Image Recognition
Expiration Date Tracker

ECE445 Design Document

Jonathan Jacobson, Kevin Choi, Vaibhav Makar
Team 66
TA: Bonhyun Ku
03/01/2021

1. Introduction

1.1 Statement of Purpose

A significant amount of food is wasted because it expires without the customer knowing. Current food expiration timers require the user to input every food and its expiration date manually, which is a chore few are willing to do. Our project proposes to create an image scanner/speaker combination that can be put inside of a small section of a refrigerator that will scan items using computer vision, estimate the expiration date based on the type of food, and automatically create timers to alert the user in the future. There will also be a gas-detecting sensor that will sense certain gases related to food expiration as a failsafe in case food expires past the expected expiration date.

1.2 Objectives

- The device will be able to detect food items in the refrigerator space and classify them according to type. It could also manage timers that are linked to specific food items.
- The device could create and delete timers based on internal logic, as well as alert the user when they expire through auditory output. Also, the device could set a custom expiration timer based on the user input through a microphone.
- The device will be able to sense the presence of gasses related to the expiration of food.

2. Design

2.1 Block Diagrams

2.1.1 System Overview

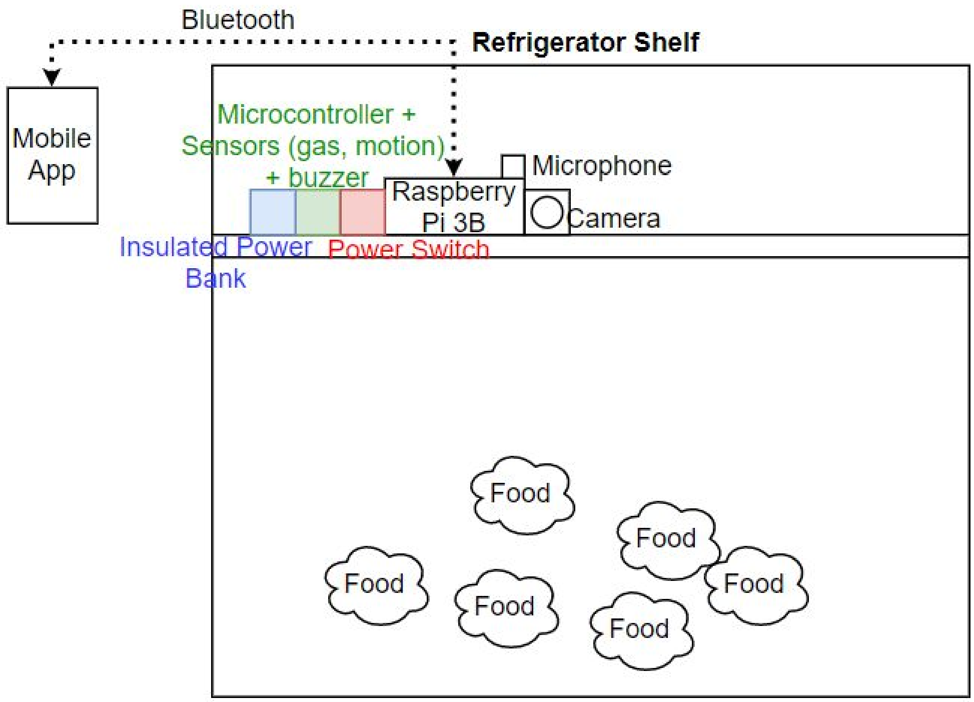

Figure 1: Visual Aid

2.1.2 Device

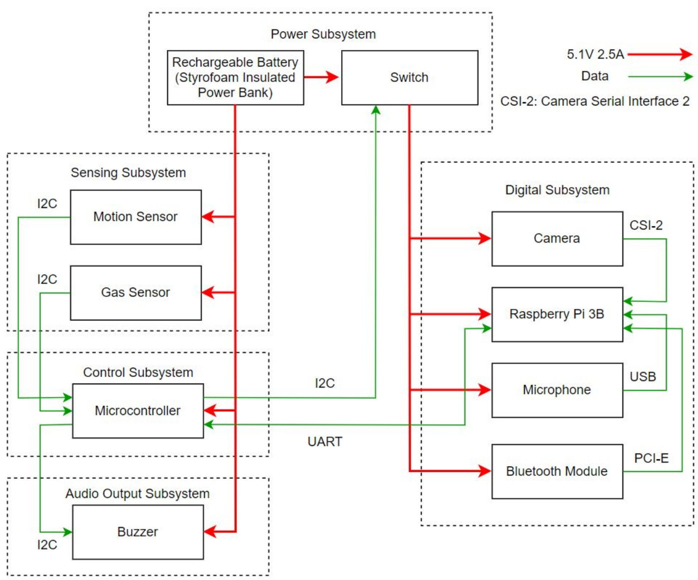

Figure 2: Block Diagram

2.2 Block Descriptions

2.2.1 Microcontroller (PIC18F25K83-E/SP)

Inputs: 5V power input, door sensor data, gas sensor data, Raspberry Pi power-up data
Outputs: Digital Signals to power board, Buzzer, and Raspberry Pi

This microcontroller senses changes in the door sensor data, telling the system that the door to the refrigerator has been opened and that the Raspberry Pi scanning system needs to come online. The microcontroller sends a digital signal to the power circuit, which will power up the Raspberry Pi and begin the scanning sequence. This microcontroller also senses data from the gas sensor and feeds it to the Raspberry Pi if gas is detected. This subsystem also takes the alarm data from the Raspberry Pi and sends a digital signal to the buzzer circuit to create the alarm.

