(1) Cover Page

ECE-492 Team #11

Sustainable Fridge Proposal

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2) Executive Summary

The project goal is to create a new type of fridge that will allow fruits and vegetables to last far longer than what they currently last do to the current fridges on the market. The fridge will be able to do this with new internal Crisper drawers using technology to control the temperature and humidity in the drawers, thus putting the internal environment of the crispers at the correct level that the fruit or vegetable likes. These new crispers will have temperature and humidity sensors to keep track of the internal levels, small mist machine to create humidity, vents and fans leading to inside of fridge for cooling and removing humidity, and a Peltier module to warm the crispers insides up. Finally, throughout all this will be a processing module controlling these devices and a display showing data about the crispers along with a user input for selection of what type of fruit or vegetable is being put where.

The benefits and deliverables to this new fridge model will be fruits and vegetables will last longer, thus allowing the modern household to not have to go to the grocery store as much. This also saves on money in the long run, and helps the environment. The project team will deliver to the project lead the new Fridge, project computer code that will be used in the processing module, and design diagrams showing how everything is hooked up. All these documents will in essence allow anyone to produce the team's new fridge model.

3) Problem Statement

Motivation:

Most families and single person homes face a crisis in the form of not having enough nutritional fruits and vegetables in the fridge. A modern family normally has to go to the store around twice a week since the normal sized fridge crisper drawers are too small to have a large amount of fruits and vegetables in them and more importantly the fruits and vegetables stored in them regrettable turn bad within days. Therefore, we have come up with a new type of crisper drawer that will keep fruits and vegetables fresh longer and more of them in the drawer. In this way families will have the nutritional fruits and vegetables they need for longer and they will not have to go to the store as often.

Identification of Need:

- To Design 2-4 large _ by _ Crisper Drawers, and 2-4 small _ by _ Crisper Drawers that will keep Fruits and Vegetables Fresh longer.
- Each drawer will be insulated using rugged cooler types of technology. Current drawers are not insulated.
- Each drawer will have the ability to affect the temperature and humidity inside. Current drawer types can allow minimal control of humidity and no control over temperature.
- An LCD display or another type of display will allow user to interact with the inside of each drawer controlling the temperature and humidity from preset measurements where the user only has to enter what type of fruit or vegetable inside the drawer. Current fridges have no interaction and control, but they do have an LCD display showing current temperature throughout the fridge.
- Drawers must keep track of temperature and humidity and compare those it to preset measurements that will determine if the temperature or humidity needs to be increased or decreased which the system will automatically do without user input.
- New fridges on the market with humidity control are expensive. Ours will be considerably less in cost.

Market/Application Review:

The new designed crisper drawers will be a major enhancement over current models. These current models only allow very small adjustments in humidity and even then, it is only in the expensive fridges that have this control; such fridges like the Samsung RF28R7351SR, or the Viking VCSB5483SS have a cost of $3000-$12,000. This project will at least match the performance of current products while keeping the design cost low. The chambers in our design will act as a replacement for standard crisper drawers. It will showcase how technology in a fridge can be utilized to extend food life and indirectly influence better eating habits.

