ECE 24: DEVELOPMENT OF A SMART REFRIGERATOR

TEAM MEMBERS

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1 Problem Description

Food wastage is a problem that everyone has run into, especially college students. It is a problem that everyone runs into, and it results in loss of both time and money. We are interested in working on this problem so we can help college students reduce the amount of food they waste and help them save money and time when budgeting for the desired time frame (monthly, weekly, bimonthly, etc.).

A smart fridge with a camera for image recognition and processing that can recognize items and record the date the item is placed in the fridge. A database containing the perishable items and their duration of usability, and the recorded data will be used to predict when the item will expire. A notification will be sent to the user's phone saying that the item will expire in x number of days. The camera will also allow the user to have an idea of the items that are present in the fridge at any given time.

1.1 Problem Statement

To develop a smart refrigerator that allows the consumers to reduce the amount of food that goes to waste due to abandonment in the refrigerator and purchase of food items that are close to the expiration date.

1.2 Core Problem

Studies have shown that America wastes about 40% of the food it consumes[1], and billions of pounds of food are wasted every day due to overbuying, poor planning, and simply forgetting when a food item was bought in the store and placed in the fridge. We, as a group, would like to reduce this amount of food waste by developing a smart fridge to help people keep track of what and when they buy groceries.

1.3 Key Features

We aim to develop a smart fridge with the following components:

- A barcode scanner outside the fridge to read the barcode from the product's package and identify the food type using an existing food database such as MyFitnessPal, for example.
- A touch screen outside the fridge to manually record the food type in case the original package does not contain a barcode or if the specific food is not in the database.
- Weight scales inside the fridge to track the amount of certain food of interest.
- A smartphone application to access and view the collected information.

1.4 Constraints

The main constraint is the size of the fridge and limited available space inside it. Due to the latter, only a few weight scales can be integrated into the fridge shelves so as not to take up too much space.

1.5 Survey Of Literature

The first emergence of a smart refrigerator was introduced by Lucky- Goldstar (LG) in 2000. These smart refrigerators are connected to the internet and can be synchronized with other smart home device applications like Alexa to look up recipes based on their refrigerator contents and create grocery lists, allow users to remotely control the refrigerator's temperature and send alerts to users' smartphones when its door has been left open for a long period of time.

Despite these amazing capabilities, most of the smart refrigerators still do not have the popularity that most smart home appliances like Amazon's Ring Doorbell, or Apple's Home Dot due to its limited functionality. To increase the popularity regarding these smart home refrigerators, most technology companies are incorporating new advanced technologies like cameras, artificial intelligence. Most of Samsung's smart refrigerators have a touchscreen that performs like a tablet with the same capabilities of an Amazon Alexa with the ability to play music, control temperatures and alert consumers of recipes based on current refrigerator contents. On the other hand, Lucky-Goldstar's current smart refrigerators only inform consumers when the filter of the refrigerator needs to be changed.

Our proposed smart refrigerator will have more capabilities and will be better suited to solve the food waste problem that other smart refrigerators have not been able to solve. The final protype of the project will be able to identify the food item once scanned with the barcode scanner, check the predicted expiration date of the item according to the database and send notifications when the food item is approaching its predicted expiration date. It will also be able to give the user an exact description of the current contents of his/her refrigerator to prevent overstocking on items that are already present in the refrigerator.

2 Design Description

We started with the question of how we can reduce overall food waste efficiently. Since most businesses have some framework in place to minimize food waste, even though they are not perfect, we thought we would make more of an impact if we helped consumers directly. Since we all had run into the issue of forgetting food in the fridge, it seemed like the best opportunity for improvement. From there we thought of different ways to notify the consumer of food that is close to its expiration date.

