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A Next Generation Refrigerator on Compartmentalization Concept with Consumption Based Ordering

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Abstract—Technological advancements are playing a major role in easing daily chores through smart home concepts. The current lifestyle demands superior technology such as intelligent kitchenware to assist people who do not have time to manage their grocery and prepare healthy food. The refrigerator is one such most essential application of intelligent systems in the kitchen. This paper proposes the integration of a normal refrigerator with the Internet Of Things (IoT) devices. This refrigerator will be equipped with a space allocation module and will also be able to track the quantity of food products stored within. The system notifies the user when the food products are close to their expiration date through an interactive Android application. The internal smart ordering system will provide the best deals to the users looking for online grocery shopping. Thus the smart refrigerator will save money and reduce the wastage of food while helping the user maintain a healthier lifestyle.

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Index Terms—Compartmentalization, Optical Character Recognition, Restful services, Food consumption analysis, NodeMCU and Load cells.

I. INTRODUCTION

The refrigerator is the most prominent kitchenware used all over the world to preserve food. Principally, this electronic appliance is used for several purposes like storing vegetables, fruits, packaged products to increase their life and maintain quality. However, with the modern lifestyle, people are very busy and not everyone can dedicate that amount of time and effort to maintain their refrigerator contents. According to the sample survey that we had conducted, it was noted that:

1) 33% of the people did not keep their fridges organized
2) 50% of the people did not keep a track of the food products in their refrigerators
3) 64% of the people missed out on the expired and stale food items in their refrigerators
4) 91% of the people preferred a smart refrigerator instead of the traditional one for convenience

Besides the difficulty in managing the refrigerator contents, a large number of consumers lose track of expired ingredients and forgotten leftovers. Fortunately, with the rising growth of technological applications in everyday solutions, many companies have started focusing on home automation projects such as Smart Refrigerators. However, these refrigerators are priced too high and thus, the market segment for this product is reduced exponentially with very few middle-class families opting for this electronic device.

Therefore, the proposed next-generation smart refrigerator can meet the user's needs and which is provisioned with prominent features. The proposed hardware system can easily be integrated with common refrigerators and provides convenience to the user in terms of entering input data and tracking food products.

In 2016, Samsung developed a new smart refrigerator that had an inbuilt camera and a 21.5 inch LCD screen. It eliminated the need for the user to manually make entry of the food list and allows the user to view the actual fridge contents in their smartphones. However, several issues were identified. Some of them are a high cost which makes the refrigerator too expensive for many families as well as its management. Most of these refrigerators track food items based on the barcode attached to them. However, most of the grocery markets do not have the barcode system which in turn causes the user to manually enter the input data.

Several research projects have been initiated within the home automation field. One of the paper proposes a cloudbased low-cost refrigerator equipped with sensors and cameras to track food present in the refrigerator allowing the user to check their food list anytime and anywhere. Some of these systems propose the idea of simply sending the picture of the refrigerator to the user. The information gained solely from the collection of fridge content can lead to getting important insights and these systems fail to utilize this information to provide additional functionalities to the user [1].

Several types of research in this domain have explored the Internet of Things (IoT) technology which is used to make the refrigerator act as an IoT object that gathers information about the items stored within it and processes this information which is passed to the user. However, these IoT devices can act as a source of DDoS attack and can compromise the whole home network. Thus, securing these devices is very crucial and necessary.

Several research papers propose the idea of equipping the refrigerator with RFID antenna and reader. These antennas will scan the presence of RFID tagged products and alert the user of the product presence within the refrigerator. However, the strength of RFID signals deteriorates withing metals. Besides, hardly any grocery store provides RFID tagged products [2].

One of the paper proposes an intelligent refrigerator that monitors its contents and keeps the count of their age. Each compartment is fitted with a 360-degree rotating camera that clicks the picture and sends it for Image Processing. Algorithms are applied to classify the food product whereas its age is determined by comparing the current picture with an older one. The solution proposed in the paper requires expensive cameras to be fit in each compartment which becomes expensive and complex to install in normal refrigerators [3].

