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## **A Smart Fridge with an Ability to Enhance Health and Enable Better Nutrition**

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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. Since modern life style is driving people spending less time on cooking healthy food at home, an enjoyable and healthy life style can be assisted with an intelligent kitchenware such as a smart fridge. In this paper we introduce a novel idea of the smart fridge which can enable better nutrition and enhance health. It is designed for managing items stored in it and advising its users with cooking methods depending on what kind of food is stored. More importantly, it can perform other actions such as dietary control, nutrition monitoring, eating habit analysis, etc. The characteristics, functions and design details of the smart fridge are presented in details. We are confident that such a smart fridge will be an important component in future smart home.*

### **1. Introduction**

Both industry and research have focused on developing smart homes [1-5]. For example, more than 100 homes offering smart technology have been built in South Korea and another 30,000 were planned [6]. Research has also focused on developing smart homes for the elderly [7]. We have seen and will continue to see significant strides in this area which will make a major impact on how we live.

Developing smart appliances is critical to the realization of a smart home [8]. Kitchen is a prominent place in the home consisting of many intelligent appliances which aim to provide better services for a household. A smart fridge is the focus of our research. We have seen many efforts in developing smart fridge in industry and research. The industry attempts to change the traditional fridge function, i.e., to store food items in a cool environment, to integrating fridge with TV, radio, and computer capabilities and even connection to the Internet. These computer-like capabilities enable the development of applications for devices such as smart fridges. In this project, we aim to develop a smart fridge that focuses on better nutrition and health.

It is a well-known fact that the fast-paced development and modern living has resulted in a change of people lifestyle towards less exercise and an unhealthy diet [9]. Poor eating patterns can cause diet related illness in late life if we do not take eating nutritional food seriously [10]. For instance, obesity resulting from unhealthy dietary habits and lifestyles is becoming a major health hazard in the developed countries. In this context, we believe that applications which focus on better nutrition and health are important. This paper presents an application geared towards the smart fridge which promotes better nutritional and health habits. The fridge being a prominent appliance in

the kitchen plays an important role in food and nutrition of a household and in our opinion is ideally suited for such an application.

## **2. Review on conceptual smart fridge models**

In this section, we review some of the emerging smart fridge concepts and features contributed by different researchers and manufacturers.

### **2.1. Siemens CoolMedia fridge freezer**

Siemens CoolMedia Fridge Freezer KG39MT90 [11] has built in a 15" LCD TV and comes with remote control and cable or DVD sockets. The difference between this LCD TV and other TV is that the screen can be swiveled out. So you can cook and watch Siemens CoolMedia TV practically from anywhere in the kitchen. The fridge aims to encourage eating and watching TV in the kitchen areas rather than in the living room.

### **2.2. LG TV refrigerator**

The latest LG TV Refrigerator LSC27990TT [12] has remote-controlled, cable-ready 15" LCD TV with DVD connection and FM radio. It also has 4" Weather Plus LCD display with forecasts based on users' area, date/time, calendar with alarm, eight-category recipe bank with 100 preloaded recipes and personal digital photo album. Other features include child lock function, room temperature display, digital user manual and product controls.

### **2.3. Electrolux screen fridge**

The Electrolux Screen Fridge [13] has the function of broadband connection and TV via wireless connection. As if Internet, email, phone, radio and MP4 player are not enough, Electrolux comes with a 15" touch screen, pop-up keyboard, and a highly advanced calendar and video messaging system so the kitchen truly becomes the center hub in the house. Every morning, users can check weather and traffic conditions, business appointments with Screen Fridge personal organizer, before he or she leaves home. It can also easily print out up-datable electronic shopping list. The refrigerator is also accessible by remote access feature.

### **2.4. Samsung Smart Zipel refrigerator**

If you're the one who can't be without TV or connectivity to the net even for a second, Samsung has its Smart Zipel refrigerator [14] for you that wears a 10.4-inch wireless LCD screen on its chest like a badge of honour. The 4x3 flat panel display lets you connect remotely to anything multimedia such as video or the Web. The Internet access might be convenient if you need to display a recipe you've found on the Web while you're busy preparing it in the kitchen. Details are sketchy at this point with no pricing or availability information forthcoming, but the refrigerator looks like a fairly high-end unit, capable of holding 26.6 cubic feet of groceries.