2.1 Concepts

The original idea involved a camera mounted on the door of the fridge pointed towards the fridge's cavity. We would use machine learning to identify the food in the fridge and using a database, it would get an estimate of the expiration date. That was a good start, but after some brainstorming, we realized that, not only would the camera have trouble with items behind other items, but it would also need a very precise learning algorithm. So, we decided on using a barcode scanner on top of the fridge, which the user can use to simply scan their food before they put them in the fridge. As far as the notification part, we were debating between developing an application that receives the data from the sensor and lists it on your phone. Or we would have the sensor connected to an Arduino which would simply send a text message to your phone whenever something was about to go bad. We finally decided on the former but using Raspberry Pi rather than Arduino because of its superior power at similar price and size.

2.2 Concept Evaluation

Delving further into the concept we realized that adding an interactive interface would be necessary, because not everyone has a smartphone to begin with, and even if they do, they might want to enter a food item manually into the system without the hassle of having to go through their phone every time. It also offered the advantage of showing the foods that are closest to their expiration date directly on the refrigerator, so the consumer is more aware of their near expired food, and they choose to consume that first. Also, integrating scales into the Raspberry Pi would help the user automatically keep track of certain foods that you cannot reliably count, such as grapes or cheese. Integrating them directly into the fridge's shelves would be ideal, but that would require the building of a refrigerator from the ground up. So instead, we decided to simply leave the scales resting on top of the shelves. And of course, we will make modifications to this concept as we get further into the development of this project.

2.3 Detailed Design

The exact design includes three major physical components, a Raspberry Pi microcontroller, a barcode scanner module, a touch sensitive screen, and digital scales. The Raspberry Pi will act as the brains of the system, taking in and processing the information inputted into it from both the barcode scanner module the touch sensitive screen, and the digital scales. The Raspberry Pi, the screen, and the barcode scanner will be packaged together in a plastic housing to make them more compact and secure. The scales will be placed on top of the shelves inside the fridge. There will also be several software components to the system, which include a data analyzer, an interactive interface, and a phone application. The data analyzer will receive the barcode data and cross-reference it with a database that contains data, such as the name of the food as well as rough estimates of expiration dates, for most common foods. The interactive interface will handle both the output and input of the touchscreen. It will show what is currently inside the fridge and at what quantities, it will also allow the user to reduce the amount of each item in the fridge and

manually input an item if it does not have a barcode or it so happens not to be in the database. The phone application will allow the user to do exactly what the tablet does, but in a more convenient way since the user can use the phone on the go.

3 Context and Impact

3.1 Economic Analysis

According to USDA's Economic Research Service, around $161 billion worth of food was wasted in 2010 in the United States[3]. This money could have been used for other purposes. Estimates show that if money were invested into cost-effective solutions to reduce food waste by 20% by 2030 would generate a net financial benefit of $73 billion[9].

3.2 Environmental Impact Analysis

The main environmental impacts of food waste are larger ocean dead zones, increased pest populations, increased trash production, soil damage, and less available land for wildlife[4]. We believe that the overwhelming decrease of food waste will thoroughly decrease worldwide waste. While the manufacturing and the disposal of the equipment will cause some waste to be produced, the overall impact of this project will be a net benefit to the environment and the world at large.

3.3 Social Impact Analysis

According to USDA's Economic Research Service, around 133 billion pounds of food were wasted in 2010 in the United States[3]. This issue was made worse due to the COVID-19 Pandemic, which increased farm food loss and food business closures[9]. This food could have been distributed to people in need.

4 Materials/Resources

4.1 Hardware

- Raspberry Pi microcontroller for controlling the barcode scanner and weight scales
- Arduino kit to be used to incorporate with the scales and the microcontroller
- Touch screen for manually recording food type and amount
- Barcode scanner module compatible with the Raspberry Pi
- Digital scales for measuring amounts of certain foods
- Fridge for prototyping and testing
- Miscellaneous wires and connectors

4.2 Software

- Python used for a program that can correctly identify the item scanned through the data and display the item on the touchscreen
- Flutter for App development on both android and iOS devices
- Database for identifying product information key to predicting food expiration date

5 Project Management

5.1 Description Of Work

5.1.1 Work Package 1 (WP1) – Technical Lead: O. Akinkugbe, K. Xhagolli, W. Brisbane, A. Alqattan and Y. Abilakim

This Work Package is the purchase and testing of equipment. This includes the purchase of the barcode scanner, wine cooler, scales and raspberry pi microcontroller and the starter kits for the Arduino and Raspberry Pi microcontrollers. This is to ensure that the various parts can work together to produce the final protype.