II. SYSTEM OVERVIEW

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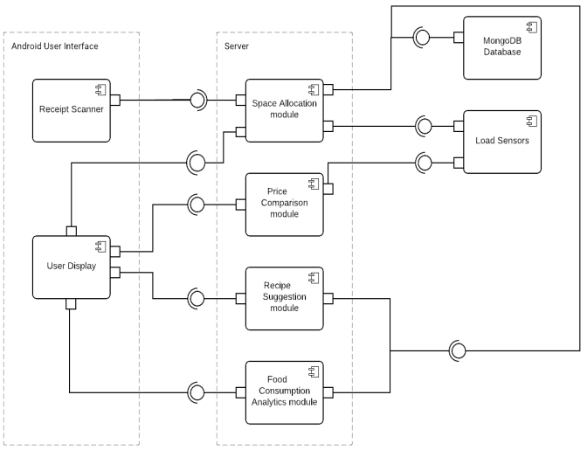


Fig. 1. Component Diagram of Smart Refrigerator

The Fig. 1. shows the Component Diagram of Smart Refrigerator with 3 tier viz. Android User Interface, Server and MongoDB.

III. Methodology

One of the main objectives of the Smart Refrigerator system is to develop a specialized, yet cheap design for replacing the traditional vegetable and food tray which can sustain compartmentalization for easy and personalized insights. Therefore, the normal refrigerator trays are equipped with IoT devices such as load cells. Load cells are used to measure the weight of each compartment. We have used single point load cells that are calibrated for 5KG weight. The load cell is located under a platform that is then loaded with weight from above.

HX711 Load Cell Amplifier is a small breakout board for the HX711 IC that assisted to easily read load cells to measure weight. This amplifier was connected to the micro-controller that was able to read the changes in the resistance of the load cell and with some calibration became very handy in getting very accurate weight measurements.

Node MCU is an embedded IoT platform. This microcontroller lies in the category of the IoTs system on chip design. NodeMCU is an open-source LUA based firmware developed for ESP8266 Wi-Fi chip. The ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems with TCP/IP protocol. The NodeMCU was powered from an external source using the USB. Once powered, a logical code was written on its flash memory using an IDE Arduino. Some of the standard functions that were used to configure the sensors and the board are:

1) The pinMode(pin number, OUTPUT/INPUT) function is to set a pin stating whether it will support an output sensing or input sensing
2) The digitalWrite(pin number, HIGH/LOW) is a function to write or provide voltage to the pin so that the sensor is activated. The digitalRead(pin number) was used to read the digital values coming from the sensors
3) The functions used for analog values were analogRead() and analogWrite()

Firstly, the data that the sensor receives is written in C language. Moreover, the sensor board used to convert physical parameters in digital parameters is a microcontroller with Wi-Fi chip, as a result, it cannot do heavy processing and machine learning algorithms cannot be written in C. Hence it is necessary to transfer all this real-time data to a python based environment. Therefore all of the received data is pushed to the firebase and retrieved onto the python processing unit [4]

[5].

Connecting the python server to the firebase storage is established by providing a few authentication details like the API key of the database, authDomain, DatabaseURL, and storageBucket. Pythons Pyrebase is a library that helps the python platform to connect with the firebase services.

This storage is used to store multimedia like images. These are the images that are received from the supermarket bills. The image from the firebase will be extracted by the refrigerator server and an OCR algorithm will be applied to it. The OCR contents will be passed on to the compartmentalization algorithm to allocate the food items into space-optimized compartments.

Secondly, firebase also acts as database services to store all the activities in the refrigerator which includes all purchases, low food products, recipes and more. This data is also used to act as a dataset to the food consumption analytics algorithms which predicts the quantity that the low products should reorder using time series.

The hardware(load cells and NodeMCU) provide the system with the total weight of the food items stored in the refrigerator. This data is pushed onto the firebase from where it can be fetched into the python server for further processing. However, weights alone do not provide the entire information regarding fridge contents. Therefore, we used Grocery Detection through image capturing from the camera which will be fitted inside the refrigerator.