4) Approach

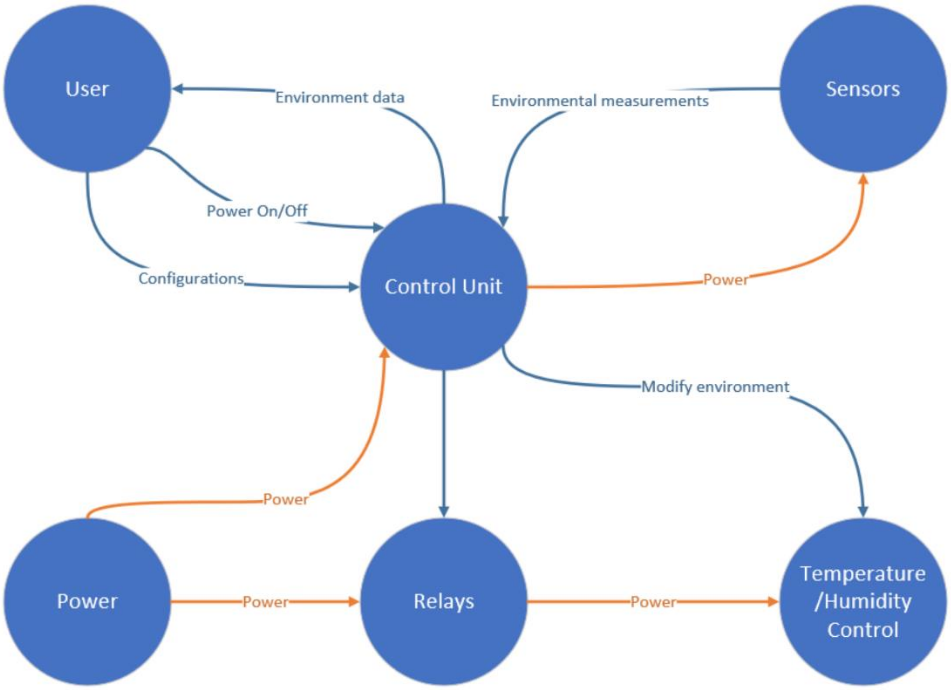
Problem Analysis

Introduction

The objective of this project is to reduce food waste, primarily produce discarded due to decay. Additionally, it will promote healthier diets by keeping vegetables fresh for longer periods of time making them more accessible to the user.

User interface design

The user interface will constantly display a splash screen with the current produce group, temperature, and humidity in each chamber. Additionally, the user will be given the option to reset individual chamber's presets for specific vegetable/fruit groups which involves adjusting humidity and temperature requirements.



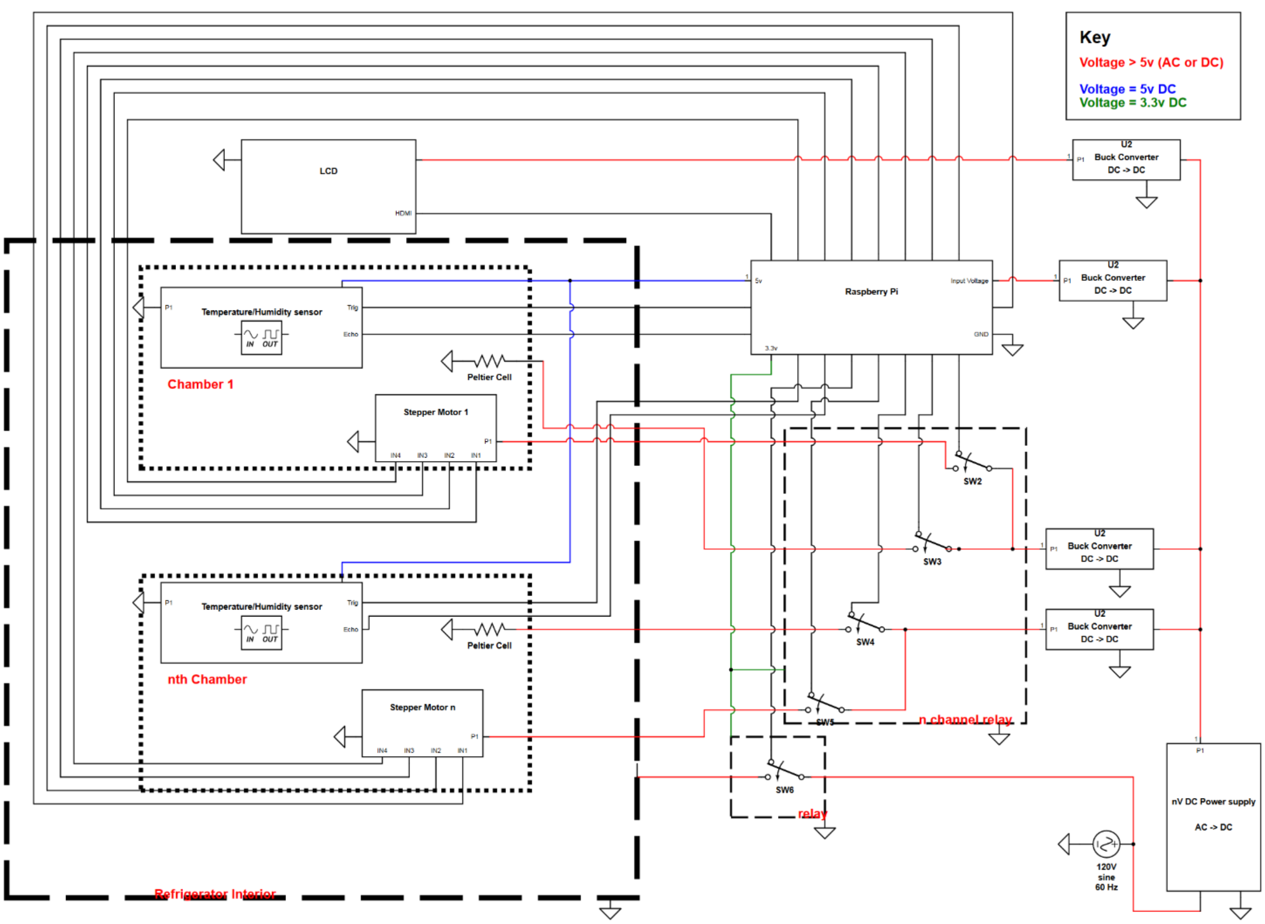
Usage Scenarios

The most common usage scenario will involve a user arriving with fresh produce. Firstly, the user will observe the splash screen to check for available chambers and what vegetable groups are currently within the refrigerator. Next the user will sperate and produce that can go into the existing chambers. After that the user will select from the display the options to configure the next available chamber, the system will display presets with descriptions of the produce that is acceptable to store in those conditions. Lastly the user will place all the produce in its corresponding chamber. The system will display updated chamber assignments and temperature/humidity readings.

