Project - Report on

Internet of Things Application in Smart Refrigerator

Submitted by,

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Abstract

With the enhancement of technologies in various fields our lives are directed to the intelligent and smarter regime. We are following new technologies rather than old approaches. Thus the devices ought to be smart enough to recognize our needs. Domiciliary or kitchen is one of the most prominent zones of intelligent appliances, one of those devices is refrigerator. Since current life style is driving people spending less time on healthy food preparation at home, pleasurable and fit life style can be supported with a smart kitchenware such as a smart refrigerator. This project deals with the designing of a smart refrigerator which is able to sense the quantity as well as quality of the food items kept inside it. With smart sensing technology, this refrigerator will keep check on the expiry of food products and the spoilage of eatable items. It will be smart enough to notify the current status of food items through an android app on our mobile phone, and will also remind us about the items are going to spoilage before they actually get rotten. Thus it will save the money and food wastage as well as help us to live a healthier lifestyle.

Chapter 1

Introduction

Refrigerator plays an important role in keeping eatables fresh providing us a healthier lifestyle. It is the central family hub device that is used by all family members at any time of the day. Many smart device integrations has been implemented for smart home automations in the recent years, Smart Refrigerator is one such device for a smart home based of Internet of Things (IoT) application which provides all functionalities of a standard refrigerator [6] with addition of smart features of smart sensing through machine learning image recognition and weight sensing, automatic refrigerator settings adjustment according to the recommended environment condition settings [7], this is made possible through various sensors and hardware integration and connecting them to internet for real time data collection and processing providing live required data and necessary details about the running status of the refrigerator and contents inside the refrigerator including live stream from the refrigerator showing contents that can be used by users at the grocery store as a reference, list of contents with options to buy from popular online grocery stores such as Amazon.in and BigBasket, Calendar integration to keep track of food addition and expiration dates, and providing possible top socially ranked food recipes that can be cooked or made from the refrigerator contents all in just one app. Along with this the device also has integration of smart voice control through Google Assistant integration.

1.1 Problem Statement

Design and develop an IoT based smart refrigerator for smart food sensing and automatically set the necessary storage conditions and provide food details to help user save money and food spoilage, wastage in order to give a healthier lifestyle.

1.2 Motivation

The main motive behind the idea of Smart Refrigerator was to avoid food spoilage/ wastage and hence provide families a healthy lifestyle. It is been found (as per an article on famous British daily newspaper company The Guardian) that maximum to all household food waste consist of refrigerated foods. The Smart refrigerator not only helps people avoid food wastage but also provides all necessary details about their refrigerator contents making them socially active about food.

1.3 Objectives

The basic idea is divided into five main objectives

- To automatically detect food contents in a refrigerator.
- To measure quantity of food contents in a refrigerator and provide the best storage conditions using IoT platform.
- To provide healthy food recipes from the available food contents in the refrigerator.
- To give food content details and data along with refrigerator state control to the user through mobile application.
- To help people save money and food wastage.

1.4 System Overview

The basic system architecture of the Smart Refrigerator system is shown in Figure. 1.1. The flow shows representation of data flow in Smart refrigerator of how data is collected from sensors like DHT11, Load Cell + Hx711, web camera passed through IoT gateway (application level) to internet to Adafrut IO cloud (IoT cloud platform) to be stored and used by its open API for accessing the data securely through custom mobile application for smart refrigerator providing user interface and accessing all necessary processed data (from IoT server) providing data about contents in smart refrigerator making it useful through open API's such as Food2Fork and AllRecipe recipe API, Amazon.in and BigBasket in-app search integration and Google Vision AI for automatic food detection.

In the proposed scheme Smart refrigerator system is equipped with the sensor and actuator. The sensor and actuator are the part of network which are connected to the device which continuously collect the information and transfer the data through communication protocol using IoT platform. The communication follows the TCP/IP client server model. IP address of the board (raspberry pi) is used for providing live contents from refrigerator to mobile app (live webcam stream) and Adafruit IO API is used for receiving the sensor data from device and sending the data to server and cloud to make it accessible to mobile application.

