Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 2 Issue 7, July - 2015

SMART REFRIGERATOR USING INTERNET OF THINGS

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***Abstract*—Intelligent appliances with multimedia capability have been emerging into our daily life. Thanks to the fast advance of computing technology and the wide use of the Internet, smart home is one of the most prominent areas of intelligent appliances. Kitchen is one of the places where such intelligent appliances have been used. The global market for industrial WSN is expected to reach $944.92 million by 2020, at a CAGR of 12.96% from 2014 to 2020. Existing systems used barcode or RFID scanning to keep track of the stock. The products currently available are expensive as the user has to purchase the whole refrigerator. The Smart Refrigerator module is designed to convert any existing refrigerator into an intelligent cost effective appliance using sensors .The smart refrigerator is capable of sensing and monitoring its contents. The smart refrigerator is also able to remotely notify the user about scarce products via SMS (Short Message Service) and email. It also facilitates the purchase of scarce items by providing a link of the online vendor of that particular item. Additional functionality includes the acknowledgement of a placed order in order to avoid the purchase of the same item by different users of the same smart refrigerator.**

The core functionality of the smart fridge, is to maintain, with minimum effort, an inventory list of food items which might want to be purchased as soon as they run out. As a result, the user is notified every time three eggs are used. The pressure sensor triggers a notification to user as soon as the applied pressure is below 0.5 kg. LDR sensors monitor the containers in which liquids are sensed. The user notifies other users of the smart refrigerator about a placed order.

Keywords—Keil software, smart refrigerator using IoT

I. INTRODUCTION

Both Research and Industry have focused on the development of the Smart Home Environment For example, more than 100 homes offering smart technology have been built in South Korea and another 30,000 were planned .Research has also focused on developing smart homes for the elderly. Developing Smart Appliances is directly proportional to Developing Smart Home environment [1]. It is a critical factor in the realization of the smart home environment.

Kitchen is one of the most important place for a Smart home as it consists of many Appliances which provides better services to the household [2]. The focus of our project is on the smart fridge. Many efforts in the development of the smart refrigerator have been made, none of which has been energy efficient or cost effective.

The modern living and the fast paced environment doesn't allow the user to keep a track of the food items inside the refrigerator.

Although efforts have been put by the industry to develop the smart refrigerator, the current or the existing technology is still not cost effective or energy efficient. The technology is too complicated or complex for a simple household user who have little knowledge of how all the mechanism behind the smart refrigerator works [3]. The internet connectivity at most of the places is still poor and there is limited network connectivity i.e. either low internet speeds or low support. The barcode is not uniform to record the essentials of the product that includes the expiration date. The smart home environment or the networked home doesn't have enough security to protect the outflow of data from the house. The privacy of user and the house can be compromised by attackers. There is no unique operating system for remote device use to control the smart system. There is no standard for the area, resulting products conforming to different specifications by different producers.

The smart refrigerator or the internet refrigerator as it is called, is used to monitor the items inside it and notify about scarce products[2]. The idea of connecting home appliances to the internet or the smart home environment has been seen as the future and is highly regarded as the next big thing.

A. State of the art development

By the late 1990s and the early 2000s, the idea of connecting home appliances to the internet (Internet of Things) had been popularized and was seen as the next big thing. In June 2000, LG launched the world's first internet refrigerator, the Internet Digital DIOS. Internet refrigerator (also known as Smart refrigerator) is a refrigerator which has been programmed to sense what kinds of products are being stored inside it and

keep a track of the stock through barcode or RFID scanning [4]. This kind of refrigerator is often equipped to determine itself whenever a food item needs to be replenished. This refrigerator was an unsuccessful product because the consumers had seen it as an unnecessary product and due to the high cost (more than $20,000) and that the problems solved were obscure. For example, many juice bottles are transparent, providing a visual reminder that a purchase is needed eventually; vegetable drawers are similarly transparent and contain items often removed from packages, thus eliminating bar codes for inventory which meant manually keying in descriptions and dates[5]. Moreover, the ability of the device to remind users of upcoming purchases when there are often multiple buyers in a household who communicate informally is not typically addressable as a use case.