### **2.5. CSIRO Australia smart fridge**

Still in its infancy, the CSIRO prototype smart fridge has the ability to exchange data with other fridges so they can share the electricity load throughout the day, according to a recent report in the Sydney Morning Herald [15]. As a part of the research organization's efforts to use intelligent software agents to dynamically manage the generation, distribution and usage of electricity to deliver benefits to consumers, energy providers and the environment [16,17], the prototype smart fridge is concentrated on future intelligent and adaptive energy use. Nicknamed the "hot-rod" fridge, the Sydney-based unit measures the energy use of several other fridges based in Newcastle and allows them to decide when they rest and when they run, which helps spread energy use.

It was claimed that if the technology is taken up, there is no reason it could not be applied to other appliances. It is expected to have a significant effect on total energy demand based on the potential to co-ordinate a whole lot of fridges.

## **2.6. The main shortages of current smart fridges**

Although great attention and efforts have been put on the development of various prototypes of smart fridge, several noticeable shortages exist. Examples are illustrated below.

The technology is too complex for most household users, needing more user-friendly interface for general users who have little or no experiences of using computer.

There is no uniformed bar code to record information such as expire date of the food.

There is limited network connection, either without high speed connection or without enough support.

Because the networked home would enable information to flow out of the home in ways that households are not accustomed to, privacy could be compromised in using smart fridge.

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

There are no functions on diet or nutrition control, failed in providing a most potential attraction to smart fridge.

There are no meal organizer and healthy food suggestion function, again failed in providing a most desirable function.

## **3. The proposed smart fridge with nutritional functionality**

As discussed in previous section, the existed fridges made with advanced technology are more concentrated on the combination of intelligent sensor [18,19], networks and information. We can see trends in developing the fridge to act as a computer, TV, DVD player, etc. However, applications focused on healthy nutritional habits and lifestyles are lacking. We see the potential and an opportunity to develop such applications for smart fridges. This paper presents the development of such a smart fridge. We believe that applications focusing on nutritional information and dietary habits of its users to be a valuable

application for a smart fridge as it is an integral part of the kitchen. Healthy nutrition intake can have far reaching and significant impact on health and well-being of consumers.

### **3.1. Perspective of the prototype**

The main aim of the project is to develop a prototype of a smart fridge that focuses on nutrition facts and dietary habits of its users. The whole system is built using computer simulation with hardware implementation as next stage. The system has a locally-built database which contains specific nutrition information. The system maintains information of each user such as weight, height, age, medical record, allergic food, to name a few. It is equipped with a bar code reader which can scan every item while the item passes the door sensor so that the fridge can record the type, the quantity and the expiry date of that item. At the time when the date is getting close to the expiring date of an item stored in the fridge, it will notify the user either by video or audio warning sign. In addition, information is displayed on the screen mounted on the door of the fridge to enquire if the user wants to use it or not. With respect to different personal preferences, the fridge is able to list the essential shopping list for that particular person once a week referring to the items which are running out.

### **3.2. The unique features of the prototype**

A significant and unique feature of this prototype is that the fridge is intelligent to propose suitable recipes for different types of people according to the materials stored in it and the particular needs of the user. It will create more than one recipe that can be chosen from using different cooking methods or seasoning. Further, if a user has pre-determined illness (such as high-blood pressure, diabetes etc.), the fridge will notify the user with the food nutrition facts and indicate what kind of food is appropriate.

### **3.3. Functions and features of the prototype**

The following list gives the features implemented in the smart fridge application.

- Generating recipe suggestions based on food stored in the fridge
- Multimedia cooking demonstration (through connection to Internet)
- Generating and updating store list
- Generating shopping list
- Warning on food which is going to expire
- Displaying calories for various foods
- Scanning food and storing its information into a database
- Friendly control panel
- Storing family information and medical record
- Calculating body mass index (BMI) to check if the user is overweight or not based on his or her height and weight
- Nutrition suggestion based on BMI for various users including some with illnesses such as diabetes, high blood pressure

## 4. System design and implementation

### 4.1. System implementation

For this smart fridge application, we used Microsoft SQL Server 2005 to build the database and Microsoft Visual Studio 2005 to create the user interface. The system follows a two-tier architectural design. User interacts with the interface of the smart fridge. VB.NET codes connect the system to the database using SQL Server classes. All the functions such as insertion, modification and deletion are manipulated using stored procedures.