The application is self maintainable as it is digitally designed (through python programming language) to sense certain condition changes in smart refrigerator and act accordingly to perform required actions and restoring back to stable or active state once the required action is performed. The program has integration with Adafruit IO connection, paho MQTT (for sending or publishing captured image file from device to server), integration with sensors and actuators for data collection and performing actuation at device end. On server end the program is configured with paho MQTT for receiving or subscribing the captured image file and then send it to Google cloud platform (Vision AI API) for prediction of food items and updating the current food item in Adafruit IO.

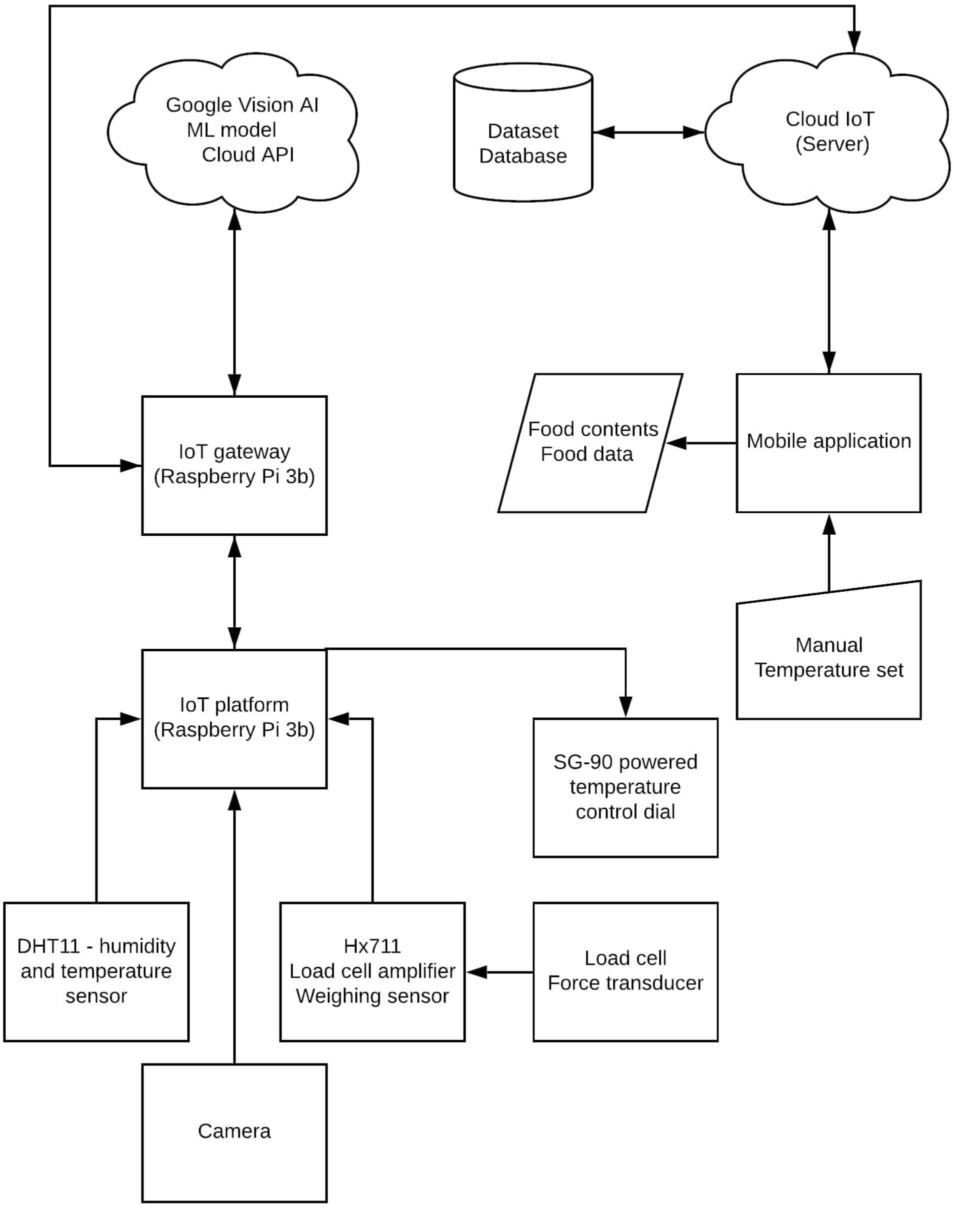

Figure 1.1: System Architecture

1.5 Resources used

Hardware platform: Raspberry Pi 3 B
Components: Load Cell (5 KG), Hx711 weighing sensor, HD web camera, DHT11 temperature and humidity sensor, SG90 servo motor
Software and Cloud: Matlab Simulink, Python, php, MySQL, Google Cloud Plat-

form (GCP), Adafruit IO
API: Google Vision AI, Food2Fork recipe API, Adafruit Cloud API, IFTTT, All-Recipe and Amazon.in, BigBasket in-app search integration

1.6 Organization of the Report

In report **Chapter 2** gives brief literature review about the Smart Refrigerator and Internet of Things. **Chapter 3** contains idea of how pre trained ML models work in terms of recognizing refrigerator food contents. System architecture, software usage, simulation results of IoT are illustrated in **Chapter 4**. **Chapter 5** gives summary on the simulation and IoT hardware results.

Chapter 2

Literature Review

The smart refrigerator system is focused on designing the traditional refrigerators smartly by having more user interface options, generally containing of web application and or text message, email alerts regarding the status of the refrigerator and its contents. Generally focused on allowing users to notify about different food contents and their quantity, few also focused on the quality of stored food item by wanting their users to scan a barcode or QR code of the refrigerated product to calculate the expiration of food making the process time consuming for the user. It also facilitates user to purchase the low quantity food contents from integrated online store, few have automated this process by automatically placing orders for stocked out contents. This paper proposes idea of automatic content sensing through load cell weight changes [1] and then capturing and predicting the food contents inside the refrigerator providing access to user about the details, live content streaming, possible recipes, expiration dates and alert, and full control of status of the refrigerator, also with automatic setting up the recommended cooling settings of the refrigerator according to the environment temperature.

