Final Project
Smart Refrigerator - can prevent foods from going bad

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Problem Statement

With the rise of storage supermarket shopping culture, people now in order to save family expenses, always buy more food, but also wasted a lot of extra food. In fact, according to investigation, in 2012, Americans wasted about $ 165 billion of foods. On average, a family of four people wasting about $2300 of foods.

Why waste food? No one waste food deliberately. Food waste problem is usually due to improper food stored in the refrigerator, or hidden behind other objects so that they are forgotten till no longer fresh and smell bad. Although the refrigerator capacity has increased by 28% over the past 10 years, people still often place some perishable foods in places where they are not easy to see or are not easy to get. In addition, every time people open the refrigerator, there will be a lot of cold air loss, the internal temperature will rise, more efficient storage of food than the ideal temperature. Survey shows that the ordinary family of four open the refrigerator 79 times a day, mostly in order to take milk, fruit juice and other beverages. Like this many times open and close the refrigerator door, eventually leading to the loss of air-cooled stack, speed up the speed of food going off.

According to media reports, a waste of food, not only caused huge economic losses, but also caused unnecessary harm on the human survival of the natural environment! Throwing away food, causing large amounts of carbon emissions, producing greenhouse gases; throwing away food, causing waste of water; food waste, aggravating agricultural pressures and threatening biodiversity.

As far as I can see, most of my friends often buy a lot of food all at once blindly, without check how many storages under the condition of food in refrigerator, buy too much food, cannot eat and not in time to eat the food result in food going off, it expires. As mentioned before, a lot of people don't realize the waste food will impact on the environment and all kinds of energy.

Refuse to food waste, improve the quality of life, from make good use of the refrigerator. Our project is made up of two parts one is use gas detection sensor setting in the refrigerator then obtain change of gas (H_2S and C_2H_4), can connect with our smart phone by WIFI. Another part come with a mobile application, through the phone camera to obtain food image texture and color characteristic value, also record the food expiration date. With this two part, people can look at what food in their refrigerator at any moment through the phone and see the quality guarantee period information. In addition, once the sensors detect the food is going to decay, will send feedback information to mobile phones to remind people.

Related work

- There are some existing refrigerators in the market to solve this kind of problem. For example:

1. [LG Door-in Door refrigerator](): Keep food conveniently organized and within reach. Effective use of storage space to meet the family's storage requirements, to view the food, reduce the loss of cold air, thus prevent food going off and waste.

2. Bosch built-in camera refrigerator: The built-in camera in the fridge can help users check the food storage in the refrigerator anytime, anywhere, and the user is no longer afraid about shopped-out question. Users can use the mobile phone application, anytime, anywhere to check storage of food in refrigerator and remote control of the refrigerator temperature.

3. Samsung Family Hub refrigerator: Not only have a large capacity, but also have multiple function, such as create shopping lists and expiration notices, share multiple calendars, photos and memos, and stream music, videos.

• After search patents.google.com, we found:

1. RFID system and method for tracking food freshness: Provided for tracking the freshness or expiration dates of food products put into storage. RFIDs are low-cost, passive or active "smart" chips or "tags" that can be embedded in or attached to articles, products, and the like, to convey information about the product via a scanner. The food products placed into storage are provided with smart tags, the smart tags containing food product information regarding the freshness or expiration date of the food product. The food products are scanned with a smart tag scanner prior to placing the products into storage, the scanner configured to retrieve the food product information from the smart tags. The user may be alerted if the retrieved information indicates that the food product being placed into storage has expired or is no longer fresh.

2. Method for detecting fresh degree of shrimp by electronic nose: Relates to a gas sensor array for grasshopper freshness detecting method.

3. System and method for inspection and monitoring of food in refrigerator: The system for inspection and monitoring of the images of the food in the refrigerator comprises at least two camera modules which are arranged in the refrigerator and are used for collecting the images, a control part used for controlling the camera modules for shooting, and a mobile terminal used for receiving a picture.

4. Refrigerator food storage and deterioration information detection system and method: Food storage information in the refrigerator can be detected through the pressure sensor module so that a user can grasp food storage timely; and then a food deterioration probability proportion value is obtained through integrated analysis of the integrated analysis determining module so that the user can grasp a food deterioration condition timely.

5. Refrigerator with a function to confirm items stored therein: The refrigerator has a reader/ writer for writing information in and reading information from a contactless memory medium, an information holding device for storing information read by the reader/writer, and an information display device for displaying the information stored by the information holding device.

• The solution discussed in the literature:

1. The Pervasive Fridge. A smart computer system against uneaten food loss: "Pervasive Fridge" prototype allows users to be notified proactively, when a food arrives to its expiration date. Speech and image recognition are also integrated in our prototype. This system combines various resources in order to scan barcode, identify and store data related to products, with a smartphone. Later, notifications are sent freely to consumers by mail to avoid uneaten food loss.

2. Intelligent Refrigerator System Based on RFID Technology: The main environmental roles involved in smart refrigerator systems include smart refrigerator users, food suppliers and supermarkets. Through the application of RFID technology and sensing technology, the refrigerator has been able to accurately determine the inherent properties of all the food in the refrigerator, including the production date, the production site, the date of purchase, the existing quantity and nutrient content. Intelligent refrigerators can be real-time scanning of the food in the refrigerator, and use these data on the inherent properties of food on the expired and not eat food to the refrigerator users to warn. When the food has been out of date and has not been eaten or thrown away, the smart refrigerator will remind user every time when they open the refrigerator.

