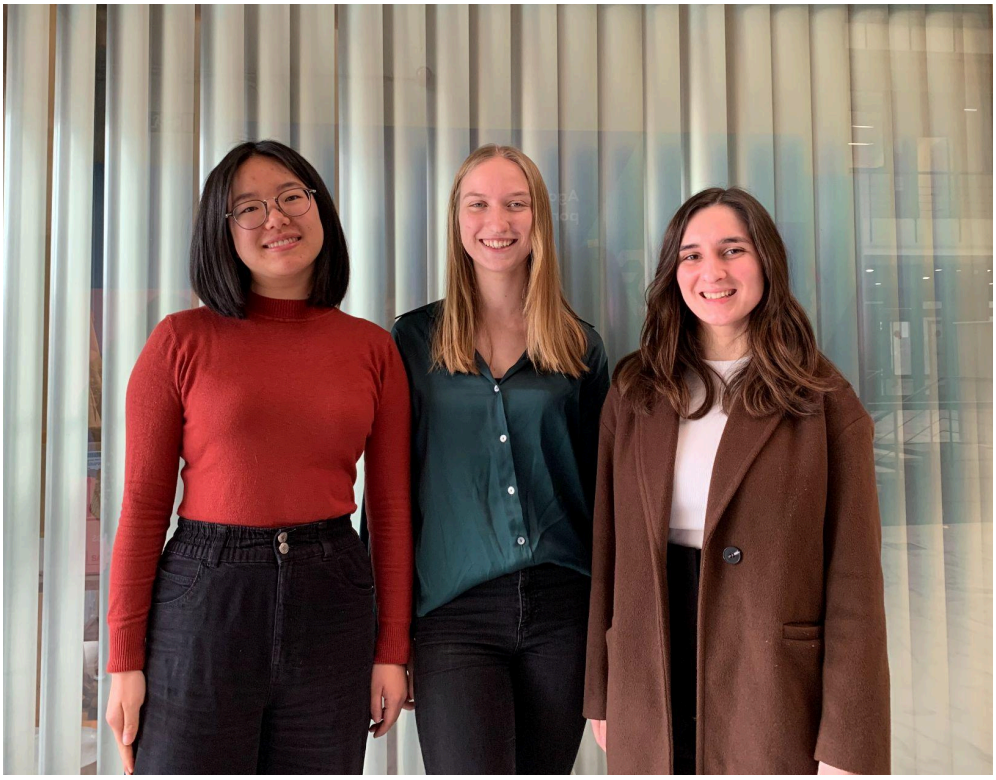
C.H.I.P. Fridge

Course: Ambient Intelligence, Campus: Alameda, Group number: 02

Group members: Ana Jin - 99176, Inês Pissarra - 99236, Juliana Marcelino - 99261



1. Introduction

The Internet of Things brought new features and facilities to human life, changing also the way we interact with our devices. Furthermore, eating and drinking is one of the basic needs of any human being and, therefore, something we also spend a lot of time on. With access to new technologies, improving this time and making it more enjoyable is possible.

C.H.I.P. (Cool Home Intelligent Partner) is a smart fridge with tons of functionalities. This appliance revolutionizes how we interact with our kitchen environment, integrating advanced technology to enhance efficiency and convenience.

With a Shopping List Integration, CHIP automatically updates your shopping list as items are used or running low, sending it through email.

CHIP tracks items stored in the fridge, recognizing the items inserted via a camera outside the fridge.

Stay ahead of expiration dates and restock efficiently with timely alerts and reminders. The smart fridge ensures you are notified when items run low or are nearing expiration.

With this solution the user can have complete knowledge of what they have in the fridge, avoiding food waste and helping to monetize the time dedicated to shopping.

2. Literature Review

Ms. Priti C. Sane et al. in Smart Refrigerator and Vegetable Identification System Using Image Processing and IoT [1], propose a smart refrigerator, focusing on vegetables, but is extensible to other products. The main goal is to reduce food waste and improve human lifestyles. This refrigerator uses a camera that continuously captures images of the vegetables from the refrigerator, and, with the help of machine learning, the vegetables are classified. It also includes sensors to measure the weight of the products, and other sensors to detect the temperature and humidity of the refrigerator.