This subsystem will be powered by the battery subsystem and will be always-on. The low-power nature of the microcontroller will allow us to have the Raspberry Pi available but not constantly consuming power.

2.2.2 Raspberry Pi 3B

Input: 5V input, Digital data from microcontroller, CSI-2 Camera data
Output: 5V USB output, Digital data to microcontroller

This subsystem is in charge of running the OpenAI script on the camera data and detecting the items in the refrigerator. It will then determine if changes to the stored timers need to be made, and will execute them. If this system determines that a timer has expired, it will send a digital signal to the microcontroller, telling it to activate the buzzer circuit. This system will also control the bluetooth module, allowing the user to connect to the computer and view and change the timer data remotely.

2.2.3 Door Sensor

Input: Force on sensor
Output: Digital HIGH or LOW signal

To make the design as robust as possible, it would be best to employ a system similar to a regular door refrigerator button. This is just a button that is pressed when the door is closed, telling the fridge that the light should be off. This design will either take advantage of this existing switch or install a similar one into the refrigerator.

2.2.4 Gas Sensor

Input: Gas particles in the air
Output: Analog sensor data

This sensor will sense the amount of ammonia in the air of the refrigerator and output this data as an analog voltage to the microcontroller. The microcontroller will be monitoring this data and will make the determination of whether the amount of gas sensed is evidence of an expired food.

2.2.5 Buzzer

Input: Digital data
Output: Audible buzzing noise.

This buzzer will ring when the microcontroller determines that there is a high amount of gas in the air, or if the Raspberry Pi tells the microcontroller that a timer has expired.

2.2.6 Power Supply Circuit

Input: 5V power from battery, Digital HIGH or LOW from microcontroller
Output: 5V power to the microcontroller and Raspberry Pi

This circuit will be controlled by the microcontroller, allowing it to determine when power is provided to the Raspberry Pi. It will have voltage regulators ensuring that the power falls within the range allowed by the Raspberry Pi.