Deepti Singh, Preet Jain [2], has proposed the system Smart Refrigerator which can sense the weight of the food items placed in the refrigerator and sends a notification to the users mobile through an application when the weight falls below the threshold value.

Emily Moin [3], has proposed the system Smart Refrigerator for Grocery Management which identifies the weight and expiry dates of the food items in the refrigerator and sends customized notification to the user. The proposed system finds the weight

and expiry dates of the food items and notifies the user through application which helps to place the order when the contents fall below the threshold value.
Folasade Osisanwo, Shade Kuyoro, and Oludele Awodele has proposed a system, Internet Refrigerator-a typical IoT [4]. This system makes use of RFID. The refrigerator is Wi-Fi enabled to transmit data.
Shama Mubeena, N. Swati has proposed a system, The Design and Implementation of a Wi-Fi Based User-Machine -Interacted Refrigerator [5], which uses Wi-Fi for wireless communication. It demonstrates monitoring of fridge and notify user through mail id.

Chapter 3

System Architecture and Software

3.1 Image Recognition using Pretrained ML models

There are various Open source machine learning and deep learning models available for training and deployment, but due to hardware restriction and limited training datasets (food) some selective models have been used in Smart Refrigerator for automatic detection of food contents present in the refrigerator. The selected models are:

- Darknet Yolo V3 trained using Pascal Dataset 2012
- Google Vision AI under GCP

Darknet YOLO V3 is a very powerful pretrained ML model trained using the Pascal 2012 dataset of objects from around the world, it supports fast and accurate object detection even on low hardware specifications, but it has limited food items in its dataset and fails to detect other food items. So, on its replacement Smart refrigerator is equipped with Vision AI, API provided by Google cloud platform which is able to recognize majority of food items and the processing is done on cloud (GCP) reducing the local hardware requirements. Vision AI supports web entity detection and hence is trained with a very large dataset. Smart refrigerator sends the captured food items and send the image to GCP Vision API and gets back the response to update the refrigerator contents with the predicted item. Also, the program makes a user defined dataset of items it is unable to predict which later can be used to train machine and deep learning models.