The Grocery tracking through an image detection algorithm plays a crucial role in the operational model which provides the user with compartmentalization and dynamic weight cut off the algorithm. The detection algorithm is based on top of Faster-RCNN algorithm which is a combination of Region Proposal Network (RPN) that shares full-image convolutional features with the detection network. The system comprises of 3 sections:

1) Training the model: The image detection model is trained to identify apple, capsicum, and tomato. The model is trained on a custom dataset which is annotated using the VOTT tool. The region of interest(ROI) is marked for the RPN network which reduces the time for model training [6].
2) Fetching Image: Image is taken from the camera whenever the compartmentalization algorithm is triggered. The image processor pulls the data from the firebase and matches it with the training data.
3) Output Generation: All the images are tested on the pretrained model to give the output of the number of items detected. This output is very important in identifying the quantity of products in each compartment and tracking their consumption.

The second objective of this system is to provide the compartmentalization of food products by scanning the grocery receipt to recognized the purchased food items along with their respective quantities. The system uses advanced heuristics for extracting required and valuable text from the grocery receipts. The efficiency of OCR result accuracy is improved. The overall system starts with basic image processing techniques. The colored image taken from a mobile camera induces noise and comes in the way of feature and edge extraction. Therefore, the image is first converted into a grayscale image for background removal. This is followed by image binarization to provide more accurate results. Thus, these operations form a very important step in getting better accuracy in cases where images contain noise and shades. Once the preprocessing is done, the image is passed through tesseract-OCR where the text is extracted from a noiseless clean image.

Tesseract is an Optical Character Recognition (OCR) Engine made available under the Apache 2.0 license. It can be easily integrated into the python server by importing pytesseract or tesseract-OCR module.

The output from tesseract OCR is further refined to give more accurate results.

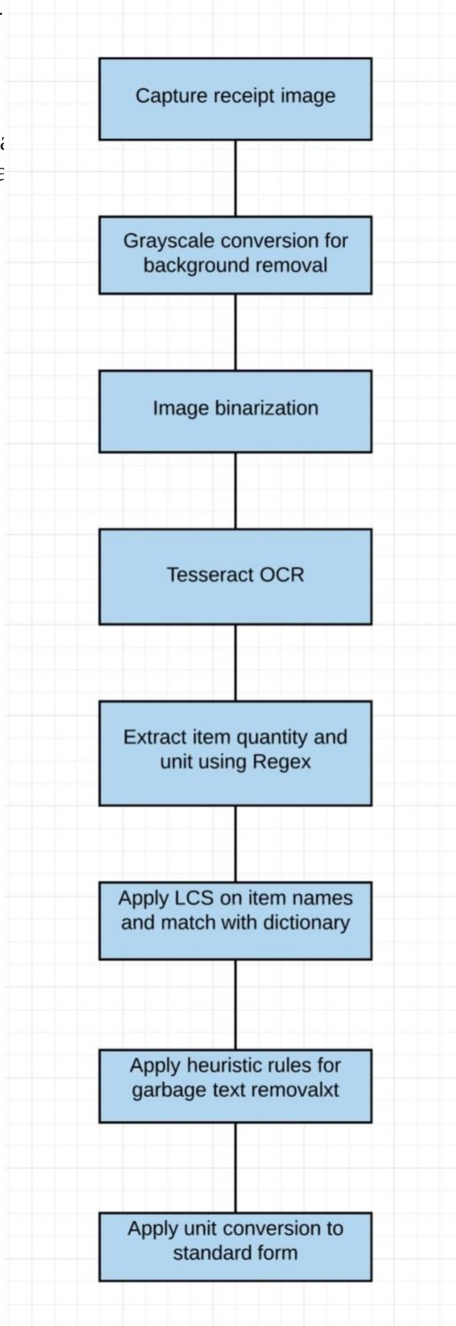


Fig. 2. Grocery Detection using OCR for Smart Refrigerator

The Fig. 2. shows the detection of grocery using OCR for Smart Refrigerator.

1) Heuristics Rules: The accuracy of text extracted by Tesseract OCR can be improved by applying some heuristic rules:
   a) ShortNames: dictionary contains short form as key and full form as value, i.e gm for gram or pc for piece
   b) GroceryDictionary: dictionary contains only food-related names i.e. food names
2) Longest Common Substring(LCS): All the item names that are extracted from OCR are not always accurate. So, they are looped against a list of words that the supermarket uses for those items. The Longest Common Substring is identified between each pair and the OCR text is replaced with the maximum LCS word that matches.
3) Regex: Generally, all food items are followed by their supermarket code. If the word contains four consecutive digits then it is considered as garbage. The quantity of the food product can be identified using a regular expression (\d+(?:\ d+)?)((?:—kg— pc)) .
4) Conversion: All the quantities are converted to grams by applying conversion formulas if they are mentioned in KGs. If the quantity is not detected then the default value is set to 0 gram or 1 piece.