Prototype

Initial design of the prototype:

**this design will be updated to use all the space for produce chambers as instructed by the customer.



Design components and specifications

Stepper motor: 28BYJ48-12-300-01

Operational voltage range: 5 – 12 V

Pull-in torque at 500pps: ≥ 0.0294 N-m

Number of phases: 2

Resistance per phase: 300 Ω

Motor driver Chip: ULN2003A

Max input Voltage: 30 V

Max output Voltage: 50 V

Max continuous collector current: 500 mA

Max continuous base current: 25 mA

Operating ambient temperature range: - 40 to 85 °C

Operating voltage: 5V

Temperature/Humidity sensor: DHT11

Operational voltage range I/O: 3 – 5 V

Max current: 2.5 mA

Operational temperature range: 0 - 50°C ± 2°C accuracy

Operational humidity range: 20-80% ± 5% accuracy

Sampling rate: 1Hz

Peltier cells: TES1-12703 (30 x 30mm)

Operational Temperature: -156°C to 80°C

Max current: 3.5 A

Max voltage: 15.4 V

Decision matrices

Cooling methods rated (1 – 3)

	Cost	Member experience	Complexity estimate	Score
Refrigeration ducts	2	1	3	6
Peltier cells (for cooling)	2	1	1	4

Sensing methods rated (1 – 3)

	Member experience	accuracy	Humidity measurement capable	cost	Complexity estimate	Score
DHT11	3	1	3	3	3	13
LM35	1	3	N/A	3	2	9

Humidity control rated (1 – 3)

	Cost	Size of equipment	Maintenance	Score
Misting system	1	1	1	3
Peltier cells (heat to produce steam)	3	3	3	9

The decision matrix above was how we determined what type of equipment would be best used. These were rated on a scale from 1 to 3. The highest score of the method would be the method that we would use on the project going forth.

Work Products

The design will require extensive programming, since it will be primarily controlled by a Raspberry Pi 3 the main program will make use of extensive open-source code. The code referenced will give the Raspberry Pi control over multiple peripherals including stepper motors, temperature/humidity sensors and relays.

Integration with existing processes

The completed project will not need to integrate with other existing systems to do its job. Making the current system information accessible on mobile devices will be on the top of our wish list for this project.

Feedback from customer

The customer was satisfied with the initial prototype design, they did stress that they would rather have a refrigerator dedicated only to produce instead of a dual-purpose system. Additionally, they proposed possibly testing vitamin A and other nutritional values in produce after prolonged storage.

Approach

To meet our project requirements the team has proposed the following approach.

- To keep similar produce groupings at optimum storage temperature we have sectioned off the main storage area of a refrigerator into individual temperature and humidity-controlled chambers.
- To measure temperature and humidity, sensors are housed within each chamber.
- To keep temperature and humidity levels at optimum refrigeration ducts and Peltier modules are installed in each chamber. If that design fails, we will switch to modifying a heat pump that will remove heat from the chamber in order to cool down the food..
- To power all added components to the refrigerator buck converters are added in parallel to the refrigerator's main power input. Relays are added to enable the control of power delivery.
- To control power delivery, monitor temperature/humidity, and adjust temperature/humidity values a Raspberry Pi 3 is added to the refrigerator. If the Raspberry Pi 3 is unable to do these tasks, we will use another processing module to run our commands, such as BeagleBone, MSP430, etc.
- To give the user feedback and control over the system conditions, an interactive display is installed.
- To test the efficacy of the system a control refrigerator will be set up with identical produce stored inside.

Project requirements specifications

Mission requirements

The system shall decrease refrigerated produce lost to decay and encourage healthier diets.