3.2 Hardware interfacing

Various hardware components have been used the smart refrigerator for various interlinked functionalities. All the sensors and actuators have been individualy calibrated for accuracy in their operation. Table 3.1 shows the used hardware components along with their functionality required in smart refrigerator.

Table 3.1: A Brief description of components used and their functionalities

Component	**Functionality**
Raspberry Pi 3 B	Hardware controller
Load Cell, Hx711 weighing sensor	Measure weight of contents
HD Web camera	Capture food picture for detection
DHT11 module	Detect environment temperature
SG90 servo motor	Temp. control dial

All sensors and actuators used have been interfaced with Raspberry Pi through GPIO pins and is configured and controlled through python programming language programs running in Raspberry Pi. All the sensors comes pre-calibrated except Hx711 weigning sensor (with Load cell), which is calibrated through a multiplying factor which is calculated through sensor readings for known weights by, suppose for weight 100 grams, the sensor readings are recorded and then the reference value is calculated through

$$\begin{aligned} Known\ weight &= 100\ grams \\ Sensor\ value\ for\ 100\ grams &= -45100 \\ Hence,\ reference\ value &= -45100 \div 100 \\ &= -451 \end{aligned}$$

Similarly, a developed python program is used to manually rotate servo motor (SG-90) through angles and not hard values.

3.3 Adafruit IO Cloud and IFTTT integration

Adafruit IO is an online cloud platform for Internet of Things applications. It provides fast data transfer services and easy integration with IoT devices and other IoT services like IFTTT. Figure 3.1 shows Adafruit IO dashboard feeds for Smart refrigerator with sample data. Through this Adafruit provides its open API for ac-

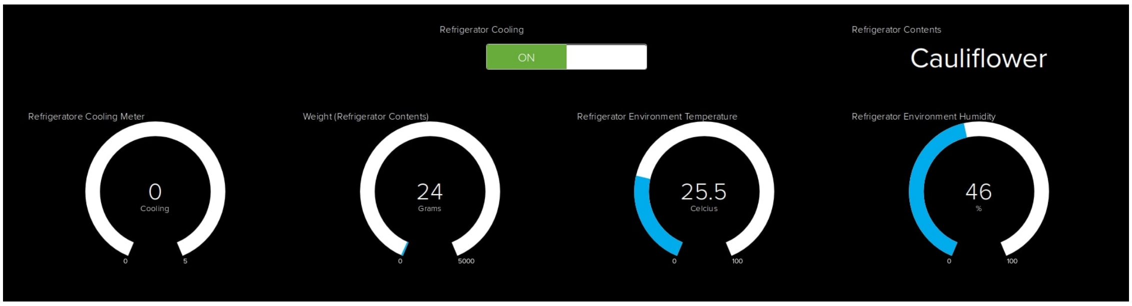

Figure 3.1: Adafruit IO dashboard feeds for Smart refrigerator.

cessing this data through mobile application and its feed integration through python program to send and receive data directly from IoT device. Smart Refrigerator also has IFTTT integration with registered user's mobile and Adafruit IO feed for smart interfacing. The used IFTTT modules are:

- Google Assistant: Support to control status of smart refrigerator through Google Assistant's voice support. Table 3.2 shows the used voice command with their respective actions.

Table 3.2: Google assistant voice control commands

Command	Action
Turn on the refrigerator	Turns ON the refrigerator status (feed and SG90)
Turn off the refrigerator	Turns OFF the refrigerator status (feed and SG90)

- Google Calendar: Whenever a new item has been places and is detected by the smart refrigerator the contents feed of Adafruit IO is updated with content name and a reminder is set on associated Google Calendar account on that date and time to help user prevent food wastage from the expiration data shown in app.

