

# The Design of a Smart Refrigerator Prototype

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**Abstract**—The technological development nowadays has enabled the use of smart appliances and machines almost everywhere. The refrigerator is considered one of the most important appliances that is being used in almost every place for the purpose of storing foods, drinks, and medicines at cold temperatures, and in a sealed place to avoid exposure. However, there are several challenges encountered with refrigerators; like the expiration of some of the items inside the fridge, the need to know the exact count and availability of the items, potential liquid leaks, and open fridge door. A smart refrigerator is proposed as a solution to the aforementioned problems. The proposed smart refrigerator uses a Radio Frequency Identification (RFID) reader, the Arduino Uno microcontroller, RFID tags for all items in the fridge, a user friendly application developed using Microsoft Visual Studio, MySQL main database developed by the suppliers to store the information related to each purchased item and Phidget Interface Kit board.

**Keywords**—Smart fridge, RFID reader, RFID tag, Arduino, Phidget Interface Kit 8/8/8, MySQL.

## I. INTRODUCTION

Finding an expired item in the refrigerator or needing an item that is no longer available in the fridge are common problems that everyone may face. The item could be a food item, a drink, or medicine. Leaving the fridge door open is another important issue, which by repetition might lead to damaging the refrigerator. Moreover, liquid's leak is another problem that can be encountered.

The RFID technology is defined as the wireless use of electromagnetic fields to transfer data for the purposes of identifying and tracking tags attached to items using radio waves. The RFID was initiated during World War II and the first application was developed by the Britain to identify friendly aircrafts from enemy aircrafts [1]. The RFID is low in price and it does not require a line of sight for its operation. It has been used as a tracking system in many different applications, such as, the radar, security systems and car parking systems as well. It mainly consists of an RFID tag which is a small microchip that is made of an integrated circuit and designed for the wireless communication with a built-in antenna. The size of the microchip is small as the size of a grain of rice. The tag is usually attached to the item to be recognized by the RFID reader.

The RFID reader could be portable, handheld, or stationary. The RFID technology has been considered as the replacement of the barcode technology. The main reasons are that the barcode technology requires a line of sight between the barcode reader and the barcode but the RFID does not. In addition, the

information stored in the RFID tags could be easily modified while the information stored in the barcode cannot.

In this paper, a smart refrigerator is proposed as a solution to all of the problems mentioned earlier. The proposed smart refrigerator will inform the user about the quantities of each item and the items that have been expired. Also, it will alarm the user if any liquid leak happens or if the refrigerator's door is left open for a long time.

This paper is organized as follows. Section II discusses and summarizes similar refrigerators. The development methodology, system architecture, and requirements are presented in Section III. Section IV describes the implementation of the smart refrigerator prototype. The conclusion of the paper is provided in Section V.

## II. SMART REFRIGERATORS IN THE LITERATURE

The intelligent iFridge presented in [3] uses the RFID technology. The purpose of the iFridge is to create a fridge with an intelligent system by leveraging the RFID technology to allow the user manage the food stored in the refrigerator. The iFridge provides many features to the user. It allows the user to efficiently manage and locate the items stored in the fridge, it also provides the user with a food tracking feature using the RFID tags that are attached to every item.

The Smart Fridge with Multimedia Capability for Better Nutrition and Health proposed in [4] focuses on the refrigerator, as one of the appliances that has been changed from being traditional to only store the food to integrating the fridge with TV, radio, internet and the computer. The aim was developing a project to have an application for a smart fridge for the purpose of having a positive impact on health and wellbeing of the consumer to achieve their goals and objectives. The proposed fridge has the following features: to recommend suitable recipes for different users according to the information stored, create various recipes that can be chosen from different cooking methods, notify the user with the nutrition facts, indicate the type of the food that is forbidden and the types that are allowed for the users who suffer from specific illness, generate a shopping list, display the calories for all the foods stored in the refrigerator, and scan the food and store the information into a database to warn the user on the food items that are going to expire.

The RFID Fridge in [5] main goal is implementing a refrigerator to maintain an updated list of the items stored in the fridge. To do so, every item is tagged by an RFID tag, so that

when the user places it in the fridge, the RFID reader will be able to identify the product's unique RFID tag, and register it as either in or out of stock in the database.