B. Problem Statement

A hardware prototype is to be developed which senses the contents inside the refrigerator, triggers when the contents inside is below a certain threshold (set by the user). In case of scarce products, this trigger is sent to the users mobile and eventually to his email id through an android application. The message comes with information about the product which is low on quantity inside the fridge and comes with a predefined link which facilitates online purchasing.

C. Objectives

This paper is intended to have an operational model which monitors the contents inside the refrigerator in real time and generates a notification to the user in case of any product which is low on quantity (as per the threshold set by the user). Also this project intends to facilitate online purchase of food items from online vendors and notify all the members of the family if the order has been placed.

D. Methodology

The system comprises of 4 sections where the sensors are placed[6] Light dependent Resistors (LDR) sensors are placed along with a counter which can be used to sense the number of eggs inside the refrigerator, Also they are used to detect the level of milk and soft drinks in the container. The fourth application is to sense the presence of vegetables in the refrigerator which is being done with the help of pressure sensors which has a threshold of 500gm approximately. Whenever the contents inside the refrigerator goes below the set threshold it generates a trigger which is being transmitted in the form of message to the user .

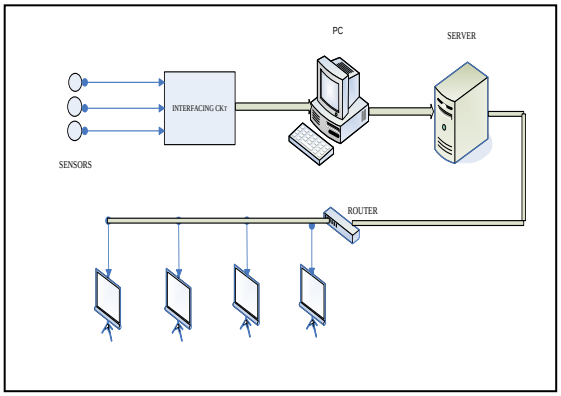


Figure 1.1: Block diagram of smart storage

SENSORS: These field sensors are fitted in Refrigerator where bottles are stored, one for each bottle. They are object sensors and if not found any object in front of them, they produce NO Object signal which is fed to Object Detector Unit for further processing.
OBJECT DETECTOR UNIT: This unit generates NO Object alert signal corresponding to field sensors signal, which is server's software format. This server understandable alert signal is fed to input port of server through suitable Interfacing stage. [Not shown in diagram]
INTERFACING STAGE: As server needs TTL compatible level signals at its input port, suitable interfacing stage must be introduced before feeding field signals directly to it to avoid any kind of damage.
PC: The Monitoring unit of this system has software module in its memory, which will be always in monitoring mode and scans its input port for any update alert signal. If any such signal found, it automatically deducts the blood bottle database for one less. So after every pre-determined time interval this updated data base is further send to Server, where user/owner's website is situated for other customer's information.
SERVER: This unit keeps the retailer's website in its memory bank and allows retailer to access it from remote end and to other retailer's customers through router.
POWER SUPPLY UNIT: This specially designed regulated power supply unit provides all necessary voltages to system for proper working.
SENSORS: These field sensors are fitted in Refrigerator where bottles are stored, one for each bottle. They are object sensors and if not found any object in front of them, they produce NO Object signal which is fed to Object Detector Unit for further processing.
OBJECT DETECTOR UNIT: This unit generates NO Object alert signal corresponding to field sensors signal, which is server's software format. This server understandable alert signal is fed to input port of server through suitable Interfacing stage. [Not shown in diagram]

Organization of the rest of the paper:
Section 2 describes about the high level design and specification, Section 3 briefs about the

implementation details, section 4 focuses on the various modules tested, Section 5 gives pictorial representation of the results and Section 6 concludes the work and gives some information to carry out as the future work.