3.4 APIs and Dataset

Various open API services has been used in the development of Smart Refrigerator and its mobile application to provide necessary available online data on user's choice on his/ her mobile application. Table 3.3 shows the list of used online API services and their functionality. These API responds with a JSON data object on a valid API request which is then parsed to a user-readable format in mobile application.

Table 3.3: A Brief description of API used and their functionalities

API	Functionality
Food2Fork	Find recipes through ingredients
Adafruit IO	Get dashboard feeds data using Rest API
All Recipe	Search integration for recipes
Amazon.in	In-app search integration
BigBasket	In-app search integration
food.unl.edu	Custom API for food expiration dates
Google Vision AI API	Trained ML model api for object detection

3.5 Mobile App

A custom designed and developed flutter mobile application has been developed for user and device interface which provides the user all necessary information about their Smart Refrigerator IoT device along with details about its contents also allowing user to perform in-app purchase from Amazon.in and BigBasket. It also shows and reminds user of food expiration details through Google Calendar integration, with all possible food recipes that can be made through that food item allowing user also to share these details with their contacts. Figure 3.2 shows the screens of Smart Refrigerator mobile application with data from IoT cloud.

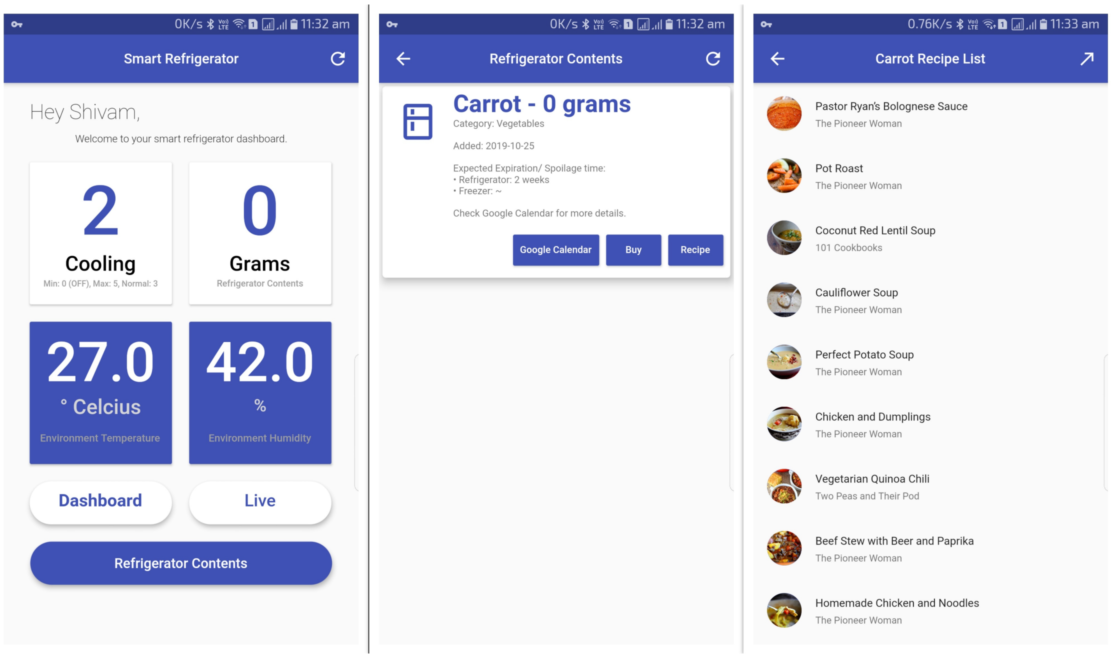

Figure 3.2: Screens of developed mobile application.

Chapter 4

Simulation and Hardware Result

4.1 Simulation

A proposed system as explained and directed in Chapter 3 is simulated in Matlab Simulink is shown in Figure 4.1. The Smart Refrigerator with DHT11 temperature and humidity sensor is integrated with SG90 servo motor for automatic adjusting of temperature control dial based on environment temperature. The values of recommended settings and control dial has been taken and adjusted accordingly for prototyping. Table 4.1 shows the applied automatic settings used for prototyping of Smart Refrigerator.