The manufacturer of the Combined Cool Media Fridge Freezer by Siemens in [6] designed a smart refrigerator that suits the needs of the customer. Their main focus is creating a smart fridge with all possible features that customers expect to encourage family members to eat and watch TV in the kitchen rather than in the living room. The Combined Cool Media Fridge Freezer has a built in LCD flat screen 38 cm in size. This LCD TV is different than any other LCDs because it is movable and the user can adjust its place wherever desired. The LCD also has an application for the food management to manage the food, and it offers the user with the choice of connecting a satellite, DVD, Camcorder and head- phones.

The main focus of the LG TV Refrigerator presented in [7] was creating a fridge that changes the idea of the need for the traditional fridge which stores food to keep them cool, to the need for the smart refrigerator that has compatible features. The LG TV Refrigerator comes with a touch LCD TV 15 inch that has an application for food management, DVD connection and FM radio. Moreover, the manufacturer created the Weather plus LCD display (another LCD which is smaller than the LCD TV that is 4-inch in size) in the refrigerator, which is especially designed for the purpose of displaying the forecasts based on your area, date and time. This LCD has a calendar with the ability to set an alarm, eight category recipe banks with 100 preloaded recipes and personal digital photo album.

The manufacturer of Samsung Smart Four-Door Fridge Freezer in [8] has created this fridge for the purpose of covering the customer's need for a refrigerator that has a 10.4 inch wireless LCD screen built in it. This LCD has many features designed for the user including the food management application. Some of the refrigerator's characteristics are: TV connection, Video player, internet connection and the ability of finding the items easily in the non-partitioned refrigerator section. Also, it provides the connectivity between the smart phones and the refrigerator by having the Bluetooth feature. The food management application allows the consumer to manage the food inside the fridge. It provides the user with different categories of foods, and according to that category, the user could easily record the items using the touch LCD. The item recorded is stored in the application's database, so the user can modify the list any time he/she would like. Also, the application provides the user with the ability to store his/her favorite recipes, and also it provides the choice of writing notes and diaries.

In the Samsung refrigerator, the user needs to manage the food manually by inserting the information of every item to the database of the application, but in the smart refrigerator, the user does not need to do that because the fridge includes the RFID reader which will identify the items and store the required information in the database. All of the refrigerators discussed offer similar features to the smart refrigerator proposed in this paper. However, the proposed smart refrigerator offers additional feature like leak and open-door detection.

### III. DESIGN APPROACH

In this section, the authors explain the development methodology of the proposed smart refrigerator, the system architecture, design alternatives, and the components used.

#### A. Development Methodology:

The smart refrigerator design uses the Waterfall model. This model is used for projects that have fixed, clear, and well understood requirements. The standard Waterfall model has six stages: requirements, design, implementation, testing, development of the system and maintenance. The Smart Refrigerator project follows the following sequence. First of all, the requirements of the overall system and subsystem are clearly defined. After listing the requirements of each design of the overall system and subsystem, the most applicable design is chosen. Then, the implementation of the design for each subsystem is done according to the requirements. Once the implementation is complete, the design is tested to check the results. The results are then verified by testing the design. If one of the phases did not work as expected or gives incorrect results, it will be adjusted to work accurately [9]. Figure 1 shows the design sequence for the smart refrigerator



Figure 1. Waterfall model

#### B. System Architecture:

The Smart Refrigerator proposed is composed of software and hardware subsystems combined together to form the main system. The subsystems included in the Smart Refrigerator are: the RFID reader, the application, the touch PC and the database server. Each subsystem has its own functions. For example, the RFID reader is used to scan every RFID tag attached to each item and add it to the refrigerator's database as well as keep tracking it; once the reader doesn't recognize the tag, the program will subtract the quantity by 1 considering this case as removing the item out of the fridge, the database server is used to store the data related to each item as specified by the retailer, the application is designed to help the user and the administrator, and the touch PC is used to run the application and to display the information for the user. The functions of each subsystem are tabulated in Table I.

The Smart Refrigerator's system architecture is shown in Figure 2. The system operates as follows: the RFID reader is connected to an Arduino Uno board. The microcontroller (Arduino) works as a converter that converts the serial communication port to digital port. The Arduino is connected to the computer/PC through a USB, it forms the link between the RFID reader and the PC. As soon as the reader is connected to the computer, the information of the tag scanned will be added to the database immediately. This is done via the connection between the computer and the database through the internet. Also, the user can use the application to see the modifications and checks the last update of the refrigerator's items. The user can use the application to insert any item into the refrigerator

even if it does not have a tag, but this action is done manually. Moreover, the system could send emails and messages to the user to inform him/her about the expired items and the items that are going to be finished. Finally, the Phidget interface kit 8/8/8 (8 analog inputs, 8 digital inputs and 8 digital outputs) USB sensing and control is connected to the PC to connect both the liquid leakage and the open door alarm sensors with the system.