5.1.2 Work Package 2 (WP2) – Technical Lead: O. Akinkugbe, A. Alqattan and Y. Abilakim

The second work package includes the purchase and installation of the software applications for the frontend and backend components of the project. These software applications include the application for the development of the smart refrigerator application, the database used to predict expiration dates and the programming language.

5.1.3 Work Package 3 (WP3) – Technical Lead: W. Brisbane and K. Xhagolli

The WP3 includes the assembly and alignment of all the parts of the project. This covers the assembly of the barcode scanner, touchscreen, and Raspberry Pi microcontroller.

5.1.4 Work Package 4 (WP4) – Technical Lead: O. Akinkugbe and Y. Abilakim

In this Work Package, the hardware and software components of the project are both programmed independently. Once the programming of both hardware and software are completed, they will then be used to test the final project.

5.1.5 Work Package 5 (WP5) – Technical Lead: O. Akinkugbe, K. Xhagolli, W. Brisbane, A. Alqattan and Y. Abilakim

In This Work Package, the entire project, and its components (application, database, mini refrigerators, scales, Raspberry Pi microcontroller, Touchscreen, and barcode scanner) will be tested for functionality.

5.2 Schedule

The planned schedule for this project is based off various due dates along with group estimates on how long each task should take. This plan is visualized in a Gantt chart, shown in Figure 1.

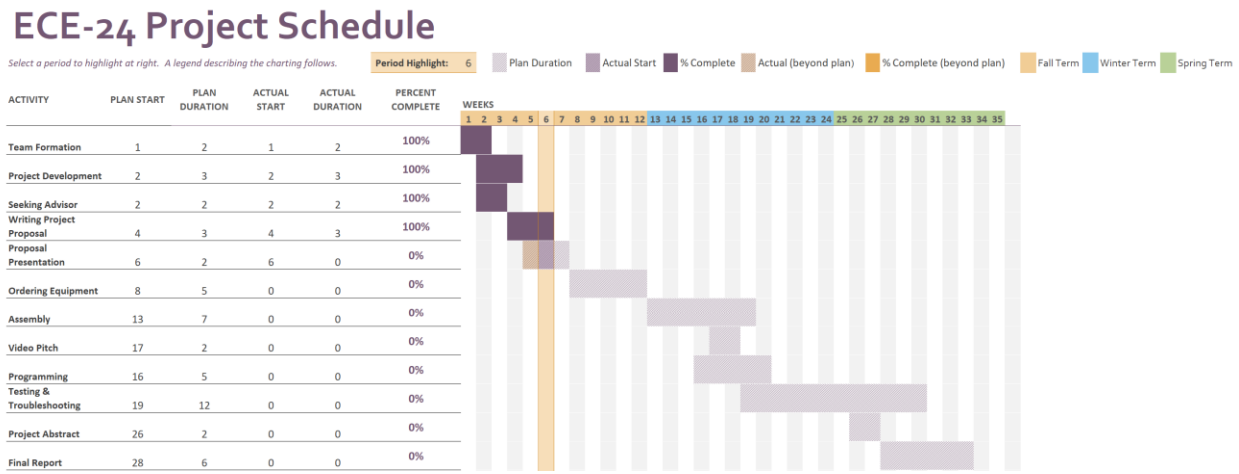

Figure 1: Gantt chart showing the planned schedule for the project, including information for how long each project. The selected period shows the current point in the timeline.

5.3 Project Budget

The estimated budget for this project is has been determined to be a total of $337.85. The following table and figure show a detailed description of the budget.

