulting in food waste if prolonged.

When I come back to Sydney for the Easter long weekend, I want to see if there are any temperature differences with the refrigerator size. I measure the temperature in the same way as previously. I put inside the refrigerator on the middle compartment and measure every minute for 60 minutes, but I only use the data for the last 30 minutes. The comparison results are shown in Figure 11 and Table 2.

Temperature Comparison.xlsx

Table 2 Temperature Comparison

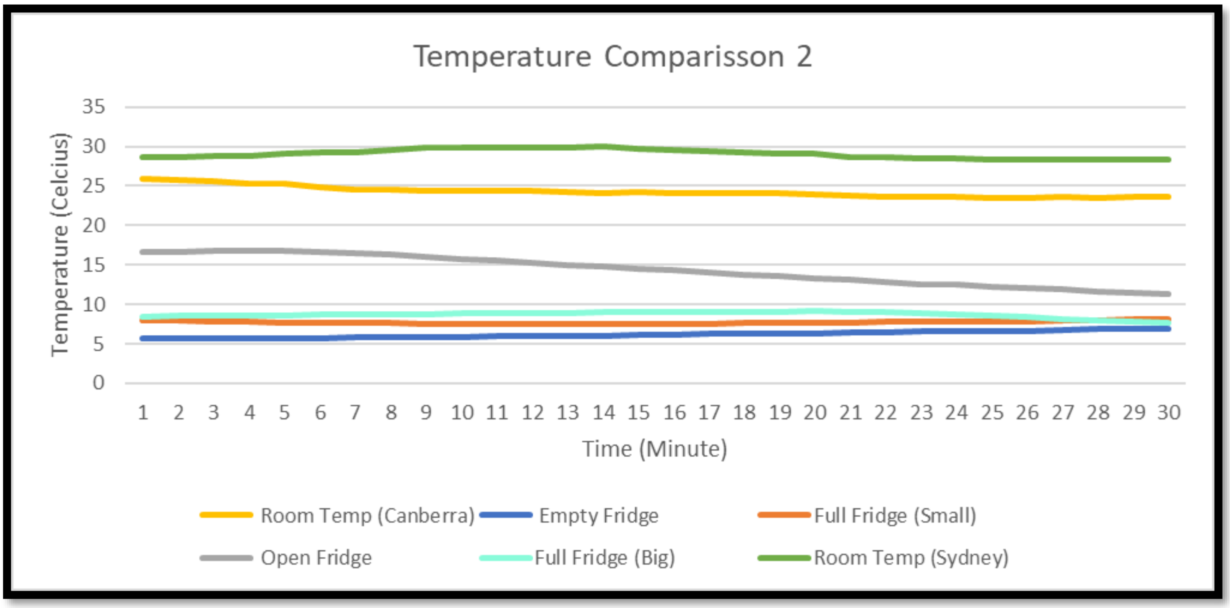


Figure 11 Temperature Comparison 2

Qualitatively, I can identify a couple of sources of error that I need to take into account to analyze the result properly:

1. The temperature sensor in the CPE to collect data might not be the correct type of sensor to use in measuring for the refrigerator because the humidity inside the refrigerator could affect the sensor's accuracy. I put the CPE inside the plastic zip bag to reduce the humidity effect on the CPE.
2. From the datasheet output in excel format, I can only see the start time and the time.sleep which is the interval for each reading that I need to change/set up at the beginning, and I have to convert them manually into meaningful information (minutes, hours, days, etc.). I also understand that the CPE can't measure the humidity or other measurement to improve temperature readings' accuracy.

Results / Discussion

Based on my analysis section previously, I need to revisit my system map. The evidence has suggested that my system map needs to change to balance the thermostat, compressor, and heat flow changes. From my initial system map, I had reinforcing (positive) feedback for all of their relationships. But the evidence that I have gathered from my experiments shows that some aspects of my original system map need some amendments. There are some ups and downs with the temperature; it's a zigzag and not a linear for all the different external conditions that I tried in my experiments. Some balancing (negative) feedback needs to be added to the system map to reflect my experiments' evidence.

The thermostat in a refrigerator is an excellent example of a balancing (negative) feedback that works to hold the equilibrium and steady condition instead of the reinforcing (positive) feedback that I thought initially. Based on the SystemViz by Stoyko (2019), I see that the thermostat system taxonomy can be classified as the Relation with the complicated element of NETWORK where the thermostat interconnected with other parts and interact directly through common linkages and the constellation of their connections, as well as COUPLING because of the tightness of ties between parts of the refrigerator system and the degrees of freedom in their relationship. The external condition can be classified as Domain that exists in the physical environment. It can influence the thermostat and another part of the refrigerator system, particularly as the Ambient Conditions that continually change the physical environment to affect the refrigerator thermostat system operations. Compressor and heat flow changes should have the balancing feedback to the thermostat, and I redraw the new system map diagram as shown in Figure 12.