Table I. Subsystems of the Smart Refrigerator and their functions

Subsystem	Provided Functions
RFID Reader	<ul style="list-style-type: none"> <li>- Scan every item inserted or taken out of the fridge.</li> <li>- Identify information related to each tag.</li> <li>- Add each scanned tags into the database.</li> </ul>
Database Server	<ul style="list-style-type: none"> <li>- Store the data of each tag by adding the information in the refrigerator database.</li> <li>- Delete and modify the stored information when required.</li> </ul>
Application	<ul style="list-style-type: none"> <li>- User friendly interface.</li> <li>- Give the user the choice to add into and delete items from the refrigerator by using the application.</li> <li>- Provide the user with the choice of requesting a report</li> </ul>
Touch PC	<ul style="list-style-type: none"> <li>- Run the application</li> <li>- Display the items currently in the refrigerator.</li> <li>- Display a warning message when some items expire.</li> </ul>

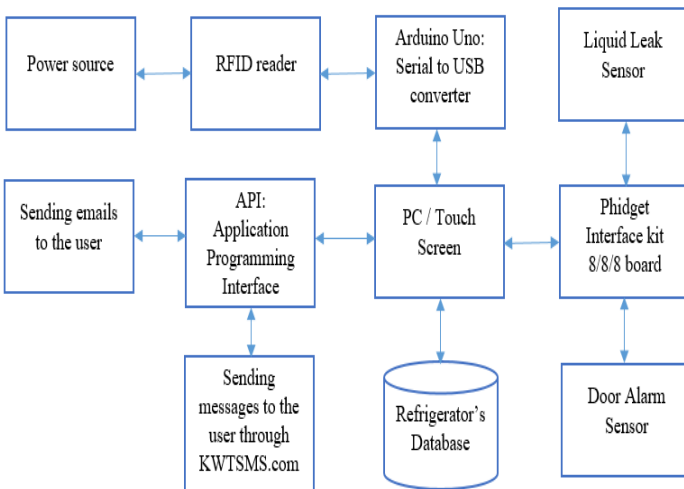


Figure 2. System architecture of the smart refrigerator

C. System Requirements:

The system requirements are the processes, tools and techniques that clearly define the needs of the system and the expected outcomes from the system. It is the guide for each subsystem to work as expected [10]. The smart refrigerator should satisfy the following requirements: reliability; the system should be reliable and not lose the data when the powered is off, user-friendliness; the system needs to be easy to use by the user, security; the system must be secure and safe and should not share

any information without the user's approval, and cost; the overall price of the system needs to be acceptable.

D. Components:

Both Software and Hardware components have been used in order to design the proposed smart refrigerator. A brief description is provided for each component used in the prototype. Furthermore, a list of all components is going to be provided with the item's price. Some components were purchased from inside the Gulf region and some were purchased online. The following list is the components needed to build the project. The list includes both the hardware and the software components:

- 1- ACM812A 2RFID reader: this component is used to scan the items that include the passive RFID tags. It has a frequency range of 902-928 MHz, it operates at temperatures between -35° and 60° C, and it can be stored at temperatures between -50° and 80° C. The reading range that it provides is 2 to 5 meters.
- 2- Terminator AC-DC adaptor: this components is used to provide the RFID reader with 12 V power supply.
- 3- Arduino Uno: the microcontroller Arduino Uno is used to work as a serial to USB converter. It works as the link between the RFID reader and the computer.
- 4- RFID tags: the tags are used to store the data of each item to be scanned. The tags consists of a built in antenna.
- 5- Microsoft Visual Studio: this software was used to build the application of the project. It was used to create the interface of the project.
- 6- Arduino Software: this software was used to upload the code written to the microcontroller.
- 7- Phidget Interface Kit Board 8/8/8: this board was used to connect the sensors with the system by programming the inputs and the outputs using the application.
- 8- Magnetic switch: this switch was used to create the door alarm sensor. It is connected to the analog inputs of the Phidget board and programmed to alarm the user when the door of the refrigerator is left open for a long time.
- 9- Copper roll, wires, and a 4.7 kΩ resistor: these elements were used to create the liquid leakage sensor.
- 10- Phidget Control Panel: this software was used to check the working functions of each sensor.
- 11- MySQL Database: the main database of the project was created using MySQL.com. This database contains all the data required for this project, such as, the information of the tags, and the main items inside the refrigerator.