The paper also mentions the problem of the expiration date of the food but does not specify how to handle it.

Focusing now on hardware, it suggests a refrigerator that has an Arduino UNO connected to Wi-Fi for data transmission, and interacts with humans via an application that can suggest some recipes and allows the user to check the vegetables available in the fridge.

The user will have to enter some relevant information such as the minimum amount of content to receive an alert to buy more if there is not enough.

The refrigerator has a push button to distinguish “storage” from “taking out for use”, but its use is not very detailed.

The author also warns of potential security flaws.

In IoT Based Interactive Smart Refrigerator [2], authored by Shalini K. J., Poornavi S. R., Sahana D. K., Sheik Thamanna, Spoorthi Y. D., the objective is to design a refrigerator prototype that reduces waste and improves shopping efficiency by allowing the users to track food items.

In this project, an Android app shows how much food is in the fridge using sensors. Eggs, milk, and bread are tracked with IR (solid item quantity), load (weight measurement), and ultrasonic sensors. The controller compares sensor readings to set limits and sends data to an online platform. The app then updates with this info, letting users order food easily. It also suggests recipes based on available ingredients by a machine learning algorithm, using a camera to identify vegetables. The camera sends images to the app, using K-means clustering to recognize vegetables by their color and number of edges, and then it suggests recipes based on the recognized vegetable.

Inside the application, it's possible to get real-time updates on the fridge and place orders from an online vendor. From the author's point of view, this smart refrigerator is cost-effective and user-friendly.

A feature highlighted by the author that could be left for future work is the expiration date scan, to alert the user when any product in the fridge expires.

3. Problem

As referenced before, eating and drinking is one of our basic needs. To ensure a good quality of life, we spend a good part of our time preparing (cooking) and choosing (shopping) our food. Furthermore, there is a lot of food waste because we don't know exactly what we have in the fridge. Therefore, we intend to make people's lives easier with CHIP, a smart refrigerator that will allow the user to monetize the time dedicated to shopping and cooking, and also reduce the problem of food waste.

Stakeholders will be young people, adults, and elderly people who cook and do their food shopping; and current fridge producers who may want to incorporate this technology into their products.

3.1. Solution Requirements

CHIP The fridge will…

R1 - … recognize the food it currently has;

R2 - … create a shopping list taking into account the user's recent history;

R3 - … detects the expiration date of the food, allowing the user to avoid food waste and also adjust the shopping list accordingly;

R4 - … alert the user when the food is about to expire / already expired;

R5 - … send alerts and shopping lists to the user's email;

R6 - … present a high level of security to protect customer's privacy, not being able to collect images out of the perimeter of the fridge and protecting the collected data (existing food history, …).

R7 - … allow the user to insert/change products' quantity

3.2. Assumptions

It is assumed that…

A1 - … the environment where the device is inserted has electricity;

A2 - … there is internet connectivity;

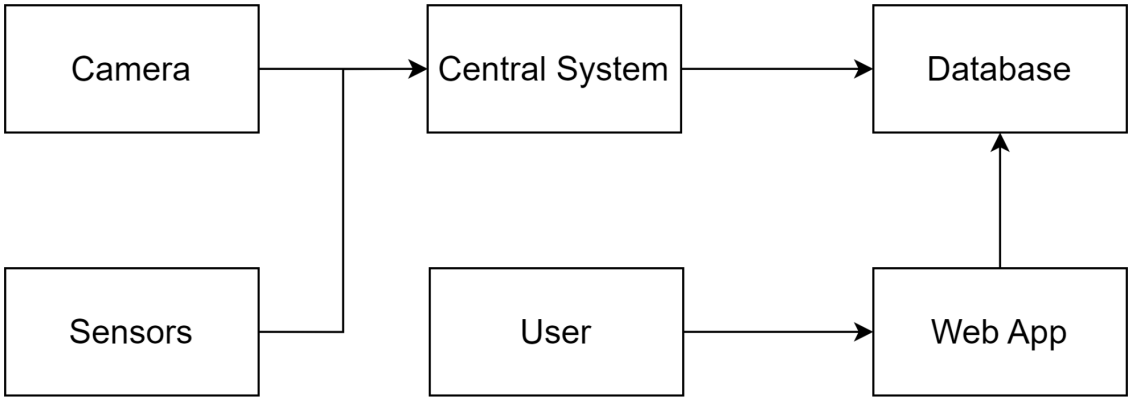
A3 - … the user understands a basic application;

A4 - … the light sensors receive information about the state of the door (open or closed).