Operational Requirements:

Input output requirements:

- The device shall take input from the temperature and humidity sensors
- The device will accept user input to adjust temperature within chambers
- The device shall use stepper/servo motors to open selected chamber for ventilation
- The device shall display measurement readouts to user
- The device should have an lcd screen to display measurement readouts
- To maintain a constant environment, the device should report measurements to the cloud every 5 to 10 minutes

Functional requirements:

- The device shall measure temperature and humidity
- The device shall select the appropriate chamber for ventilation
- The device should report measurements to the user through the cloud every 5 to 10 minutes
- The device should detect errors and report to the user

Technology and system-wide requirements:

- The device shall use a Raspberry Pi because it meets our project requirements and high number of GPIO ports allow us to control multiple components at the same time
- The device should be low-cost
- The device will display data on an LCD
- The device should have internet access and communicate data to the cloud in order to report sensor readings and system status to the user

Alternative approaches

Our proposed solution involves a dual approach of informing and educating the user and temperature and humidity monitoring and control. Having both of these allows for more customization to the user's needs. Alternative approaches could focus solely on one of these components and disregard the other. For example, focusing mainly on educating users on how to best store food, or leaving out the end-user aspect and taking a broader optimization approach. This might involve keeping the entire fridge at temperatures and humidity levels that are optimal only for common fruits and vegetables. Other approaches might focus on Ultraviolet light, which has been used successfully in many areas of the food industry, especially dairy. Having UV light as a potential deterrent for bacteria and mold growth could possibly extend the shelf life of some refrigerated items. Finally, another approach might go into depth on controlled-atmosphere storage, keeping oxygen and ethylene gases in low concentrations to prevent microbial growth.

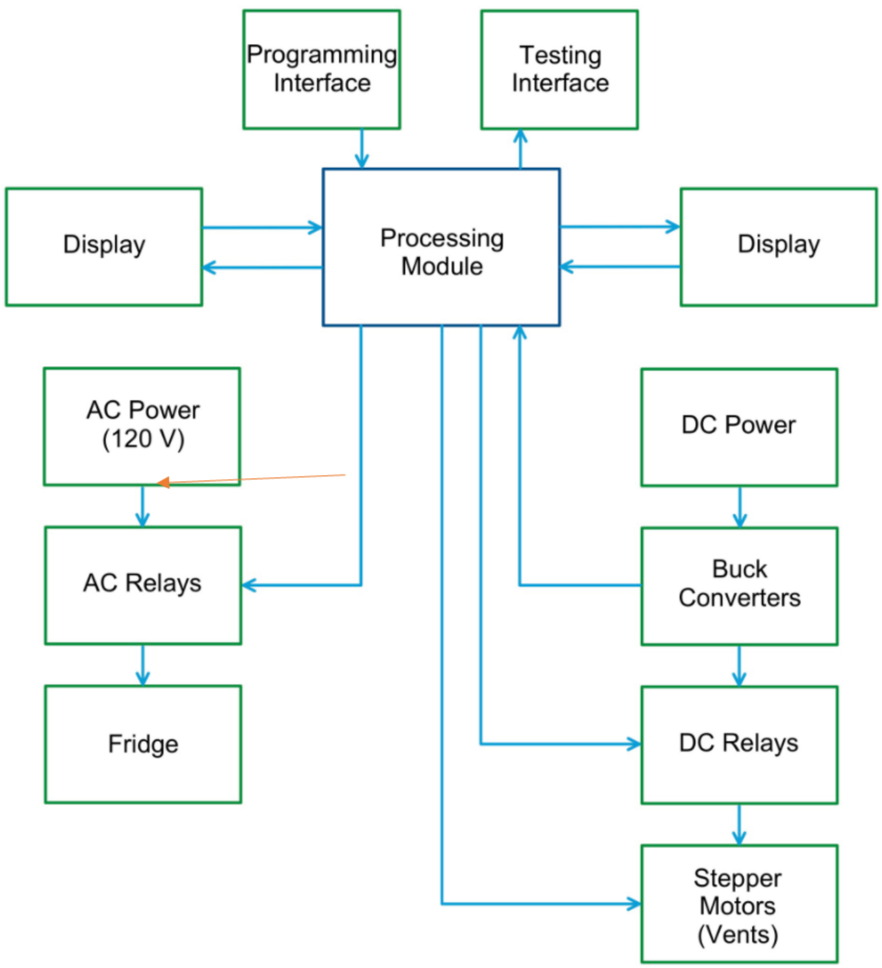
Introduction to background knowledge/phenomenology supporting the project

The more we learn about nutrition and health, the more we realize how important it is to eat a wide variety of fruits and vegetables. In a 2015 report, the CDC stated that fewer than 10% of Americans are eating enough fruits and vegetables (1). However, in the United States nearly half of all produce is wasted, mostly at the retail and consumer level (2). In addition, the United States Department of Agriculture (USDA), states that most adults need to eat between 1.5 - 2 cups of fruit and 2 - 4 cups of vegetables every day (3). The need for our project becomes very clear when you combine all of these with recommendations to make fewer trips out of the house amid the Covid-19 pandemic and the fact that most refrigerators on the market have very limited vegetable storage space. Building a refrigerator designed to store more produce and optimized to keep it fresh addresses all of these problems. When consumers can store enough produce and trust that they have enough time before it goes bad, they can take fewer trips to grocery stores, have enough vegetables on hand to meet USDA recommendations, and waste less food.