Table II lists all the components purchased along with their quantities and price.

Table II. Components purchased and their prices

Component's Name	Quantity	Price	Purchase method
RFID Reader	1	\$199	Online
RFID Tags	20	\$3.3	Online
Terminator AC-DC Adaptor	1	\$8.28	Kuwait
Arduino Uno	1	\$9.88	Kuwait
SQL Server	1	\$72.1	Online
Phidget Board	1	\$65	Online
Copper Roll	1	\$14.95	Online
Copper Wires	10	\$0.99	Kuwait
4.7 k $\Omega$ Resistor	1	\$0.16	Kuwait
Magnetic Switch	1	\$2.5	Online
	<b>Total Amount</b>	\$376.16	

#### IV. IMPLEMENTATION

In this section, the prototype of the proposed smart refrigerator is explained in details. The prototyping has been implemented using all the mentioned components as follows.

##### A. Connecting the RFID reader with the Arduino Uno

The Arduino is used to connect the RFID reader with the computer through a USB. This has been done by writing a program in the Arduino software to convert the serial data into digital data. The Arduino software offers a library called "Software Serial" [11]. This library is developed to allow serial communication on the digital pins of the Arduino. Once the programming side is done, it has been downloaded to the Arduino board. Figure 3 shows the connection between the RFID reader and the Arduino Uno.

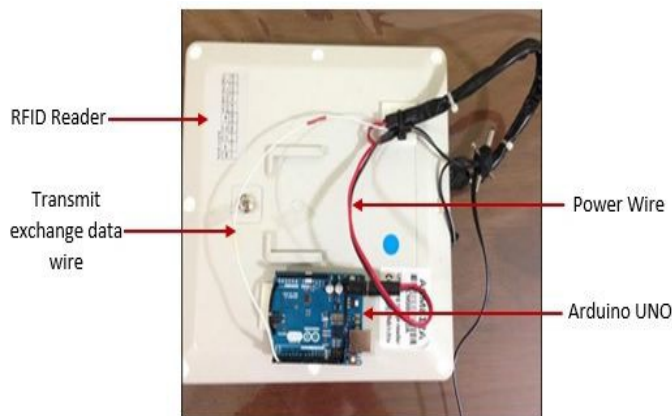


Figure 3. The connection between the RFID reader and the Arduino Uno

##### B. Connecting the RFID reader to the computer

This step makes use of the previous step in connecting the reader with the computer through the microcontroller. Once the connection has worked successfully, the RFID tags have been read by opening the serial monitor in the Arduino software and passing the tags through the active range of the reader. Each tag has a unique three digit number. This number has been used to

write the information related to each item by the retailer and then stored in the refrigerator's database, so that when the tag is scanned by the user, the information is ready to be viewed.

##### C. Setting up the application in Visual Basic

The application has been set up through Microsoft Visual Basic. This software has been used to create the main interface for both the user and the programmer. The application has been designed to have three different forms. The first form is designed to ask the user for a password in order to access the smart refrigerator system. This form is called "LOGIN". The second form which is "Administrator" is designed to be used by the user and the programmer. The programmer uses this form to program a tag by entering the RFID number, item's name, notes and the expiration date. While the user uses this form if he/she has chosen to enter his/her own items into the refrigerator without using the scanner. The information entered in this form is directly transferred into the refrigerator's database through the internet connection. The third form is the form that displays the item information when the tag is being scanned. It displays the item's RFID number, item's name, quantities, image, notes, expiration date and the notification messages. Moreover, in this form, the user can enter his/her email address and mobile number in order to receive the expiration date and finished items notification. Any modification done in the application is going to be reflected in the database as well.