4. Proposed Solution

4.1. Overview

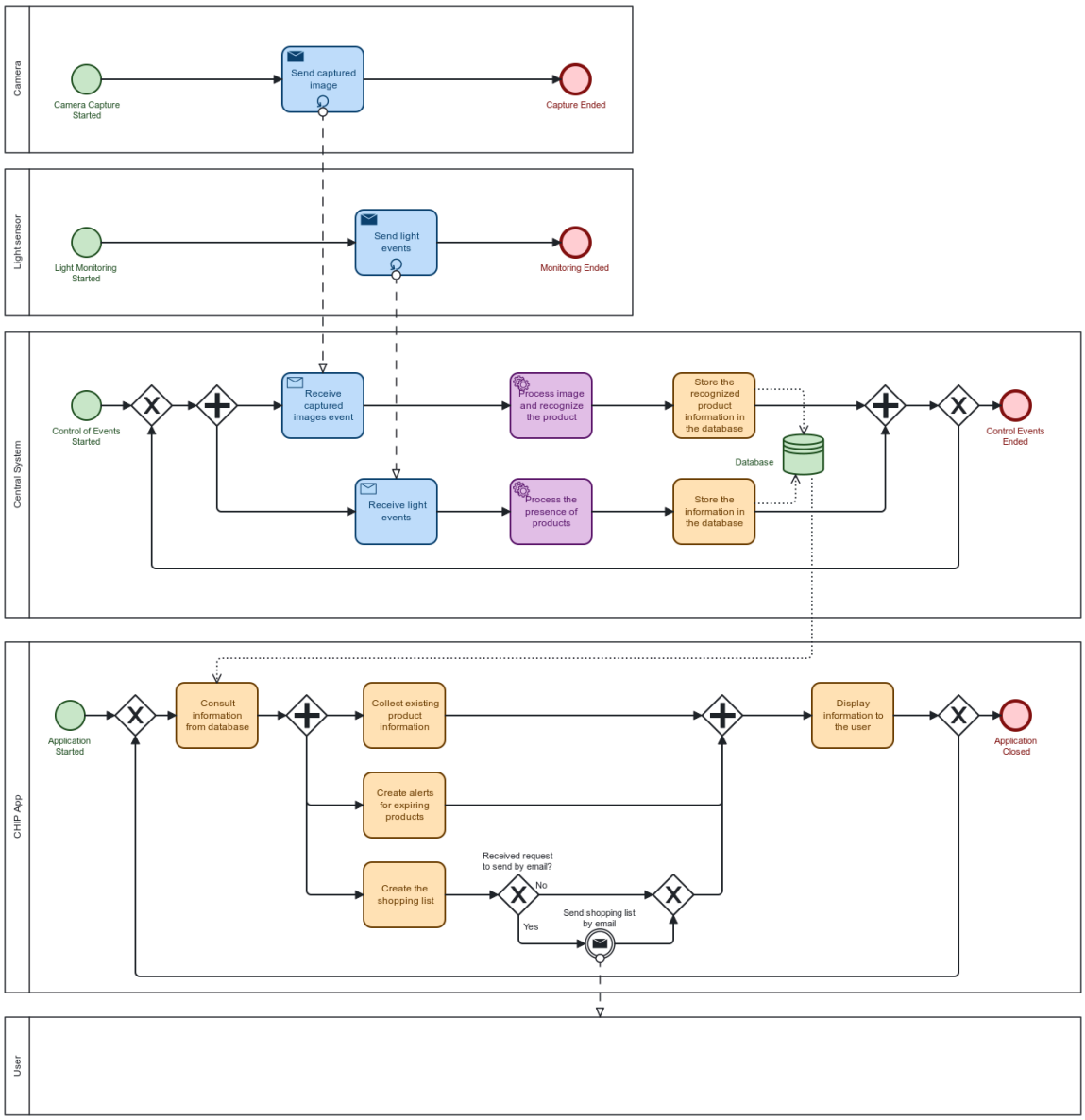
The idea of our project is to create a smart fridge that will help the user reduce food waste and have better management of what they have in the fridge. This way they can save money and time. We want to create a simple application to reach more people. Another goal is to automate the process as much as possible. It would be possible for the user to change information anyway.