II. DESIGN AND SPECIFICATIONS

A. *High Level Design*

This chapter discusses the High Level Design that will be used in the development of the SRIOT (Smart Refrigerator Using IOT) module. This chapter lists the techniques and approaches used during development of this module and also provides a detailed analysis. This module could be seen as a combination of smaller modules namely:

1. Sensing module
2. Control module
3. Transmission module

These modules work together to determine low contents of a particular product inside the refrigerator and notify the user about the scarce product via SMS (Short Message Service) or e-mail.

B. *Design Considerations*

This section addresses the issues that need to be resolved before attempting to devise a complete design solution.

1) *General Constraints*

The following constraints must be kept in mind while developing the design.

- Power supply should be switched off when module not in use
- Module has to be installed such that there is availability of strong network in order to notify the user
- The food items have to be placed in their respective slots.
- The pressure sensor output has to be kept high.
- The design must be applicable any existing refrigerator

2) *Architectural Strategies*

This section describes the design decisions and strategies that affect the overall organization of the system and its higher-level structures. These strategies will provide insight into the key abstractions and mechanisms used in the system architecture.

3) *Programming Language*

The programming language plays a major role in the efficiency as well as the future development of the project. 'embedded C' was the effective option among others to be chosen as programming language.

C. *Future Plans*

The successful completion of the module will introduce many new possibilities that could be integrated with the existing system. The module can be extended to include many new and advanced sensors and new ways of communicating with the user. Current module supports a few essential applications but it can be designed to meet the needs of a particular user.

1) *User Interface Paradigm*

The output is shown on a circuit board which consists of the smart refrigeration module. LED's are placed at various places to indicate the flow of execution. A buzzer is used to highlight a trigger by any of the sensors.

2) *Error Detection and Recovery*

The possible source of error include replacing of food items without using them. If the user extracts an egg from the tray and places it again at the end the module will detect the use of one egg which could to lead to false notification. To recover from such an error, the module could be reset or a dedicated application could be implemented .

3) *Data Storage Management*

Data storage management is essential to the efficient nature of the program. It must be ensured that all dynamically allocated variables and objects are efficiently de-allocated and cleaned up.

4) *Communication Mechanism*

The smart refrigeration module communicates with the users via a GSM (Global System for Mobile communication) module.

D. *Design And Specification Of Smart Refrigerator*

This section deals with the implementation and design of the components used. For the first application i.e. detection of scarcity of eggs in the refrigerator an LDR is combined with a counter to keep track of the contents in the egg compartment. In this implementation as soon as 3 eggs are used, the user is notified.

The second and third application involves the use LDR sensors for sensing items inside the refrigerator which are placed inside specific containers. Placing of sensors is to be done according to the requirement of the user or threshold level required. The next application makes use of a pressure sensor. As vegetables are measured according to weight and not size a pressure sensor is used to sense the scarcity of vegetables in a particular compartment. In this implementation the threshold kept is around 0.5 kg

1) *Block diagram of smart refrigerator*

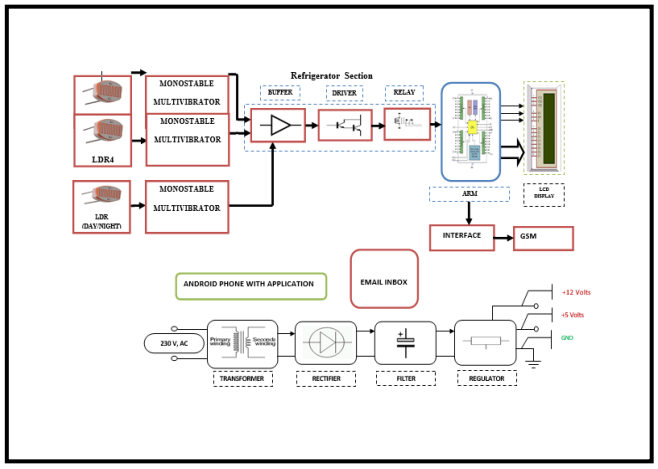
Figure 2.1 module needs two voltages viz., +12 V & +5 V, as working voltages. Hence specially designed power supply is constructed to get regulated power supplies. A photo resistor or light-dependent resistor (LDR) or photocell is a light-controlled variable resistor. The resistance of a photo resistor

Figure 2.1 Block diagram of smart refrigerator

decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photo resistor can be applied in light-sensitive detector

circuits, and light- and dark-activated switching circuits.