Table 4.1: Recommended refrigerator settings for a traditional refrigerator

Environment Temperature	**Settings**
≥ 35.0	5, Max Cooling
≥ 30.1 & < 35.0	4
≥ 20.0 & ≤ 30.0	3, Medium Cooling
≥ 10.0 & < 20.0	2
≥ 5.0 & < 20.0	1, Minimum Cooling
< 5.0	0, OFF

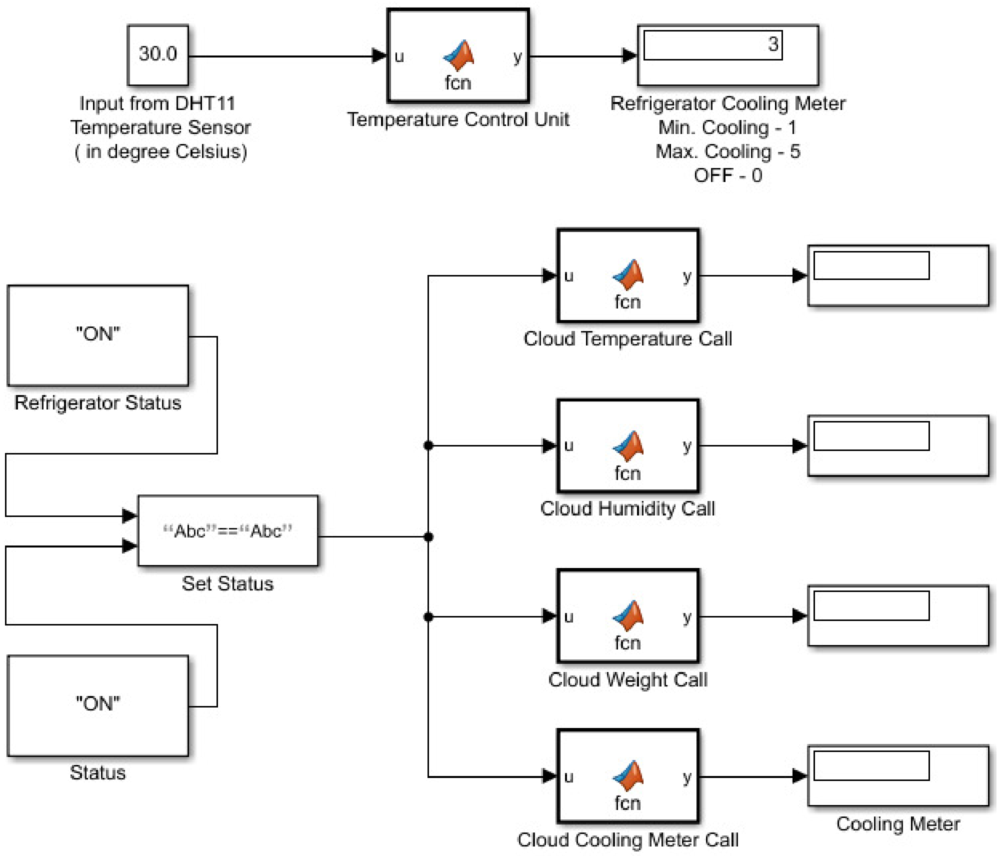

Figure 4.1: Matlab Simulation for smart refrigerator modules.

The simulation also have all Adafruit IO api tested before deployment to app.

4.2 Hardware Result

A Smart Refrigerator prototype has been designed and developed on the IoT platform using Raspberry Pi along with the sensors and actuators described in Chapter 3. The overall data flow and functional link is shown in Figure 4.2 which briefly describes the data flow between the IoT cloud, platform and user interfacing app.

Raspberry Pi collects all the data from sensors and sends it directly to the Adafruit IO cloud, and then process the environment temperature accordingly to set the recommend refrigerator cooling settings as shown in Table 4.1 and is all controlled through python program through GPIO pins.