- Camera: Identify the items present in the fridge
- Light sensor: Identifies the presence of products
- Central system: Process information received from the sensor and camera
- Web App: The user can see the data collected and manage his shopping list on the fridge's screen.

4.2. Logical design

- The central system, when receiving the images captured by the camera, recognizes the products using machine learning, processes them, and sends the data to the database, where the information is stored.
- The light sensor detects if the product is inside the fridge, sending the information to the central system.
- If a product is removed from the fridge, the central system updates the information.
- The central system has a database in which the expiration dates are stored, sending an alert when this date is closer.
- The central system can create a possible shopping list with the history of products added to the fridge and consumed.



4.3. Technology selection

The primary development platform needed is Visual Studio Code, although Arduino IDE and OpenMV are also used. For the programming language for implementation, Python was chosen.

There's a camera outside the refrigerator that sends images to the central system by Wi-Fi. The light sensors are responsible for identifying the presence of products and the data is also sent to the central system. These pieces of information are then processed and sent to the database so that the user can see everything in real-time on the fridge's screen.

5. Bill-of-materials

5.1. Hardware

- Camera (Nicla Vision) - To identify the food inside the fridge
- Arduino (Arduino Starter Kit) - To identify the presence of products with a light sensor
- Central System (Computer) - To run data processing code
- Display - A screen to display the web app

5.2. Software

- OpenMV IDE - To program the camera
- Arduino IDE - To program the Arduino
- Visual Studio Code - To program the remaining code
- RectLabel - To create the dataset for the machine learning models
- Google Colab - To train the machine learning models
- MySQL - To store the information of the products (our database)
- PyTorch - To train the models that recognize products
- Pytesseract - To recognize the expiration dates
- Flask - To create the web app
- Smtplib - To send the shopping list to the user by email

6. Conclusion

As was said previously, the main purpose of this project is to provide a solution that streamlines the user experience in the kitchen environment, reducing food waste and optimizing the time spent on shopping.

Throughout the project development, we were able to achieve several of the initially defined requirements, while some others were not met, specifically:

R1 - **The fridge recognizes the food it currently has.** The structure of this requirement has been achieved. Due to limited resources and time, our dataset does not cover all possible products. Despite this, we have a good machine learning structure that would be easily expanded with the collaboration, for example, of a team that takes photos of all current market products. It would also be necessary to use a good machine to train the model since large machine-learning models can take hours or even days to train. In the project's README, there is also an explanation of how the training process can be done.

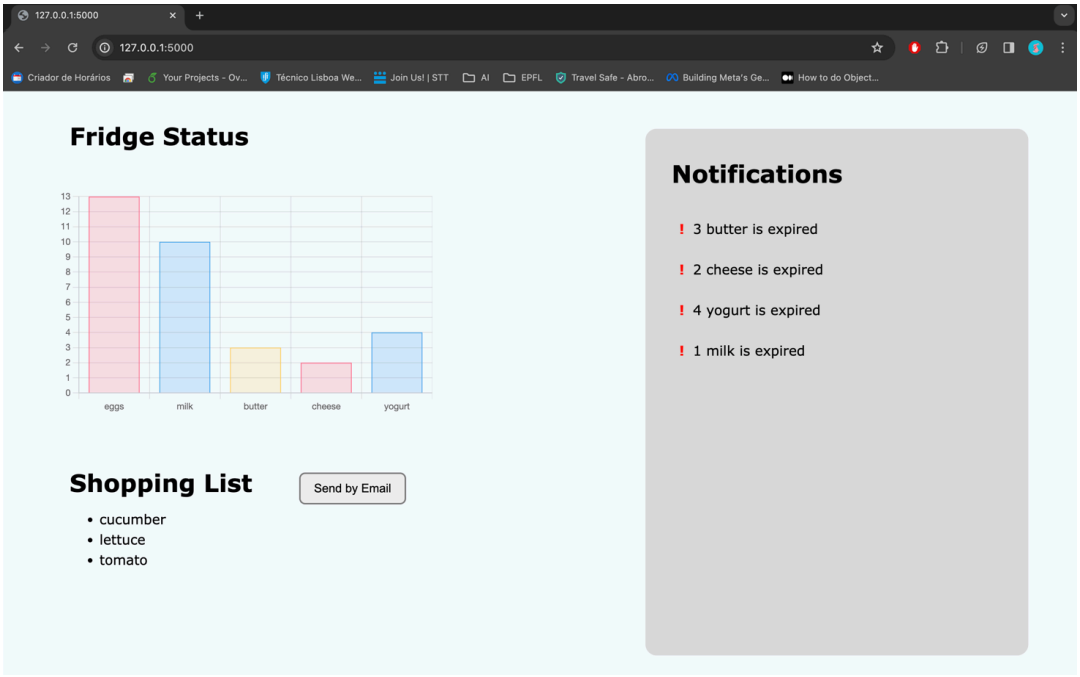
The dataset and models used are too big to be uploaded with the project but can be found in the following links:

- Dataset and model from the model created from scratch: https://drive.google.com/drive/folders/1BwTqUBPTOYiVevAY4tJy5jK9-yekGmWB
- Dataset and model from the pre-trained model: https://drive.google.com/drive/folders/15AGG313OgU8PVDHnomRwuMnfar2_iWbs

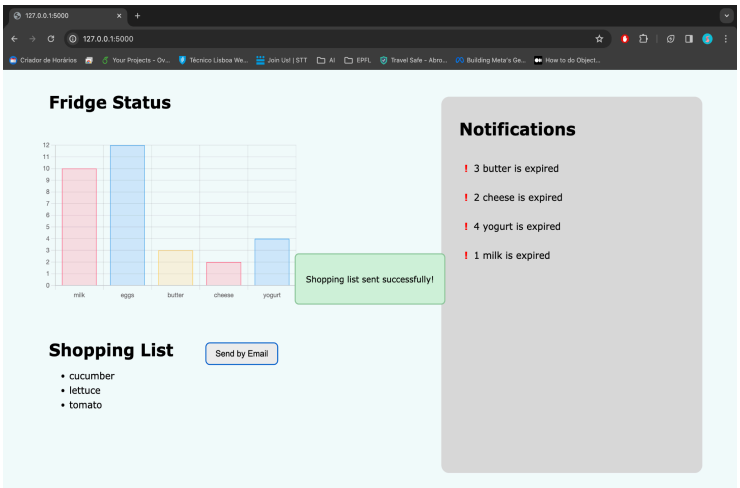
R2 - **The fridge creates a shopping list taking into account the user's recent history.** This requirement is also achieved by maintaining the history of the products that have already been in the fridge. It also adds products that are almost out of stock to the shopping list.

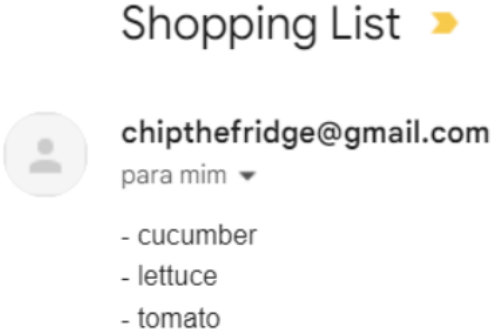
R3 - **The fridge detects the expiration date of the food, allowing the user to avoid food waste and also adjust the shopping list accordingly.** We have difficulties in fulfilling this requirement, since camera quality was limited and many of the expiration dates on products are faded (see the picture on the left). To make this requirement possible it would be necessary a camera with better resolution, and the cooperation of food companies so that expiration dates could be more clearly defined. Despite this, the code presented offers the ability to recognize a date that is well-defined (tested with products whose expiration date was clearer and with pictures taken with the mobile phone).

R4 - **The fridge alerts the user when the food is about to expire / already expired.** This requirement has been achieved. The fridge has a display (an application running locally) that shows all the alerts about food that has already expired or that expires in the next few days.