Buffers do not affect the logical state of a digital signal (i.e. a logic 1 input results in a logic 1 output whereas logic 0 input results in a logic 0 output). Buffers are normally used to provide extra current drive at the output but can also be used to regularize the logic present at an interface. Drivers are used to drive the



relay where the output is complement of input which is applied to the drive but current will be amplified.

An electromagnetic device is used to drive the load connected across the relay and the o/p of relay can be connected to controller or load for further processing. A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers and confirmation of user input such as a mouse click or keystroke. Indicator provides visual indication of which relay is actuated and deactivated, by glowing respective LED or Buzzer.

III. IMPLEMENTATION

This section deals with the detailed description and implementation of the various components and pertinent connections to obtain the working model of the Smart Refrigeration module.

A. Hardware and Software Implementation

This section mentions the hardware and software used for implementation of the Smart Refrigeration module.

The hardware used for Smart Refrigeration module are: Power supply unit, mono stable multivibrator, electromagnetic relay, buffer driver and switching stage[7]

The Keil Software LPC2148 development tools are programs that are used to compile the C code, assemble the assembly source files, link and locate object modules and libraries, create HEX files, and debug the target program. µVision for Windows™ is an Integrated Development Environment that combines project management, source code editing, and program debugging in one single, powerful environment[8].

The ARM7 ANSI Optimizing C Compiler creates re locatable object modules from the C source code. The ARM Macro Assembler creates re locatable object modules from the LPC21XX assembly source code. The Linker/Locator combines re-locatable object modules created by the Compiler and the Assembler into absolute object modules[7]. The Library Manager combines object modules into libraries that may be used by the linker. The Object-HEX Converter creates Intel HEX files from absolute object modules.

1) Development Tools

The **Keil development tools for ARM** offer numerous features and advantages that helps to quickly and successfully develop embedded applications.It is easy to use and guarantees to help and achieve the design goals. The µVision IDE and Debugger is the central part of the **Keil ARM development tools**. µVision offers a Build Mode and a Debug Mode. In the µVision Build Mode the project files are maintained and application is generated. µVision uses either the GNU or ARM ADS/Real View™ development tools[9]. In the µVision Debug Mode the program is verified either with a powerful CPU and peripheral simulator that connects the debugger to the target system.

The ULINK allows to download the application into Flash ROM of the target system.

2) Create a Project

µVision includes a project manager which makes it easy to design applications for an ARM based microcontroller. One needs to perform the following steps to create a new project:

- Start µVision and select the toolset
- Create a project file and select a CPU from the device database.
- Create a new source file and add this source file to the project.
- Add and configure the startup code for the ARM.
- Set tool options for target hardware.
- Build project and create a HEX file for PROM programming.

IV. TESTING

Testing was done in a room with normal daylight. The temperature during testing was recorded to be 26^0C.

A. Testing of the Sensor Module (Eggs)

The Egg Compartment is tested and test cases are tabulated in the tables. The two tests performed were

to check whether a message is generated to the user in case of the number of eggs go beyond three.

Unit test 1 was done to check if two eggs are lifted from the compartment i.e. light is allowed to pass two times to the LDR sensors then no message should be generated.

Unit test 2 shows that the user will be notified when the fourth egg is lifted from the compartment i.e. light is passed four times. As the value of the counter is set to 3, the user gets a notification along with an option to purchase online.