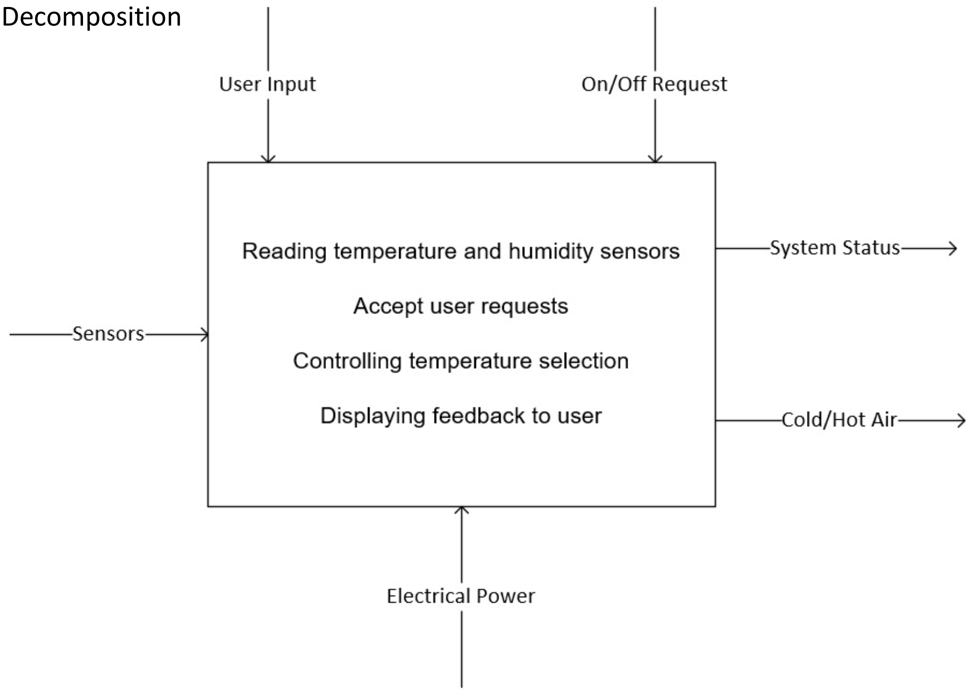
Spoilage in fruits and vegetables is most commonly caused by bacteria, yeast, or mold growth. Thus, delaying spoilage can be accomplished by delaying the growth of these three things. The controllable factors that have the greatest impact on microbial growth include “nutrient availability, moisture, pH, oxygen levels, and the presence or absence of inhibiting substances (e.g., antibiotics)” with temperature being the most impactful parameter in regards to food storage (4). While having a low temperature is important for preserving food, stability of temperature also plays a significant role. Limiting temperature and humidity fluctuation caused by air movement that occurs when refrigerator doors are opened will help to slow microbial growth and enzyme activity that contribute to spoilage (4).