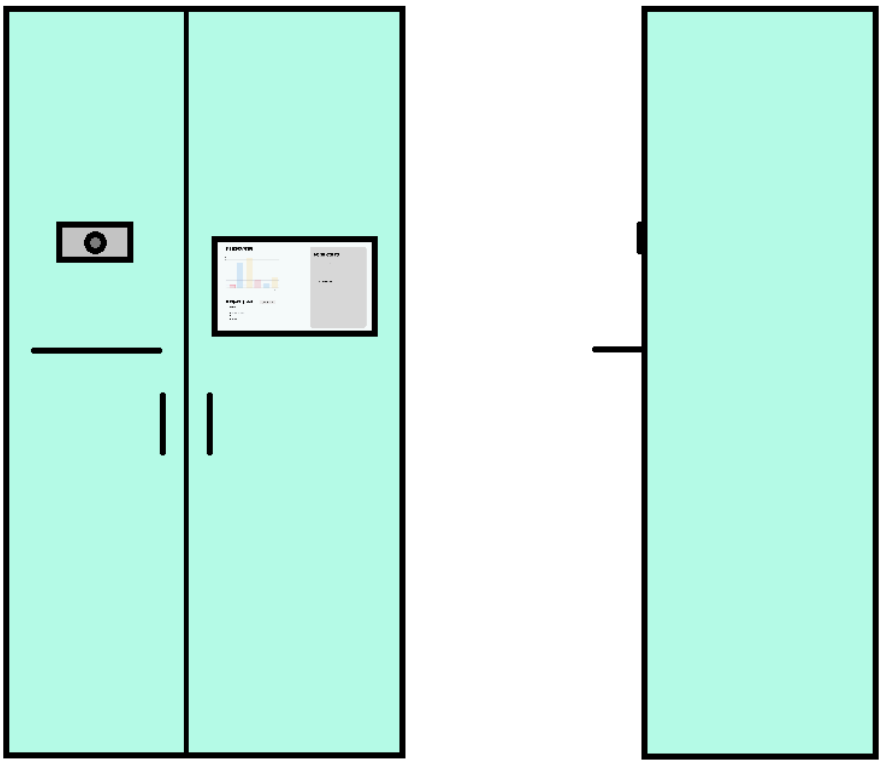


R5 - **The fridge sends alerts and shopping lists to the user's email.** We decided to send only the shopping list (and when required) since we felt it would be too invasive to send too many emails about the food being almost out-of-date. This way, the user can check the out-of-date products directly in the fridge display and receive an email with the shopping list only when desirable.





R6 - **The fridge presents a high level of security to protect customers' privacy, not being able to collect images out of the perimeter of the fridge and protecting the collected data (existing food history, …).** The fridge's design (shown in the image below) allows the user to maintain privacy since the camera is oriented to point down. Besides that, the database is only accessed locally, which increases information security.



R7 - **The fridge allows users to insert/change products' quantity.** This functionality aimed to reduce the need to scan duplicate products. However, we found a more automated solution for this: We assume that, if a product is scanned and several are placed, they are the same. In this way, the central system is responsible for counting products of a type, based on the information it receives from the sensors.

It is also important to note that, if the user wants to take a product out of the fridge for quick usage and then put it back (for example, take a juice, fill the glass, and put it back in the fridge) it is not necessary to scan the product. This is because CHIP the fridge stores information about the last product removed or scanned. This was a decision taken to make the refrigerator more automated, making its use more fluid.

In future work, we would like to improve the recognition model in order to include more products. It would also be of interest to have a camera with a better definition for date recognition. The camera doesn't necessarily need to have Wi-Fi (it could be directly connected to the central system).

Another goal would be to implement intelligent recipe suggestions that take into account the products in the fridge.

Finally, the estimation of the expiration date for fruits and vegetables is a theme we aspire to explore even further as it's a difficult task even with nowadays' technology.

7. Bibliography

[1] Ms. Priti C. Sane, Prof. Harish K. Barapatre, Prof. Ankit Sanghavi, "Smart Refrigerator and Vegetable Identification System Using Image Processing and IoT", Open Access International Journal of Science and Engineering, vol. 6, Issue 4, April 2021

[2] Shalini K J, Poornavi S R, Sahana D K, Sheik Thamanna, Spoorthi Y D, "IoT Based Interactive Smart Refrigerator", International Journal of Advanced Research in Computer and Communication Engineering, vol. 10, Issue 6, June 2021