### 4.2. Database design

Database is a very important part of the smart fridge system. Entity-Relation (ER) diagram [20] is used to depict all the 15 tables of the database, including basic information of the tables and the relationship among the tables. All the tables have been normalized to the Third Normal Form [20]. Figure 1 shows the ER diagram.

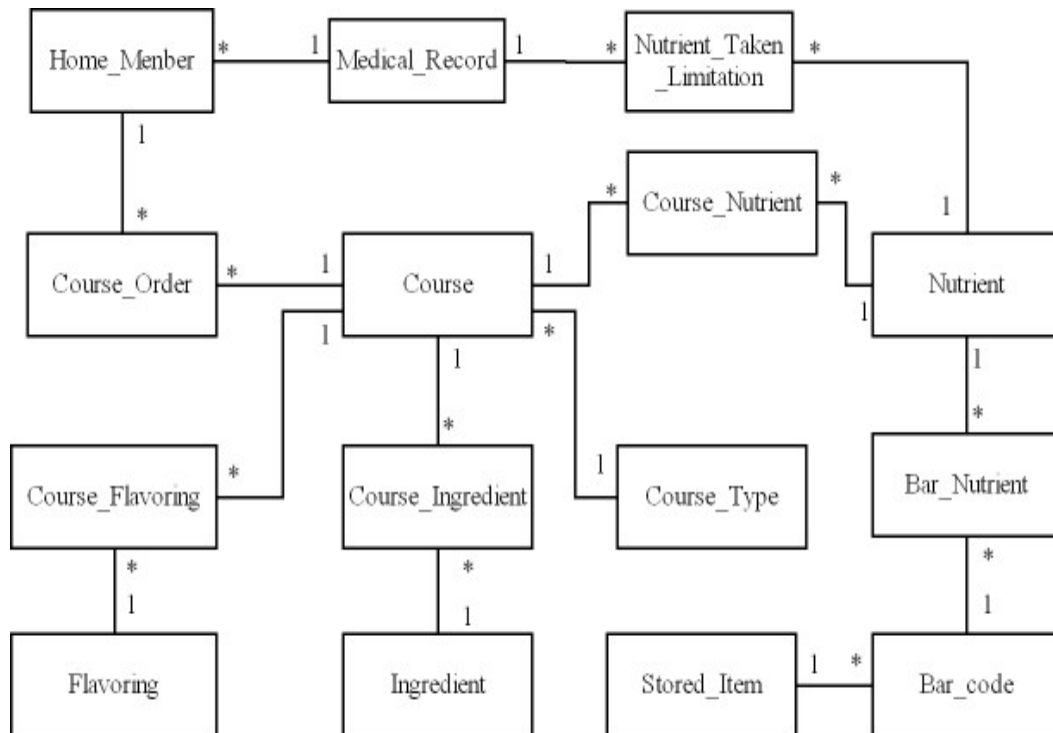


Figure 1. The E-R diagram of the database

Where square block indicates entity (table); entity name is labelled inside the square block; connecting line indicates relationship between entities; 1 indicates single relationship; \* indicates multiple relationship.

The details of the 15 tables, including names, usages, variables, etc., are described below.

**Home\_Member:** This table represents the all user information, including user name, DOB, height, weight, gender, etc.

*Medical\_Recorder:* In this table, there are MR\_ID and Detail columns. They store the information about every user's medical recorder. It is connected to Home\_Member table by MR\_ID primary and foreign key connection.

*Nutrient:* This table includes all possible nutrients in each dish and item.

*Nutrient\_Taken\_Limitation:* This table contains the data about different nutrient limitations for different diseases.

*Bar\_code:* The columns in this table include barcode, product name, units, quantity, expire date etc. It stores all different products' information.

*Bar\_Nutrient:* This table connects Bar\_Code and nutrient tables, representing how much different nutrition each product contains.

*Stored\_Item:* In this table, the columns include barcode id, item id, quantity and input date. It is connected to Barcode by barcode id primary and foreign key connection.

*Course:* This table contains course id, name, CT\_ID, method, demo and picture and so on. All courses user can choose are stored in this table.

*Course\_Type:* This table stores the information about the main course section and connects with course by CT\_ID.

*Course\_Nutrient:* This is the middle table between course and nutrient table. The columns include: Course\_ID, Nutrient\_ID, Units and quantity.

*Course\_Order:* This is connection table between Course and Home\_Member table. This table stores the information about different user ordered different course and order date too.