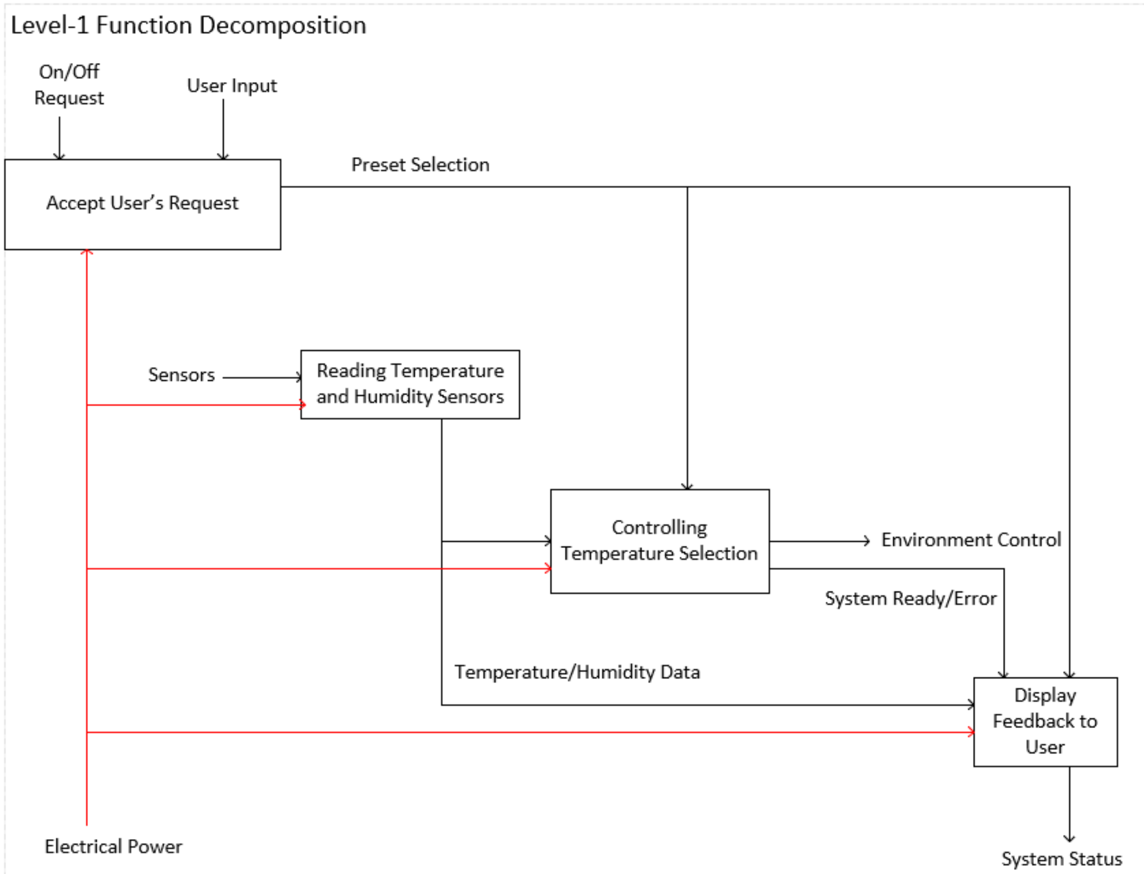
There is some fluctuation in the environment best suited for different fruits and vegetables. In general, vegetables need higher humidity than fruits, which usually equates to less air circulation. Further, ethylene producing plants need more air circulation to displace ethylene gases that speed up ripening (5). Having separate compartments that can have varying temperatures, air circulation levels, and humidity levels is critical to delaying spoilage of produce. A thorough solution to extending the shelf life of fruits and vegetables needs to consider the interactions between optimizing air circulation and humidity while maintaining a stable low temperature in a way that is convenient and adaptable.

5) System Design



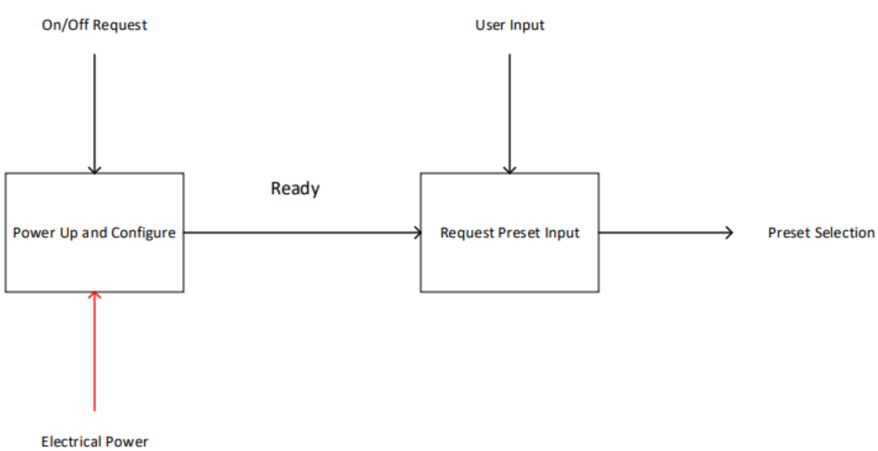
Level-0 Function Decomposition



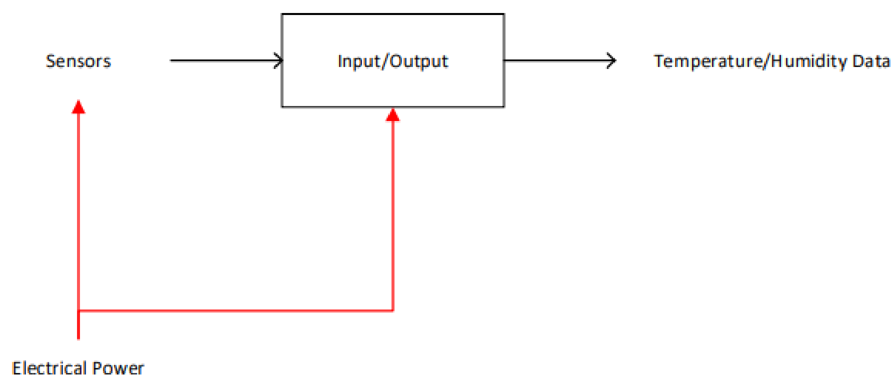


Level-2 Function Decompositions (4)