2.3 Schematics of Overall System

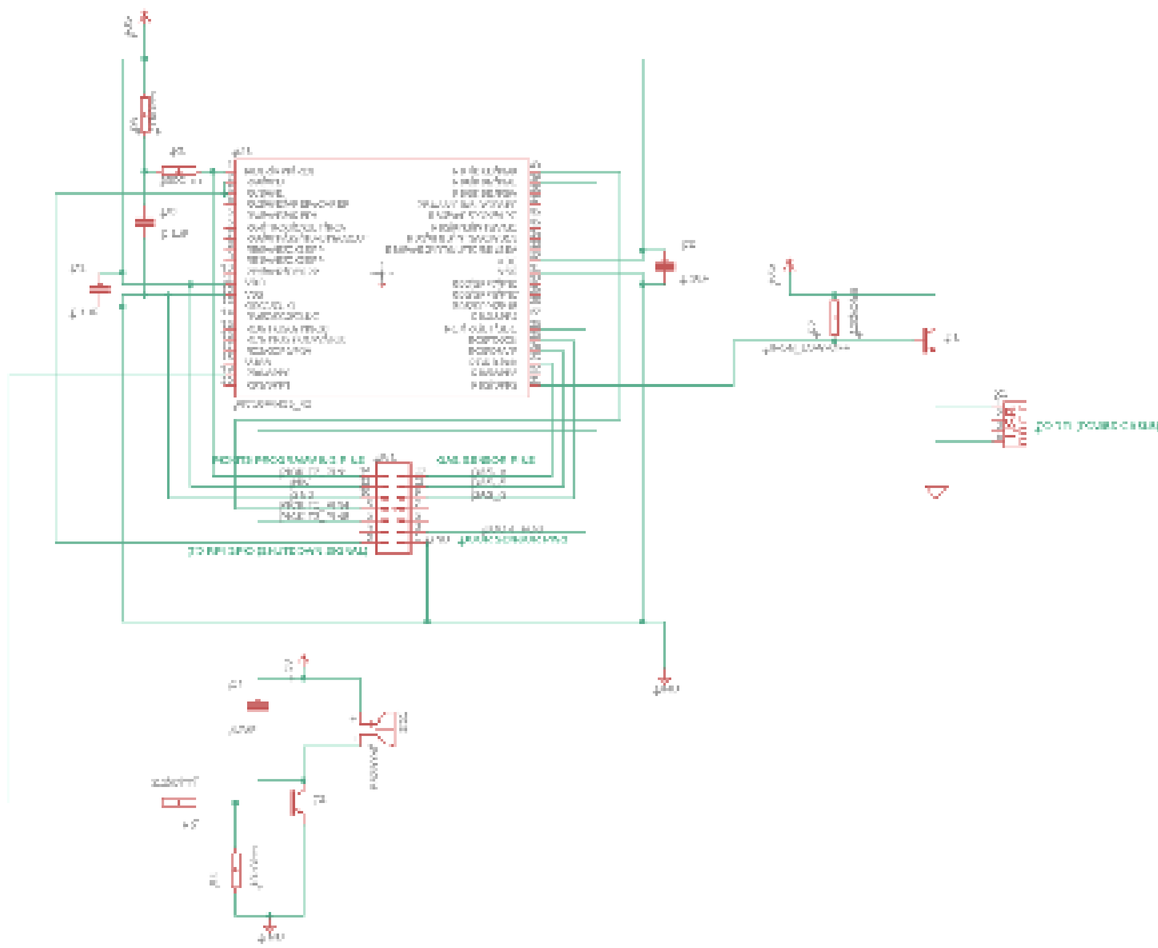

Figure 3:: Circuit Schematics

3. RV Table

3.1 Sensing Subsystem

<table>
<tr><td>The system detects when the door is opened and closed again.</td><td>Begin with a closed door.
Open the door for at least 10 seconds.
Close the door.
Wait a few moments (~30 seconds)
Open the door again.
Check to see if the Raspberry Pi turned on and scanned the food items. (It should still be on during this time)</td></tr>
<tr><td>The device will be able to sense the presence of gasses related to the expiration of food</td><td>Begin with an empty fridge
Verify that there are no gasses detected
Add a closed item that has expired (e.g. eggs)
Wait and see if gas is detected
Next, add an open item that is expired (e.g. leftovers)
Wait and see if gas is detected</td></tr>
</table>

3.2 Digital Subsystem

<table>
<tr><td>The device can classify food items and create corresponding timers</td><td>Scan each food item
Check if the food item is correctly classified and the corresponding timer was created (app or debug software)
Repeat steps 1-2 until the system fails to classify.</td></tr>
<tr><td>The device can set a custom expiration timer based on the user input</td><td>Check if there is a recently scanned food item
Speak a certain phrase (e.g. “set duration”) to enable the custom expiration date setting and check if the buzzer gives out a feedback
Speak a certain duration (e.g. three days) to set the custom timer and check if it is correctly set</td></tr>
</table>

	4. Repeat steps 1-3 until the system fails to set a custom timer

3.3 Power Subsystem

The switch will be able to supply and decline power to Raspberry Pi 3B in a certain set of pre-set intervals	1. Measure the maximum time for Raspberry Pi 3B to boot up, supply power to the lamp, take a picture of the shelf, process the image, update its database, and terminate 2. Verify that the switch can supply the constant power consumption that Raspberry Pi 3B requires during the process 3. Verify that the switch can supply the power for the maximum time required by Raspberry Pi 3B and decline it completely afterward

4. Plots

The following plots show the levels of various gases emitted during the rotting of food. Through them, we can determine that for gases such as Ammonia, we can detect rotting of food at levels between 100 and 1000 ppm, which is within the range of sensitivity of our sensor.