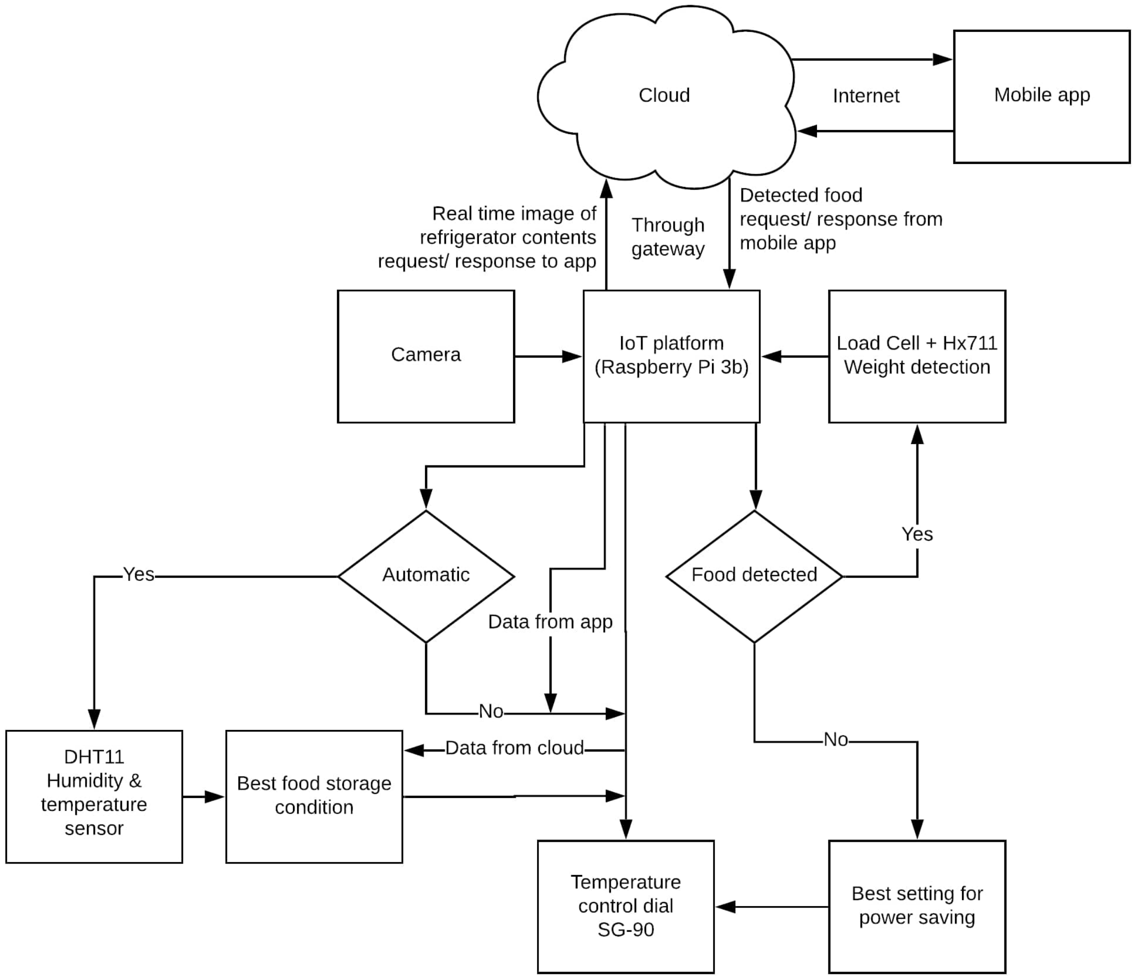

Figure 4.2: Smart refrigerator IoT application flow

The prototype is tested with sample food contents (both with real food and images) to test the image detection (through Google Vision AI) of food contents inside the refrigerator and is found to work with majority of cases, and the cases which it failed is due to poor image quality/ lighting condition and loosed focus of camera along with improper positioning of camera. Also, it is tested for different environment temperature for proper actuation of SG90 which is found to be working except for the delay in data transmission on Adafruit IO along with this IFTTT integrations, mobile application features are made to work as expected with proper error handling and debugging.