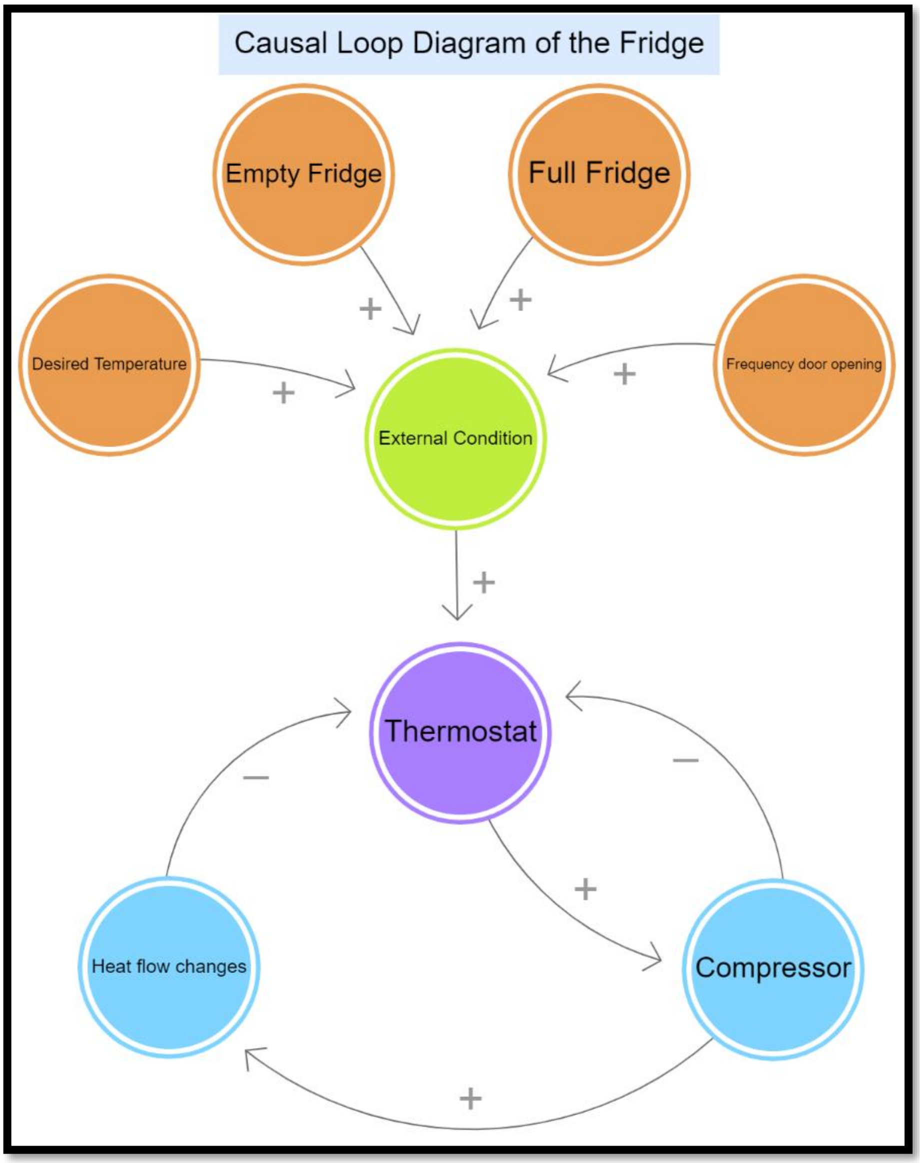


Figure 12 Balancing Feedback

One of my experiment's limitations is that I only use one type of equipment/device provided, which is CPE. I didn't try to use any alternative equipment, mainly because of the time constraint. My first attempt was half failed because the readings stopped halfway through. The follow-up attempts also failed few times. Every time I changed the slide switch and pressed the reset button, the CPE kept erasing the Boot.py, Code.py, and temp excel file. I tried with not just one or two but three CPEs, and all had the same outcome, still unable to see the files at all and automatically reset each time I tried to sync it over the laptop with the LED D13 turn red, as shown in Figure 13.

Figure 13 CPE Error

Thank you to Chloe for lending me her CPE that she used (the 3rd CPE that I tried), and thank you, Johan and Mina, for your help in solving the CPE reset. Johan found out that I didn't have any space left in my CPE. Apparently, I have too much reading data from the previous weekend readings that I used up all the 2 M.B. of SPI Flash storage as I didn't delete anything and kept saving them all each time. So, I had to save the existing files first, rename and save them in a different location/folder. Then, delete the data on the CPE excel file to have enough space for the subsequent readings. This seems to solve the reset issue, and I can carry on for the following experiments. But then the LED D13 red light turned on again halfway on my new experiment.

Given that I have fixed the storage issue and I have tried 3 different CPEs, also I checked the codes, and it worked previously. I assume it must be something so critical that it keeps giving me the red-light issue, such as the battery. So, I replaced the batteries with the new set and tried to do the following experiment again, and it finally worked. I realized that I've been using the old batteries from my previous experiments, the CPS story build session with Mark Thomson. I learned that I need to keep saving and removing the CPE data after every experiments and data collection. If using electronic devices, always start the experiment with a new battery 😊.

Conclusion

The temperature difference between the readings during weekdays and weekends is not significant. The comparison of temperature measured using a circuit playground express for every second for 30 minutes and every 10 minutes over 2 days shows no relationship between these two temperatures. This could mean that the temperature measured using the circuit playground express does not represent the refrigerator's proper operating conditions. When the temperature data are analysed for all refrigerators without distinguishing the external condition, the mean temperature is 6.5 C. However, when the analysis was performed considering the external condition, the mean temperature was varied for each condition. Sydney has a higher room temperature than Canberra, which influences the CPE reading slightly higher for my bigger refrigerator in Sydney compared to my mini refrigerator in Canberra.

My research shows that the combination of the external conditions (desired temperature setting, volume of the food, frequency of door openings) seems to have a valid impact on the refrigerator temperature. Furthermore, temperature impact on the growth of microorganisms and food waste or using a different device to measure the other parameters, such as organising the refrigerator compartment to optimise the power consumption and food preservation, can be exciting topics to research in the future.

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