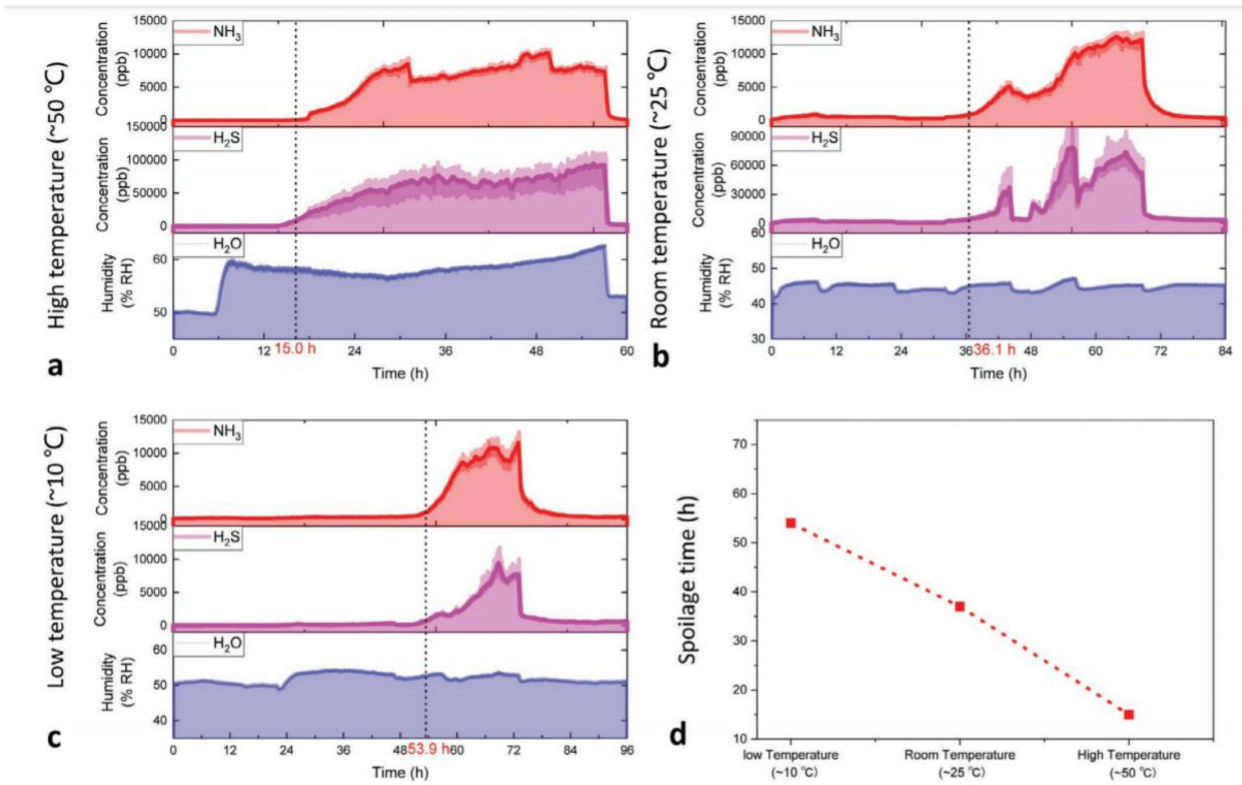

Figure 4.1

Gases released during Pork Belly Spoilage over various temperatures. The dotted line indicates when food was spoiled. [1]