ECE 24: Development of A Smart Fridge Project Proposal					
	Equipment	Description	Quantity	Base Price ($)	Amount ($)
1	**Raspberry Pi Starter Kit**	This Raspberry Pi Starter Kit will be used to create a circuit that will communicate with the microcontroller. The starter kit contains wires, UDB cord	1	$49.95	**$49.95**
2	**Barcode Scanner**	The barcode scanner will be used to scan the food item and cross reference the item with the database to correctly identify the item and its expiration date	1	$13.99	**$13.99**
3	**Scales**	The scales will be incorporated into the miniature refrigerator to weigh items that are difficult to weigh.	3	$7.98	**$23.94**

4	**Arduino MEGA 2560 Starter Kit**	This Arduino MEGA 2560 Starter kit will be used to incorporate with the scales and the microcontroller	1	$62.99	**$62.99**
5	**Wine Cooler**	This wine cooler will serve as a mini fridge for testing the application and microcontroller	1	$50.99	**$50.99**
6	**Raspberry Pi Microcontroller and Touch Screen**	The Raspberry Pi Microcontroller will be used to interface with the software program and barcode scanner.	1	$135.99	**$135.99**
					$337.85

Table 1: A detailed table showing the equipment and description for each description that make up the proposed budget for the senior design project.

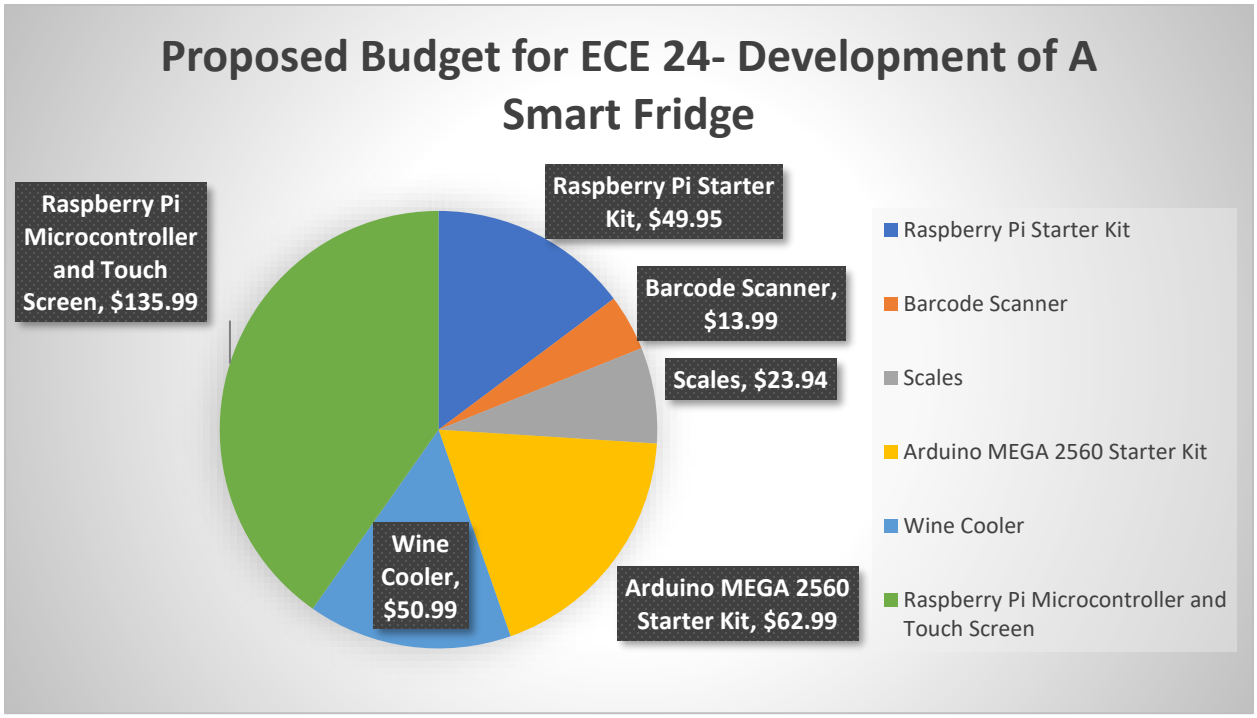

Figure 2: A detailed pie chart showing the percentage of each equipment on the total budget. This pie chart is used to better visual the budget as well as the which equipment takes a bigger bulk of the budget.