*Ingredient:* The columns in this table are Ingredient\_ID, name, units. This table stores the information about all ingredients used in cooking different dishes.

*Flavouring:* The columns in this table are Flavouring\_ID, name, units. This table stores the information about all flavourings using in cooking different dishes.

*Course\_Ingredient:* This is the middle table connecting the course table and Ingredient table. It represents how many ingredients each course needs to use. The columns include Course\_ID, Ingredient\_ID, Units and Quantity.

*Course\_Flavouring:* This is the middle table connecting the course table and Flavouring table and represents each course to use how many flavouring. The columns include Course\_ID, Flavouring\_ID, Units and Quantity.

The complete relationship among the tables depicted in figure 1 can be summarized as below. Where FK represents foreign key.

- One to many relationship between Medical\_Record and Home\_Member, MR\_ID as FK;
- One to many relationship between Medical\_Record and Nutrient\_Taken\_Limitation, MR\_ID as FK;
- One to many relationship between Home\_Member and Course\_Order, User\_ID as FK;
- One to many relationship between Nutrient and Nutrient\_Taken\_Limitation, Nutrient\_ID as FK;
- One to many relationship between Course\_Type and Course, CT\_ID as FK;

- One to many relationship between Course and Course\_Nutrient, Course\_ID as FK;
- One to many relationship between Nutrient and Course\_Nutrient, Nutrient\_ID as FK;
- One to many relationship between Course and Course\_Ingredient, Course\_ID as FK.
- One to many relationship between Course and Course\_Flavoring, Course\_ID as FK.
- One to many relationship between Ingredient and Course\_Ingredient, Ingredient\_ID as FK.
- One to many relationship between Flavoring and Course\_Flavoring, Flavouing\_ID as FK.
- One to many relationship between Ingredient and Bar\_code, Ingredient\_ID as FK.
- One to many relationship between Bar\_code and Bar\_Nutrient, Code\_ID as FK.
- One to many relationship between Nutrient and Bar\_Nutrient, Nutrient\_ID as FK.
- One to many relationship between Stored\_Item and Bar\_code, Code\_ID as FK.

### 4.3. Interface design

The interface of the smart fridge is a touch screen on the door of the fridge. It is assumed that the users are normally the members of the family. The user interface should be as friendly as possible to make different types of users interact with the fridge easily. There are eight control panels in the smart fridge, including Main Control Panel, Recipes Panel, Store List Panel, Cooking Demo Panel, Family Information Panel, , BMI Calculator Panel, Nutrients Check Panel, and Shopping List Panel,.

The main control panel of the smart fridge receives the requests made by user and displays the results back to user as shown in Figure 2. It leads to various function choices.

The recipes panel, as shown in Figure 3, displays recipes in two different ways. One is to create recipes based on food stored in the fridge, and another is to generate recipes from database based on different types of dishes the user selects.

The store list panel, as shown in Figure 4, is to display various foods stored in the fridge on the touch screen of fridge without opening the door of fridge. It also contains information about food name, expiry date, and weight.

The cooking demo panel, as shown in Figure 5, shows the cooking demonstration video of each course. It helps users to feel more realistic when they are cooking.

The smart fridge is able to store information of each member in a family with their medical records so that it can create suitable dishes for those who have diseases like diabetes or high blood pressure. The family information panel provides such function as shown in Figure 6.

The BMI calculator panel, as shown in Figure 7, allows users to check if they are normal or overweight based on their height and weight.

The nutrients check panel, as shown in Figure 8, is to show the nutrients of each course and the nutrition facts of each item by entering its barcode.

The shopping list panel, as shown in Figure 9, is to display a suggested shopping list to the user so that the user needs not to bother to consider what to buy.



## 5. Conclusion and future work

We have introduced a novel smart fridge application with intelligent multimedia capability. The proposed smart fridge can enable better nutrition and health. It is designed for managing items stored in it and advising its users with cooking methods depending on what kind of food is stored. More importantly, it can perform other functions such as dietary control, nutrition monitoring, eating habit analysis, etc. The characteristics, functions and design details of the smart fridge are presented in detail. We are confident that such a smart fridge will be an important component in future smart home

Although the proposed model has shown its potential in maintaining better nutrition and health, it is still in its preliminary stage. There are many features and areas that can be improved and explored. Possible extensions include: (a) set Internet connection to allow downloading of recipes in real time, online shopping instruction etc.; (b) use advanced radio-frequency identification (RFID) tag system [21] to replace bar code system to uniformly store item information; (c) integrate into the fridge a scale to allow automatically weight food or drink such as milk; (d) weekly meal design, including previous meal nutrient calculation and meal design; (d) automatically set microwave to defrost frozen food before use; (e) connect to oven to control the time of oven when baking; (f) implement mobile control to allow user remotely control the fridge using mobile phone.

