Smart Shelf for Smart Kitchen

An Internet of things initiative

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Abstract— *This paper presents a conceptual design and operation of the sensor based Smart Shelf that is capable of measuring the availability of different types of grocery items and alert the User when the grocery item has reached a predefined threshold level as well as trigger a replenishing order to a predefined grocery store with the User approval or preauthorized list. The Smart Shelf consists of two different sections each leveraging two sensing mechanisms; weight sensing and level sensing. Level sensing section consists of fixed size container having RFID tag defining container size with product description, RFID tag reader, and an Ultrasonic or laser level sensor for measuring the levels of the content in the containers from the top of see through cap. The weight sensing section consists of RFID tags with similar container specification and content identification, RFID tag reader, and weight sensor measuring all contents on that shelf. The embedded sensors measure the level or the weight of the items which is updated to the database whenever the items are placed or taken out. The design comprises of several algorithms; 1) algorithm measuring the availability of a grocery item in a container using the level sensor, 2) algorithm measuring the availability of grocery item in a container using the weight sensor and 3) inventory management algorithm managing the inventory of products inside the Smart Shelf. This design will simplify the responsibility of grocery management, which further can lead to more sophisticated kitchen utility applications. It might be incorporated as a stand-alone operating module in Smart home or Smart Kitchen.*

Keywords— Door Sensor, Internet of Things, RFID tag, Ultrasonic Laser Sensor, Weight Sensor.

I. INTRODUCTION

Today Internet of Things is driving the innovation very rapidly, encompassing every field gradually. This initiative is an ideology that allow a plethora of devices to be connected and share their huge amount of data. The Kitchen is a new focus for innovation in the Internet of Things era. A combination of smart applications, the internet, sensors and other technologies can reinvent the kitchen to be more responsive and intelligent. Implementing Internet of Things in the kitchen will embed sensors, internet or cloud, grocery stores and items to facilitate the exchange of data among them and perform complex intellectual tasks.

With busy schedules, it is very hard to manage grocery stocking and shopping. Lacking proper planning and appropriate consumption pattern, entails visiting stores several times a month for buying grocery items. Eventually, it becomes a tedious task to observe family consumption, refill interval and stock required to cater guest visits. On other hand, grocery stores encounter overstocking or under-stocking which also requires streamlining.

In this paper, we devised a concept of Internet of things in the kitchen Shelves to make them responsive towards grocery stocking, which is supposed to incorporate an interactive application by utilizing a set of sensors. Cloud data sharing to enable grocery stores for customer location and grocery shopping list tracking which would lead to successful inventory management.

This idea leads to following features; first three of these are included in this paper:

1) An Inventory Management System for kitchen grocery.
2) Shopping list generation and alert messages to indicate grocery required.
3) Dynamic customer grocery request monitoring.
4) Grocery store inventory overstocking and under-stocking reduction.
5) Leading to smart shopping that includes home delivery of the items present in the shopping list.
6) Enable diet monitoring and provide online recipes which can be cooked from the existing grocery items.

Here, grocery item sensing constitutes of two approaches:

1) Weight Sensing: Sends the information pertaining to the weight of every item that has a unique RFID tag.
2) Level Sensing: Sends the information pertaining to the level of content in fixed size containers that has a unique RFID tag. The RFID tags are considered to be universal as their master list will be present with all grocery stores. Thus standardizing and streamlining the shipping and inventory management.

This paper comprises five segments: In Section 2, generalized approach and system architecture details are explained. In Section 3, both the algorithms and working scenarios are illustrated. In Section 4, future works and enhancements are discussed. Section 5 holds limitations and assumptions. Finally, Section 6 concludes the paper.

II. SYSTEM ARCHITECTURE

This section comprises the technical description, functionality of components utilized and describes overall system designs

2.1 Device Specifications

First, the essential component is RFID tags attached to the items which will uniquely identify the item. RFID tag has an integrated circuit and an attached antenna, compositely called as inlay. This integrated chip or circuit has a tag identifier and electronic product code marked on it. Every product will contain a universal tag identifier and the grocery item name as the product code.

Mounting RFID antenna in the shelf is the second requirement that would read the information stamped on the tags. This antenna will communicate with the tag antenna to get useful information and then transmit it to our application.

Level Sensor: The UCL-510 is a general purpose ultrasonic Continuous level Sensor based on non-contact sensing. This sensor is used to sense solids and liquids. This sensor is safe as manufactured through ISO certified supplier. The sensor is used to the wide range of substances and small in size. This sensor will be mounted on a panel so that it can move within the shelf.

Weight Sensor: Ultraprecision mini load MDB cell series are available in the different variants, the most appropriate one is MDB 2.5 that includes most sensitive load cell.

Door Sensor: There is mainly three door sensing technologies used. The technologies are active infrared, passive infrared and microwave. Active infrared sensors are more suitable to activate a door and detect the presence of the person.

2.2 System Design and Working

This section describes the technical design of the shelf.

Each container or item possess an RFID tags. RFID Antenna is mounted at the top corner of the shelf.

Moreover, one shelf will hold a Level sensor mounted on a moving panel at the ceiling, while another shelf will have a weight sensor mounted under its floor.

Door Sensor will trigger the RFID Antenna, Level Sensor, and Weight Sensor. Depending upon their output, signals will be sent to the wireless router, which will further send it to the application. The application will then analyze the data, detect item and store weight or level for both shelves separately in the database. After an appropriate algorithm is performed User is notified if necessary.

The user will be able to set the threshold for every item. If it is not set then the system will take the last refill quantity as the maximum quantity. A percentage of which will be treated as threshold after monitoring one week's consumption.

Through User's smart device, this application can interact with them. The application will be able to perform following tasks:

• Notify if any item's quantity has reached below a threshold level.