Smart Refrigerator Prototype

The prototype of smart refrigerator has been made with MDF prototyping board (5.5 mm) with all fixture locations defined for each component. Figure 4.3 shows the designed prototype of smart refrigerator along with required positioning of components. Also, the problems identified has been tried to resolve by centering of load cell for accurate sensing, additional LED lights for proper lighting condition for camera.

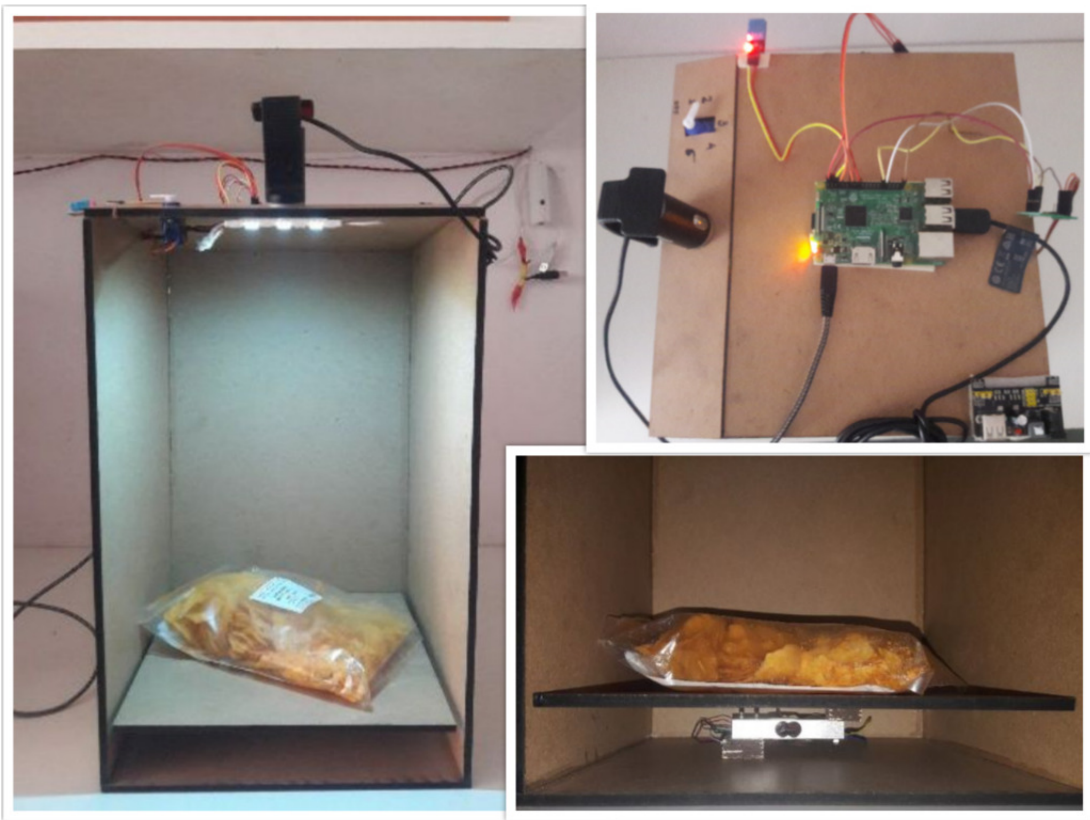

Figure 4.3: Smart refrigerator IoT application hardware prototype

4.3 Future Corrections

Smart refrigerator can be improved in the future by using a better camera and high quality image for more accurate image recognition of contents, compartments can be redesigned and camera can be positioned at refrigerator door for classifying different items in refrigerator, also more smart options for electricity saving can be added.

Chapter 5

Conclusion

5.1 Summary

A detailed understanding of Internet of Things application has been applied through Smart Refrigerator project through which AI/ ML model, python programming, IoT architecture, IoT application, IoT network architecture and its connectivity, designing and development, hardware interfacing and calibration topics were covered with detailed understanding. The smart refrigerator IoT application prototype was able to automaticaly sense any food item places and predict it and allow user to get all detailed information of the status and contents of the refrigerator using a custom-developed mobile application.

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