5.4 Deliverables and Success Benchmarks

The deliverables and success benchmarks for this project are thee following:

1. Fully Equipped Smart Refrigerator with the ability to identify food items and incorporate the Raspberry Pi Microcontroller and touchscreen to allow the user to manually input the item and allow the consumer to visual the barcode scanned food items of on the touchscreen
   Success Benchmarks: Smart Refrigerator can correctly to identify the food item and display all the food items on the touchscreen. The barcode scanner correctly scans and displays the food item the touchscreen.
2. Smart Refrigerator Application that can effectively communicate with the physical Smart Refrigerator. This application should be able to send notifications when the food item's expiration date is approaching. The application will have the same capabilities of the touchscreen in the sense that it will also be able to show the user the refrigerators' contents.
   Success Benchmarks: The application can correctly send notifications to the consumer's smartphone when the expiration dates of food items are close by. The application can also accurately display the refrigerator's contents to the user automatically.

5.5 Team Organization

This project is comprised of five students at Drexel University's College of Engineering in the Department of Electrical and Computer Engineering. The names and project roles of each student are discussed in more detail below.

Oluwasijibomi Akinkugbe: Application Development and Machine Learning.

O. Akinkugbe, a Computer Engineering major, will be the main pointer in charge of the developing the smart refrigerator using Flutter. She will also create a machine learning algorithm that allows the item scanned with the barcode scanner to search the database of food items to predict the food items expiration date and send appropriate notifications to the consumer.

Keidi Xhagolli: Microcontroller Development and Programming

K. Xhagolli, an Electrical Engineering major with a Computer Engineering minor, will be the main point for programming and developing the Raspberry Pi microcontroller and its components.

Wyatt Brisbane and Abdulwahab Alqattan: Hardware Assembly

W. Brisbane and A. Alqattan, both Electrical Engineering majors, will be the main points for creating the circuits for the Raspberry Pi and ensuring that all the hardware components of the smart fridge system working harmoniously.

Yelnur Abilakim: Data Analysis

Y. Abilakim, an Electrical Engineering major, will be the main point guard for developing a Python software program that can correctly identify the item scanned through the data and display the item on the touchscreen.

6 Benefits

The first advantage of having a smart fridge is a reduced environmental (or ecological) footprint – the effect people have on the environment, that is, the amount of natural resources they use. By wasting food, people waste resources that went into producing that food. Those resources include labor, materials, equipment, and, most importantly, scarce natural resources. Using a smart fridge helps minimize the amount of food one wastes and therefore saves the natural resources.

The second benefit of using a smart fridge is not having to remember how long each food has been in the fridge and guessing whether it is still edible or not. With a barcode scanner and a touch screen, people can easily add their food to the system by either scanning the barcode on the food package or entering the information manually. The system will then estimate when the food is set to expire and also keep track of the amount of time it spent in the fridge.

The third pro of buying a smart fridge is always knowing how much food one has left in the fridge. With the weight scales placed conveniently inside the fridge, the foods of one's choice are always weighed and monitored, so one can easily keep track of available food and know exactly what to buy when grocery shopping.

The fourth benefit of having a smart fridge is a constant access to all the data related to one's food through a mobile application. How much time the food has spent in the fridge, when the food is expected to expire, and how much food is left – one can find answers to all these questions in a smartphone app. The barcode scanner, the touch screen, and the weight scales have all been integrated into one system and act together as a union to send the information to a mobile app.

7 References

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8 Appendices