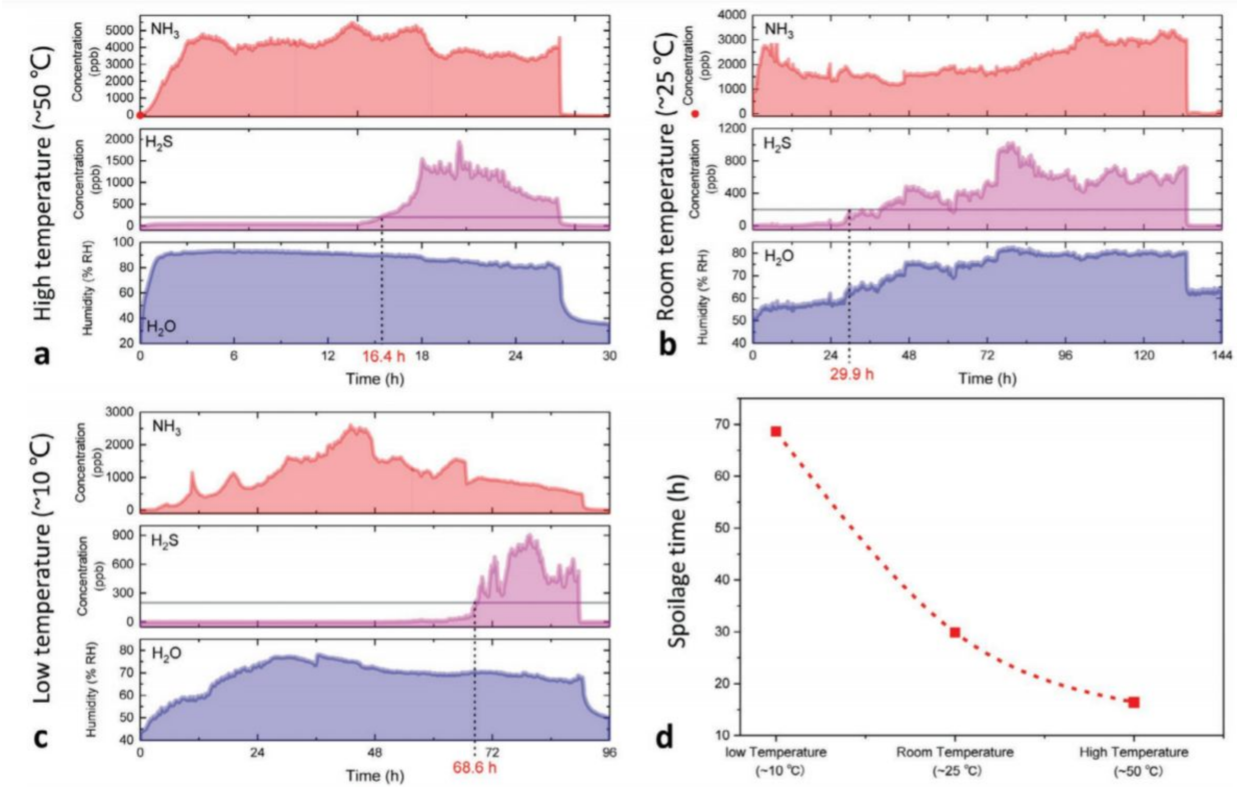

Figure 4.2

Gases released during Egg Spoilage over various temperatures. The dotted line indicates when food was spoiled. [1]