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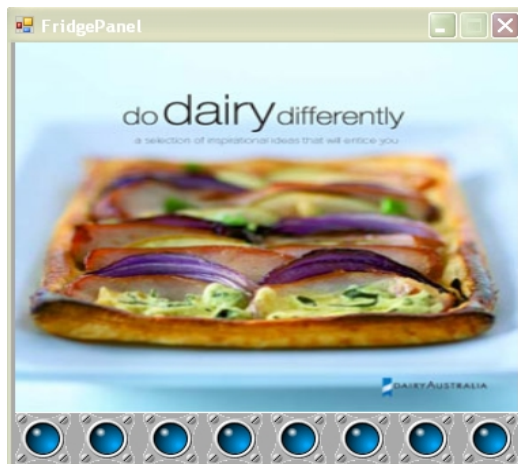


Figure 2. Fridge Control Panel



Figure 3. Recipes Panel

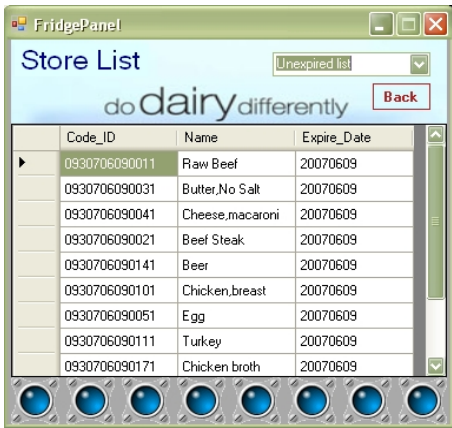


Figure 4. Store List Panel



Figure 5. Cooking Demo Panel



Figure 6. Family Information Panel

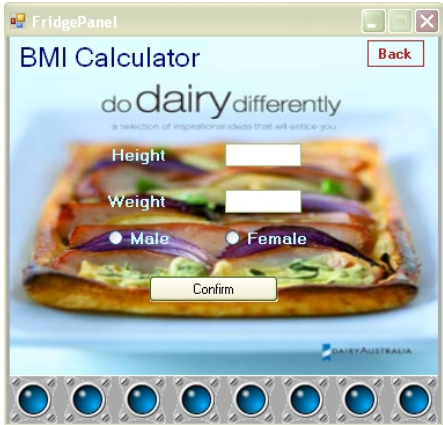


Figure 7. BMI Calculator Panel

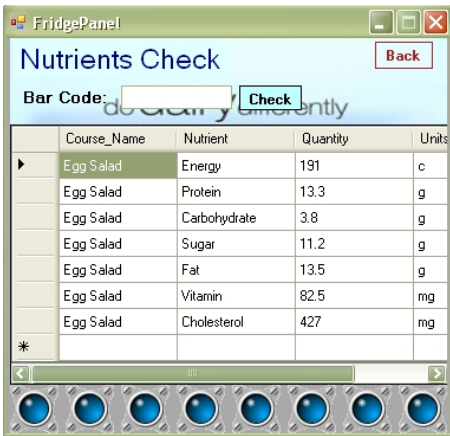


Figure 8. Nutrients Check Panel

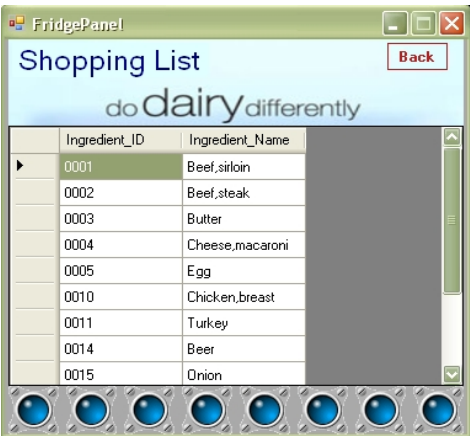


Figure 9. Shopping List Panel

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