##### D. Programming the RFID Tags

In order to know the unique number of the RFID tag, the serial monitor of the Arduino software provides the ability to show the tag's ID. Once the programmer has identified the tag's number, he/she can use the Administrator Window using the application to be able to enter the information related to that tag. Through this window, the programmer can program the tag by entering the item RFID, item name, estimated expiration date, the item's image and any note if required. When the programmer enters all the required information, the Add button is pressed. By pressing on the button, the information of the tag is saved in the refrigerator database.

The database also provides the admin with the ability to delete and modify the information stored in both the tag and the database. Figure 4 shows programming of an RFID tag that has the ID equal to 593. The item name has been saved as "KDD Cocktail Drink" with an estimated expiration date of thirty days. Once the button Add has been pressed, the information inserted has been transferred directly to the refrigerator's main database. After this action, if the user scans the item, all the information will appear in the third form as was discussed before and the item will be added to the list of the current items stored in the refrigerator.



Figure 4. Programming an RFID tag

#### E. Setting up the Liquid Leakage sensor:

The main goals of implementing this sensor are to detect the liquid leak and to alarm the user about it to avoid any damage. The sensor shown in figure 5 has been implemented using a copper roll, copper wires and 4.7 k $\Omega$  resistor. Five columns of copper roll have been set up on a piece of cork. In order to come up with a power of 5 volt, three of the columns are connected together by soldering the end part of each with the red copper wire. To connect the signal, the remaining two columns and the first side of the 4.7 k $\Omega$  resistor were soldered with the white copper wire. Then, for the ground, the other side of the resistor was soldered with the black copper wire. After that, all wires clipped and plugged in the Phidget board to get the required power, signal and ground from the board. Finally, after programming the sensor using the application, as soon as it detects the required level of liquid, it will start the alarm to notify the user.

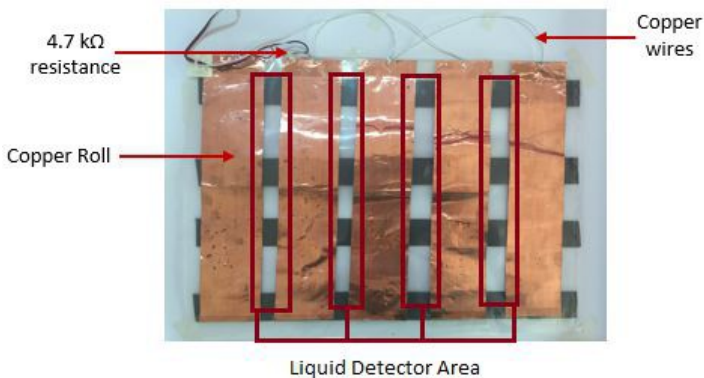


Figure 5. Liquid Leak sensor

#### F. Setting up the Door Alarm:

This sensor's main goal is to avoid leaving the door of the fridge open for a long time. It was implemented using the magnetic switch as shown in figure 6. This switch has two magnets, one is wired; which is plugged in port 3 of the analog input in the Phidget board and stuck on the refrigerator's door, and the other is non wired; which is stuck on the refrigerator. The sensor was programmed in the application to detect that as soon as the two magnetics are not stuck together, the door of the fridge is left open. The alarm will notify the user if the door was left open for more than ten minutes.

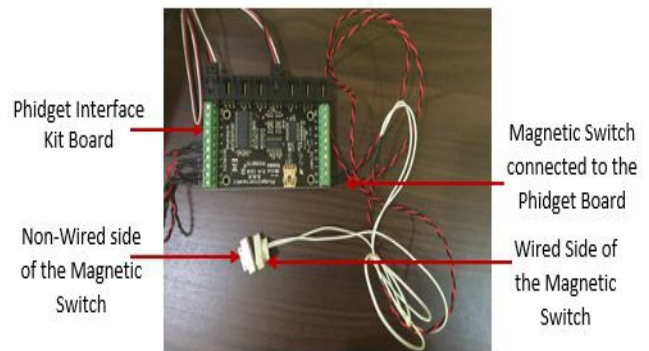


Figure 6. Door Alarm sensor using a magnetic switch

## V. CONCLUSION

In this paper, the design of a smart refrigerator prototype has been introduced. The proposed smart refrigerator is connected to a main data base that includes information related to different items. This information is provided by the retailer and is connected to the unique ID of the RFID tags attached to the items. The smart refrigerator will inform the user about the quantities of each item and the items that have been expired through email and text messages. Also, it will alarm the user if any liquid leak happens or if the refrigerator's door is left open for a long time.

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