• Allow user to set the threshold for different items.

• Generate the shopping list with those items.

• Take users permission and share it with local grocery stores to do smart shopping or order home delivery.

• Enable user to know the status of all grocery items whenever required.

Figure 1, shows the system overview and functional modules.

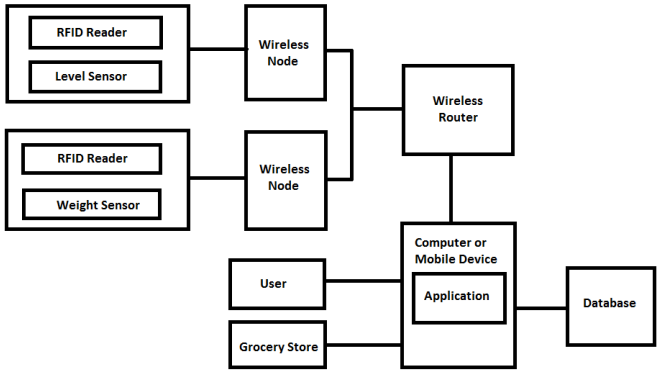

Figure 1. Functional modules

III. ALGORITHM TO IDENTIFY, TRACK AND MANAGE INVENTORY

This section defines few potential algorithms to support inventory management. Every algorithm will be applicable when the system is in the stable state. In both the shelf, the events would be:

1) An item's or container's addition to the inventory.

2) An item's or container's removal to use it and put it back.

3) The item's or container's removal from the inventory altogether.

3.1 Item identification and tracking in shelf having weight sensors

Whenever an item gets added to the inventory, the weight in the current state would be greater than the previous state's weight. On the other hand when an item was removed from the shelf, the weight of current state would be less than the previous state. For identification, we can compare the set of previous RFID tags to current RFID tags obtained from RFID scan. All of the above scenarios would be cover in the following steps.

Algorithms:

Wn	Weight of shelf at nth state
Wn-1	Weight of shelf at n-1th state
Xi	Weight of item at nth state
Rfn	Set of RFID tags of shelf at nth state

Rfn-1 Set of RFID tags of shelf at n-1th state

IF (Wn > Wn-1) THEN ……...new item addition
Rfi := Rfn - Rfn-1 ….RFID tag of item added
Xi := Wn > Wn-1
ELSE IF (Wn < Wn-1) THEN ……item removed
Rfi := Rfn-1 - Rfn
…..RFID tag of item removed
Xi := 0
END IF

3.2 Item identification and tracking in shelf having level sensors

The shelf would be dependent on two states; Shelf door open and closed. Sensor would scan the whole inventory and take the readings in least operating hour. The reading time-frequency can be set by the user. The system's sensor would move to the top of each container and take the level readings.

3.3 Threshold estimation

The User would be able to set threshold level, but a threshold estimation technique is derived here. There are two methods that can be applied to calculate the threshold values of weight and level. These values would be helpful while generating notifications to the user and preparing the shopping list. The first method calculates the percentage of the maximum reading recorded initially in the database. The other method evaluates the frequency of item utilized in a month and number of days grocery remains.

Lth	Level threshold for a container
Wth	Weight threshold for an item
Lmax	Maximum level recorded till now for a container
Wmax	Maximum level recorded till now for an item
t	Number of times an item/container is used in day
n	Number of days entered by user
Qav	Quantity utilized on average per day
qi	Quantity utilized at ith time

3.3.1 Percentage based estimation:
Here percentage P is estimated to be 30%
Lth = Lmax * 30/100
Wth = Wmax * 30/100
3.3.2 Based on consumption for n days
Qav = ∑ qi / t
Lth = Qav * t * n
Wth = Qav * t * n

3.4 Kitchen utility algorithm

This procedure will generate the notifications based on the calculation performed. The following pseudo code can be implemented in the database:
IF (Li < Lth) THEN
Notify user
Get item name from RFID – item mapping table
Add item of the container to shopping List
END IF

IF (Wn < Wth) THEN
Notify user
Get item name from RFID – item mapping table
Add item to shopping List
END IF

3.5 Grocery Store inventory management

The system generates the shopping list for the user. The user will be able to choose the items that they need to purchase. A grocery store will be able to analyze the list of its previous customers and generate a list of potential shoppers. The store manager would be able to analyze and manage inventory effectively.

IV. FUTURE WORK

The future scope of the smart kitchen can incorporate drone delivery system that uses the shopping list generated by the system to purchase groceries and deliver them directly to the shelf. The system can be upgraded to store nutrient values of each item and help the user to customize his nutrient intake. The system can also include the way to store a diet plan suggested by the doctor that the User is following.

V. LIMITATIONS AND ASSUMPTIONS

The manufacturers are assumed to have the master mapping list of items. RFID tag of each item is labeled with the RFID code and item name to generalize the solution. The system would have two different shelves in the kitchen and the inventory items acquired by these will only be accountable. Items are taken and placed once at a time from shelf having weight sensor. Also, the shelf having level sensor will work only if the containers have a transparent cover. The shelf would work only with the specified container sizes there can be three variants in the sizes and details of their size and item is again imprinted in the RFID tag. The item and container mapping cannot be modified by the user. After every usage, the gate of the shelf is closed. Also, there is a time slot in which the kitchen shelf is not used.

VI. CONCLUSION

This system is an initiative towards the smart kitchen that includes two sensing techniques level and weight sensing. This system is efficient to identify and track usage of the grocery items. It is a conceptual idea when implemented can streamline the inventory management of kitchen and

grocery store. This would reinvent the kitchen to become more responsive and intelligent to support inventory stocking and shopping list generation. It can be implemented to support the smart home initiative and become an essential prototype as currently, there are oven and fridge.

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