On-the-go compartmentalization is the salient feature of this system as it simplifies the tedious task of grocery shopping allocation for the user [1]. Firstly the purchased items along with their quantities are detected from the receipt and are arranged in descending order of quantity within the algorithm and the food list is iterated. The compartmentalization breaks down the process into three cases.

1) Any of the purchased item already exists in at least one of the compartments with enough space
2) Purchased item exists in the compartment but which does not have enough space
3) Purchased item does not exist in any of the compartments

In the 1st test case, if multiple compartments exists with enough space for the entire item allocation, then the compartment with less remaining space is chosen.

In the 2nd test case, different permutations of compartments in which the item exists are tried that have enough space to allocate the purchased item. Out of these permutations, the one with the least remaining space after allocation is chosen.

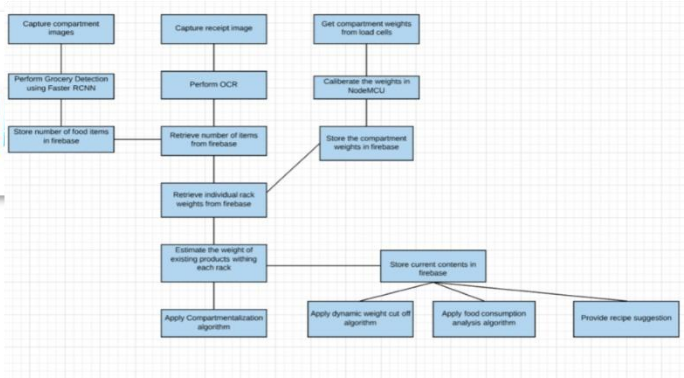
In the 3rd test case, different permutations of compartments in which the item exists are tried that have enough space to allocate the purchased item. Out of these permutations, the one with the least remaining space after allocation is chosen.

The system also alerts the user when some food item is running low. The food consumption engine is used to track the historical purchases of the user and based on this data, predict the quantity of the food items running low (which is depending on the load cell detection). The purchases of food items are recorded with respect to the time. Hence to predict the future quantity, a machine learning model is used to analyze the earlier quantities and their time and apply the time series concept to predict how much quantity of a certain item the user should buy.

The AutoRegressive Integrated Moving Average (ARIMA) is a time series model popularly used for a statistical method that captures a suite of different standard temporal structures in time series data. The ARIMA model is used to predict future quantity with respect to time. The ARIMA model has three important parameters p, d, q. The p (autoregressive model order) values are decided from the auto-correlation graph of the dataset and the q (moving average model order) parameter is calculated from the plot pacf statistical graph whereas d is the degree of differentiation.

For the existing data, an average accuracy of 74% is achieved.

1) A database is maintained to keep a track of all food items and their purchase and consumption.The model has to be trained every time for every new purchase made



2) The model is split is a way where 70% of the data is the training set and 30% is the testing set.
3) Once that is predicted, this value is added to the training dataset and the model is re-trained to figure out the next time-based value

The decision on when to trigger the alert for low food quantity is based on the dynamic weight cut off the algorithm. The threshold identification is a dynamic task as the user can have varied tolerance for different food item quantities. The process comprises of following stages:

1) Tracking Past User Behaviour: Whenever the user purchases any grocery, the purchased quantity using OCR along with the current quantity from load cells is stored in the database. This helps in identifying the total quantity that is required by the user.
2) Predicted Quantity for Purchase: The predicted quantity derived from the ARIMA model helps us derive the expected current quantity at that point of time.
3) Prediction: The median value of the historical data from step 1 signifies the all-time required quantity of a grocery by the user. The predicted purchase quantity is subtracted from the total median value to calculate the expected current quantity in the refrigerator.
4) Sending Notification: If the actual quantity is less than the expected quantity, then the alert is sent to the user.