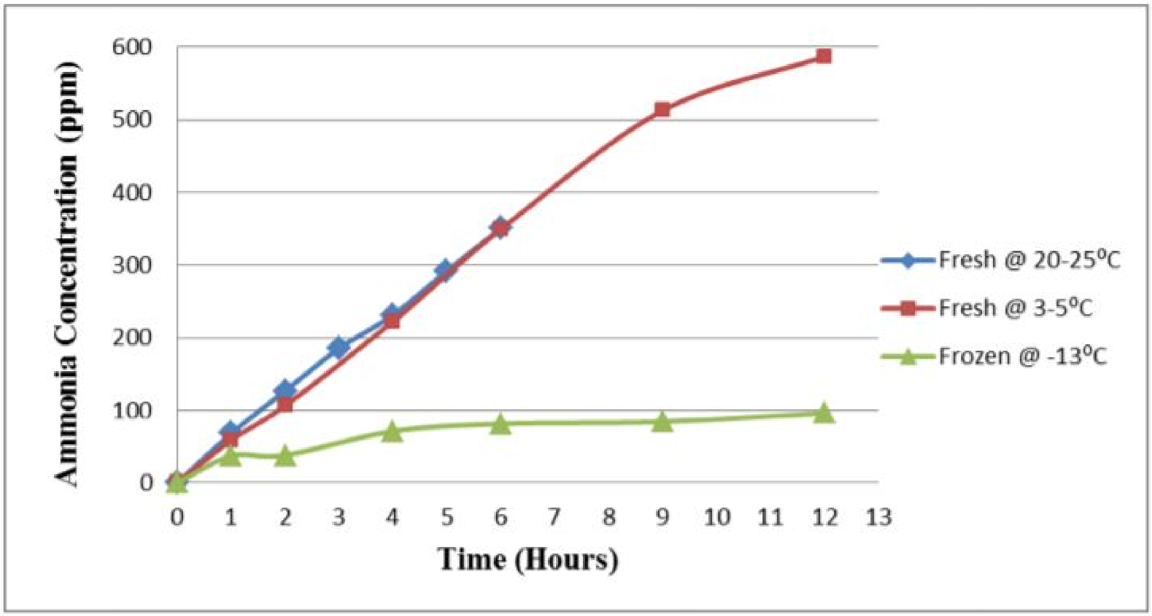

Figure 5

NH3 concentration (ppm) in fresh meat at ambient and refrigeration temperatures, and frozen meat at freezer temperature, at varying exposure times [2]

5. Tolerance Analysis

Rating of:	Tolerance:	Works with our Project?
Storage/Operating Temp. of Microcontroller [3]	-40°C to +85°C	Yes
Storage/Operating Temp. of Raspberry Pi 3B [10]	0°C to +70°C	Yes
Storage/Operating Temp. of Battery Pack	10°C to +55°C	No, needs to be insulated with a styrofoam pouch
Battery Life (with avg. use)	3.93 hours ~	Yes
A current of a p-channel transistor (power circuit) [5]	Up to 60A	Yes
Voltage/Current of Raspberry Pi 3B [9]	5.1V, 2.5A	Yes
Voltage/Current of Microcontroller [3]	-0.3V to +7.5V, 250mA	Yes

The load on Raspberry Pi 3B consumes 690mA (3.52W with 5.1V + 1W from the LED, a total of 4.52W), and the selected power bank stores 10,000mA (37Wh with 3.7V). Since the battery capacity decreases up to 40% in extremely cold weather, we can assume that the actual capacitance of the battery would be 6,000mA (22.2Wh with 3.7V), which technically can provide 4.91 hours of power to our most power-consuming device, Raspberry Pi 3B. If we deduct an extra 20% considering the power consumption of other parts, a 10,000mAh power bank could provide at least 3.93 hours of power to the device. This time will be stretched by the fact that the Raspberry Pi will only be operating for a limited time each day (<20 minutes per day). [8]

6. Cost and Schedule

We are assuming that each of us would spend about 20 hours completing the project. Since the hourly rate of an undergraduate ECE student is $15.75, the total labor would be 15.75 * 60 = $945 in total.

Description	Manufacturer	Part #	Supplier	Cost	Remarks
Raspberry Pi 3B	Raspberry Pi		Owned		
Pi Camera	Arducam		Amazon	$13.99	
USB Microphone	SunFounder		Amazon	$7.99	
Power Bank	Charmast		Amazon	$20.69	10,400mAh
Microcontroller	Microchip Technology	PIC18F25K83-E/SP	Digi-Key	$2.95	
Switch	Microchip Technology	MIC2090-1YM5-TR	Digi-Key	$0.21	
Gas Sensor	SparkFun Electronics	SEN-17053	Digi-Key	$37.50	
Motion Sensor	Adafruit Industries LLC	1528-4667-ND	Digi-Key	$1.95	
Buzzer	Murata Electronics	PKM13EPYH4000-A0	Digi-Key	$0.32	

The total cost of the parts + shipping (Digi-Key $7.99) would be $90.95 including a 6.25% state sales tax. The grand total would be $103.95.