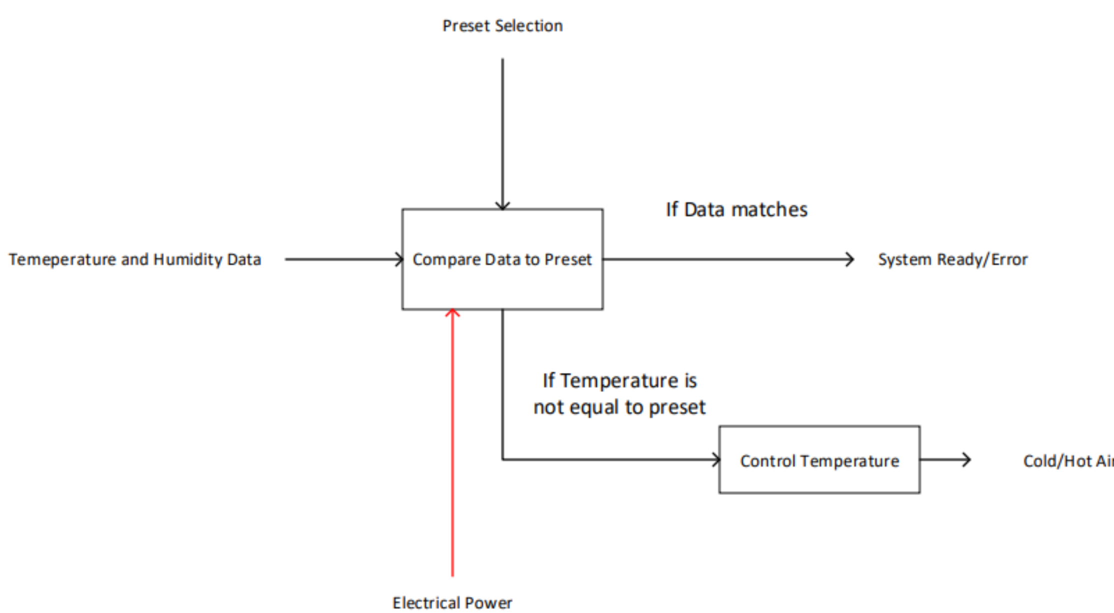
Function: Accept User Request



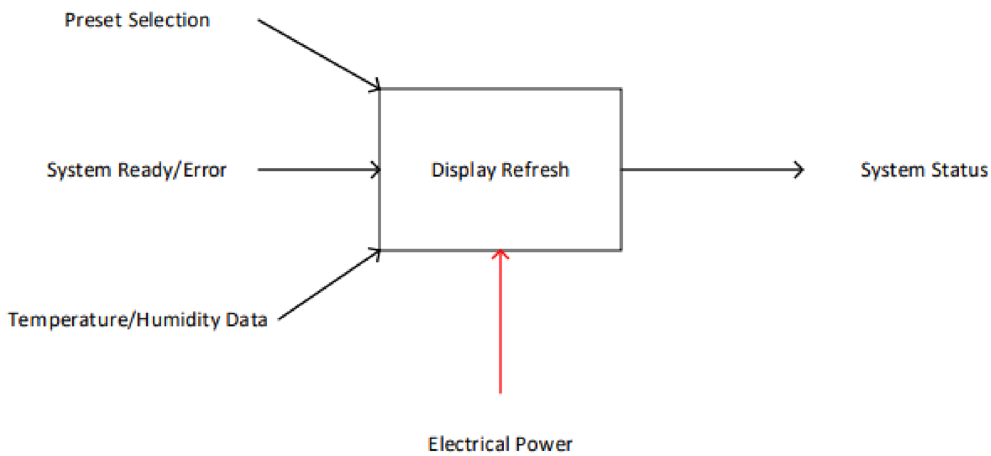
Function: Reading Temperature and Humidity Sensors



Function: Controlling Temperature Selection



Function: Reading temperature and humidity



6) Preliminary Experimental Plan

Requirements for experiential validation.

- Existing data on preserving different types of food shall be verified.
- The fridge shall have constant temperature and humidity.
- The fridge touchscreen will have data and quick sets for various fruits and vegetables.

Experiments to be conducted next semester.

By controlling the temperature and humidity we should obtain similar results to the university of Maine. We can verify this by setting up a normal fridge with the same food in it as the modified fridge. By comparing the two groups of food from the same source we will be able to record how much longer one sample lasts then the other. A test should be performed for vitamin A in the control and experimental groups. The experiment involving vitamin A samples is much more scientific then simply looking at or smelling the food to see if it is rotten. Data points from multiple vitamin A tests will be used to make comparison graphs where we will be able to prove that our fridge is having the effect that we are looking for.