Besides just giving alerts for low running food products, the system does more for the user by comparing the prices for the same on several online portals. These values are obtained by scrapping a few real grocery e-portals using the pythons inbuilt libraries called urllib for hitting the URL and getting the data and beautifulsoup4 for extracting the relevant data. The user will be able to see the break up costing of the food products for each e portal so that the user can compare prices and choose the suitable portal. Moreover, he will have options to either modify the automatically generated list, order online or to keep and save the list for manual grocery shopping.

The system also assists the user by providing several different recipe options based on the fridge contents. The result consists of a list of a variety of food recipes both vegetarian and non-vegetarian based on some of the raw ingredients that are present in the fridge. It has calories label and more features that can be helpful for the user to gain knowledge about the recipe.

Fig. 3. System Process Flow of Smart Refrigerator

The Fig. 3. shows the System Process Flow of Smart Refrigerator.

All the above-mentioned algorithms are integrated within a Flask based Restful server written in python language. It is a lightweight abstraction that works with existing ORM/libraries. Flask-RESTful encourages best practices with minimal setup. The server exposes several APIs for different features which are consumed by the frontend of the system. The frontend is built in Android as it provides the convenience to the user of getting updates irrespective of the location or time [7].

IV. Results

The algorithms collaborate together to provide wide range of functionalities and useful features to the user.

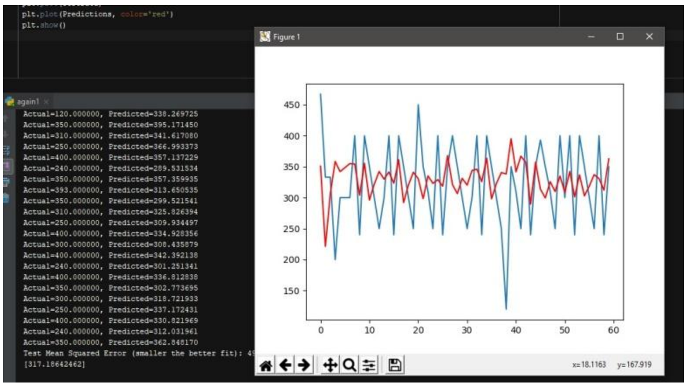


Fig. 4. ARIMA Model Prediction Graph of Smart Refrigerator

The Fig. 4. shows the ARIMA Model Prediction Graph of Smart Refrigerator.

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The accuracy of the ARIMA model in Fig 4. was tested to give 74% efficiency. Thus, prediction of the quantity for next purchase is fairly accurate based on user behaviour and will be improved as the personal dataset increases.

The suggestion recipe feature in Fig 5. accurately provides relevant recipes based on Grocery detection within fridge and processing the weights received from load cells.

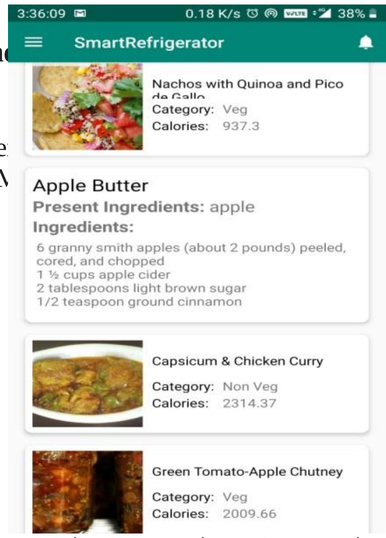

Fig. 5. Android Suggestion Recipes for Smart Refrigerator

The Fig. 5. shows the Android Suggestion Recipes for Smart Refrigerator.

V. CONCLUSION AND FUTURE SCOPE

The work presented in this report is related to simulation of a smart refrigerator with unique features like compartmentalization with embedded single point load cells to track the shortage of food products, expiry date tracking, online product price comparison, GPS based notifications and recipe suggestion based on the fridge contents.

The detection of the freshness of the food products based on chemical, pH, temperature, humidity composition and image detection of food item rotting can be done to prevent spoilage of unattended fruits and vegetables. The recommendation of food items intake and suggestion of apt recipes based on the users' fitness diet and which can handle multiple accounts on the handheld devices. Finally, the speech-based response and request model can be integrated with the refrigerator to increase the interactivity and performance.

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