7. Schedule

Week	Jonathan	Kevin	Vaibhav
3/1	Research Microcontrollers	Research and test cameras and gas sensors	Research gas emissions from rotting food
3/8	Design Schematic	Research Image Recognition Software for Raspberry Pi	Research Image Recognition Software for Raspberry Pi
3/15	Set up Microcontroller	Finalize Camera and Gas sensor	Finalize Camera and Gas sensor
3/22	Finalize Schematic	Program rotting detection based on Gas Sensor input	Program Image and Voice Recognition
3/29	Work on waking and sleeping Pi on motion detection	Set up Pi's communication with Sensors	Program Image and Voice Recognition
4/5	Interface with Pi and Sensors	Program and test sensor for door open	Program and test sensor for door open
4/12	Finalize Enclosure	Finalize Enclosure	Finalize Enclosure
4/19	Conduct testing and debugging	Conduct testing and debugging	Conduct testing and debugging
4/26	Prepare Final Presentation & Paper	Prepare Final Presentation & Paper	Prepare Final Presentation & Paper
5/3	Final Paper & Evaluation	Final Paper & Evaluation	Final Paper & Evaluation

8. Discussion of Safety and Ethics

Due to this device being located inside of a fridge, it must satisfy certain food safety requirements. It cannot release any gasses or materials that are unsafe for human consumption and cannot actively contribute to food spoilage in any way. By carefully choosing the materials our device casing will be constructed of, we can meet these criteria. Also, due to the nature of our design, we must make sure that just because our product does not detect expired food, that the user knows that the food is not certified to all be safe. There could still be expired or inedible food in the fridge that our product did not detect [11]. The device would just be an added safety precaution that the user has to supplement their own judgment and memory. It is not to be used as a substitute for the user knowing what looks and smells expired. Additionally, our device does not determine the expected expiration date from the date stamped on the item. It merely detects the type of item and makes an educated decision on the expected date. In the future, this system may be perfected, but for now, the most accurate determination will be made by the user. [12]

9. Citations

[1] Yuan, Z., Bariya, M., Fahad, H. M., Wu, J., Han, R., Gupta, N., Javey, A., Trace-Level, Multi-Gas Detection for Food Quality Assessment Based on Decorated Silicon Transistor Arrays. Adv. Mater. 2020, 32, 1908385. https://doi.org/10.1002/adma.201908385

[2] Prajitna, Sely. (2011). EVALUATION AND ANALYSIS OF BEEF CONTAMINATION BY LOW LEVELS OF AMMONIA. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1012&context=foodscidiss

[3] Microchip Technology, Inc., “28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology”, PIC18F2455/2550/4455/4550 Data Sheet, 2006. http://ww1.microchip.com/downloads/en/devicedoc/39632c.pdf

[4] tcrosley (https://electronics.stackexchange.com/users/1322/tcrosley), Power Switching with Microcontroller, URL (version: 2015-08-23): https://electronics.stackexchange.com/q/186959

[5] Vishay Siliconix, “P-Channel 60 V (D-S) MOSFET”, Document Number: 68633, Dec. 2020. https://www.vishay.com/docs/68633/sup53p06-20.pdf

[6] Zhengzhou Winsen Electronics Technology Co., Ltd, “Ammonia Gas Sensor”, Model: MQ137, Mar. 2015. https://www.sparkfun.com/products/17053

[7] Zhengzhou Winsen Electronics Technology Co., Ltd, “Hydrogen Sulfide Gas Sensor”, Model: MQ136, Mar. 2015. https://www.sparkfun.com/products/17053

[8] Eames, Alex. “How Much Power Does the Pi4B Use? Power Measurements.” RasPi.TV, 25 June 2019. https://www.raspi.tv/2019/how-much-power-does-the-pi4b-use-power-measurements

[9] RASPBERRY PI FOUNDATION, “Power Supply.” Power Supply - Raspberry Pi Documentation. www.raspberrypi.org/documentation/hardware/raspberrypi/power/README.md

[10] RASPBERRY PI FOUNDATION, “FAQ”, Raspberry Pi FAQ. https://www.raspberrypi.org/documentation/faqs/#pi-performance-temps

[11] C. Di Natale et al., "Advances in food analysis by electronic nose," ISIE '97 Proceeding of the IEEE International Symposium on Industrial Electronics, Guimaraes, Portugal, 1997, pp. SS122-SS127 vol.1, doi: 10.1109/ISIE.1997.651747.

[12] A. Pal and K. Kant, "IoT-Based Sensing and Communications Infrastructure for the Fresh Food Supply Chain," in Computer, vol. 51, no. 2, pp. 76-80, February 2018, doi: 10.1109/MC.2018.1451665.
https://innovate.ieee.org/innovation-spotlight/iot-sensor-supply-chain-food/