B. *Testing of the Sensor Module (Milk and Soft drinks)*

Unit test 3 was carried out to determine whether a message will be passed to the user or not in case the contents of the container go beyond the set level. The LDR sensors can be placed at a certain level and it acts as level sensors. When the contents go below this set level a trigger is generated which is sent in the form of message to the user. The test conducted was to check for Soft drinks and milk, As milk and soft drinks are opaque and doesn't allow light to pass through it, LDR sensors are used as level sensors in the container.

C. *Unit Test of Sensor Module (Vegetables)*

In unit test 4, the pressure sensors are tested for the presence of vegetables in the refrigerator compartment. A trigger is only generated if the weight inside the fridge's tray will go below the threshold of the pressure sensors which is appx.500gm. As the weight falls below this level, the user is notified in the form of a message.

D. *Testing of order placed notification*

The ORDER RCD keyword is a special keyword that can be used by the user to inform all other users that the order has been placed by him/her. The LED should glow which shows that order has been received by the vendor and also it is an indication to the other users of the family that the order has been placed.

E. *Test of the Keyword "THANK YOU"*

The LED should glow which shows that order has been received by the vendor and also it is an indication to the other users of the family that the order has been placed. The keyword "Thank You" is used by the user to notify the user that the placed order has been delivered to the user. The test was successful. This test is done in order to notify other users in the family that the order placed was successfully delivered. The LED which was in the ON state goes to OFF state which gives an indication that the order has been received.

The keyword "Thank You" is used by the user to notify the user that the placed order has been delivered to the user. The test was successful. This test is done in order to notify other users in the family that the order placed was successfully delivered. The LED which was in the ON state goes to OFF state which gives an indication that the order has been received.

V. RESULTS

This section shows the results.

A. *Pictorial Representation of Results*

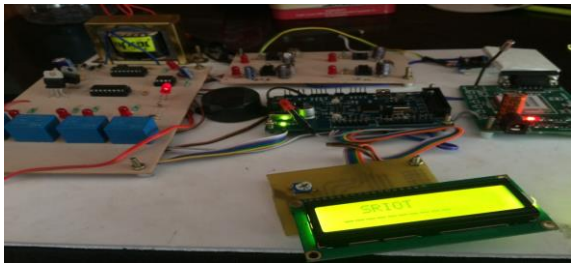


Figure : 5.1 Smart Refrigerator module

Figure 5.1 depicts the smart refrigeration module. It shows the LDR and the pressure sensors which is connected to a 555 times to create a trigger. It also shows the buffer, driver and relay which is connected to the micro controller which is further connected to the GSM module. The LCD display confirms that the power supply is turned ON.

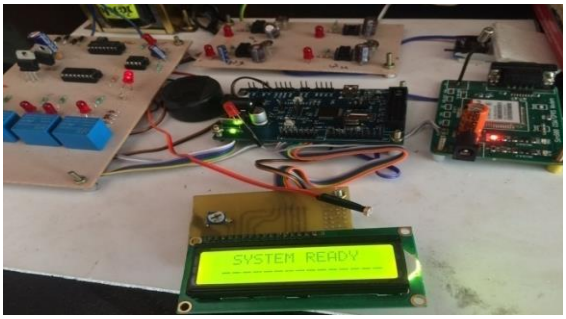


Figure 5.2: System Ready

Figure 5.2 depicts the SRIOT module when it is ready. After turning on the power supply we need to wait for the system to be ready for it to function properly. This is an indication that all the components are properly connected and working fine.

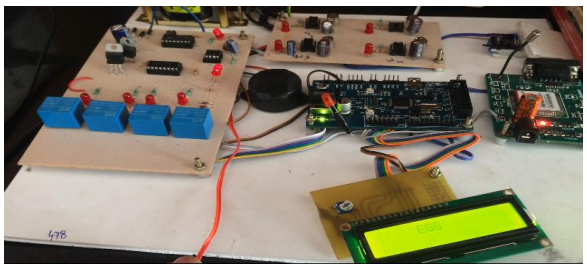


Figure 5.3: low on eggs

Figure 5.3 shows that the refrigerator has sensed for low contents of egg. As soon as the count of the Eggs inside the refrigerator goes below 3, the SRIOT module confirms by displaying EGG on the display and sends this information to the user on his mobile phone and email id.