Besides the main tests there are a few small tests that should be done. It will be easy to verify through the sensors that our temperature and humidity are constant and at the desired levels. If our output data shows, there is too much variance in our conditions then our smart fridge shall be adjusted.

Power usage is another thing that we can check. A simple current measuring device

7) Tasks to complete

- Have the Programming module to communicate with the Display, Temperature and Humidity Sensors, and Stepper motors
- Have the Temperature and Humidity sensors and Display give information back to the processing module
- Have the programming module control the relays to power the fridge and stepper motors when needed to
- Have a DC power supply go to a buck converter to distribute power to the processing module and relays
- Have the Temperature and Humidity Sensors give back data to the processing module to determine other actions

Responsibilities

Everyone on the team will need to take VSL training before the building part of the project. We will need this to use the lab that will be our place of storage for our fridge. This will make sure if someone cannot help due to reasons, other people on the team can support and help with the work.

Nestor will be in charge of finding a fridge to modify. This will be done using websites like Craigslist or Facebook Store to find the fridge we would need. Our primary location to find a fridge will be in the Northern VA area. Once we find a fridge that looks similar to our conceptual sketch, we will decide as a team if this will be the fridge we wish to use. If we have a majority vote (4 out of 6 votes) say yes, Nestor and another member of the team will be in charge of bringing the fridge to our allowed location (Peterson 4000) to build and modify the fridge.

Ahmed, Zach, and Cameron will be the primary members in making the code for the processing module. Nestor, Michael, Matthew will be supportive members on this task and will assist the primary team if requested. The code will be either Python3 or C programming language. We will use code that is either made by the team or use open-source software that can be implemented with the components. Once that is done, we will then combine the different pieces of code together for the fridge.

Ahmed, Zach, and Cameron will lead the team in finding ways to have the program have better overall performance with the rest of the team supporting. Ahmed will be in charge of making sure the code's performance overall is good because of his background knowledge in coding.

Nestor, Michael, Matthew will be the primary members for designing the fridge and the electrical components. Ahmed, Zach, and Cameron will be supportive members on this task and will assist the primary team if requested. These tasks include wiring, checking for electrical safety, soldering, and any other task that uses power.

Schedule (ECE 492)

Assignment	Due date	Deliver to	Status	FS Feedback by	Part of the syllabus schedule
Project Title Form Delivery	10-Sep	FS,CC	**DONE**	N/A	Yes
Draft Proposal	1-Oct	FS	**DONE**	Oct 5th	Yes
Proposal Presentation Slides Draft	6-Oct	FS	**DONE**	Oct 8th	Our own schedule
Proposal Delivery	8-Oct	FS,CC		Oct 15th	Yes
Proposal Presentation	15-Oct	FS		Oct 15th	Yes, Pushed back by a week
Oral Design Draft	27-Oct	FS		Oct 29th	Our own schedule
Presentation Slides Delivery Draft	27-Oct	FS,CC		Oct 29th	Our own schedule
Oral Design Review	5-Nov	FS		Nov 5th	Yes
Presentation Slides Delivery	5-Nov	FS,CC		Nov 5th	Yes
Draft Design Document Delivery	12-Nov	FS		Nov 17th	Yes
Design Document Delivery	3-Dec	FS,CC		Dec 14th	Yes

Key
FS= Faculty Supervisor
CC= Course Coordinator
Final Assignment Due
December 3rd
Prefer To Finish By
November 23rd

8) Potential Problems

Knowledge and skills to be learned:

- Each team member shall take the VSL training before using the bioengineering lab on GMU campus
- Team members shall become familiar with cooling/heating components that will be potentially used, ie. Peltier Cells, etc.
- Team members should research specific nutritional information for potential produce to be stored properly in the end product, ie. What ideal temperature to preserve specific vitamins, etc.

The team will repurpose used fridge(s) in this project, therefore some risks shall be considered:

- Team members shall address the potential sanitary issues.
- Team members shall be careful when disassembling/reassembling the fridge knowing the hazards of electric shock and potential decompression of the pressurized system.
- Team members shall research the components to be used and assess compatibility with the existing components within the fridge.

9) Sources:

(1) https://www.cdc.gov/media/releases/2017/p1116-fruit-vegetable-consumption.html

(2) https://www.unep.org/thinkeatsave/get-informed/worldwide-food-waste

(3) https://www.myplate.gov/eat-healthy/vegetables

(4) https://www.britannica.com/topic/food-preservation/Packaging#ref50584

(5) https://www.canr.msu.edu/news/refrigerator_humidity_effects_on_produce_quality