Similarly, the SRIOT module senses for the low contents of vegetables in the refrigerator by the pressure sensor as the weight on the sensor is below the threshold level. The SRIOT module confirms by displaying vegetables on the LCD display. This information is further sent to the user in the form of an SMS and email. The SRIOT module has been designed to sense for low contents of Soft drinks in the refrigerator. It further confirms by displaying Soft drink on the LCD display. This message is then passed to the user in the form of an SMS and email.

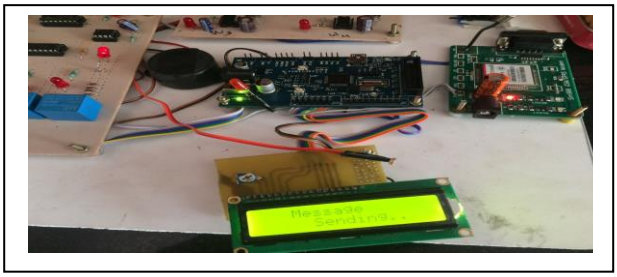


Figure 5.3: Sending message to user about scarce food items

Figure 5.3 depicts that the information gathered by different sensors about the low contents inside the refrigerator is sent to the user in the form of an SMS with the help of the GSM module.

Figure 5.4: Link to online vendor included in the notification

Figure 5.4 depicts the option for placing an order. If the user wants to purchase any food item which is low on stock then he/she can do from an online vendor.

The SMS comes with the link of the online vendor which gives him/her an option to buy online

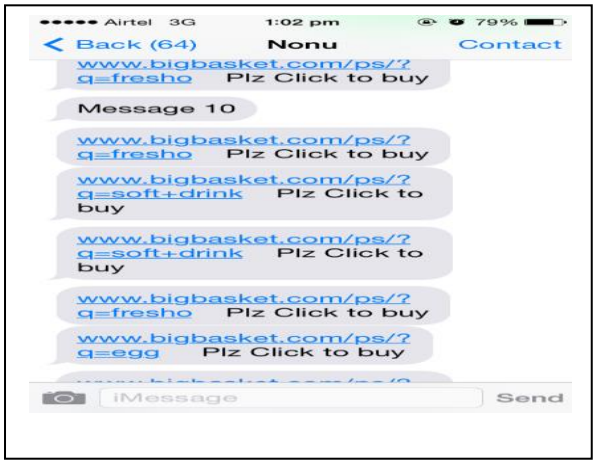


Figure 5.5 Message received on user's mobile

Figure 5.5 shows the screen shots of the messages received on the users mobile phone while testing the various case of the SRIOT module.

VI. CONCLUSION

The Smart Refrigerator module is able to remotely notify the user about the low contents inside the refrigerator. It also facilitates purchase of the scarce food items from an online vendor. The link to the online vendor is incorporated inside the notification that is sent to the user via SMS (Short Message Service) and email. This module allows the user to indicate a placed order and the other users to acknowledge the placed order.

A. Future Work

The concept of smart fridge is far more reaching than notifying the user about the contents of the refrigerator. It should give importance on maintaining a healthier lifestyle by providing the nutritional value of the contents. The future smart fridge will use 'nano-articulated technology' shelf surfaces which, whilst smooth to the touch, will have millions of independently controlled micro-tiles which will manoeuvre products which soon need to be eaten to the front of the fridge.

The fridge will also monitor gases released by degrading foods and push these to the front of its shelves.

Ultrasound-scanning technology built into the door will allow the fridge to 'swipe and capture' the food on a plate before and after mealtime, meaning it can assess what type and amount of food is wasted.

The fridge of the future would then be able to cross reference and act on reducing the ingredients used in future meal suggestions and helping to minimize food waste.

ACKNOWLEDGMENT

Special thanks to Anmol Seth and Dixit Jaiswal for their contribution in this work.

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