3. [Characterisation of food freshness with sensor arrays](#): The detection of volatile compounds with chemical gas sensors is of increasing interest in the non-destructive determination of food quality. They have investigated the problem in relation to fish freshness.

- Here is the competitive analysis table:

For existing refrigerators in the market:(☆from 1 to 5, represent from low to high.)

Refrigerator	Capacity	Aesthetic	Practicability	Price
General refrigerator	☆☆	☆☆	☆☆	☆☆
LG Door-in-Door	☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆☆☆
Samsung Family Hub	☆☆☆☆	☆☆☆☆☆	☆☆☆☆	☆☆☆☆☆
Bosch build-in camera	☆☆☆	☆☆☆	☆☆☆	☆☆☆

From the perspective of technology:(☆from 1 to 5, represent from low to high.)

| Technology	Easy to implement	Accuracy	Practicability
Gas detect sensor	☆☆☆☆	☆☆☆☆	☆☆☆☆
RFID	☆☆☆	☆☆☆☆	☆☆☆
Electronic nose	☆☆☆	☆☆☆	☆☆☆
Build-in camera	☆☆☆☆	☆☆☆	☆☆☆☆

Proposed solution

- For the hardware part, our sensor integration consists of two parts. One is we use gas sensor setting in the refrigerator then obtain change of gas. By the investigation and statistics, we found that fruits and vegetables will release ethylene (C_2H_4) in the process of decay. Meat, eggs and milk will release hydrogen sulfide (H_2S) in the process of decay. There is a gas detection sensor can detect these two kinds of gas at the same time. Another part is used to connect with user's smart phone. Users can receive the information about food rot in refrigerator via WIFI.

Here are the example links of hardware components in our project.:

1. [C_2H_4](#) and [H_2S](#) Gas Detector: The operating temperature will be in -20°C to 50°C,so those sensor still can run normally in the fridge.

2. [WIFI](#): Uses a simple command set to configure and connect to another device. This module allow wirelessly communication to a mobile phone. The operating temperature from -40 ° to 125 °, can run normally in the fridge.

- For the mobile application part, here are some screen mockups as following:

(1) Open the APP: We can see two rectangle buttons, choose which position they used. Then click circle button to add user's item in the list.
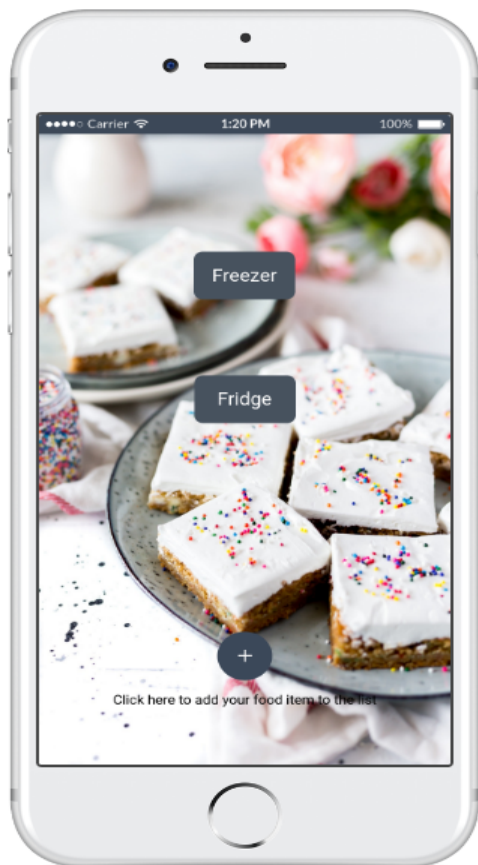
(2) Choose Freezer OR Fridge, can see three choices: Shopping list, Meal plan and Add food to the Fridge (or Freezer).
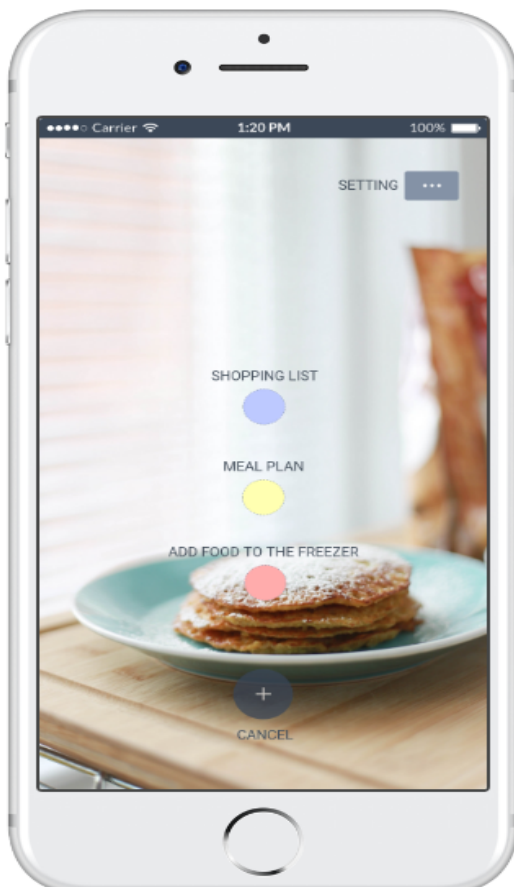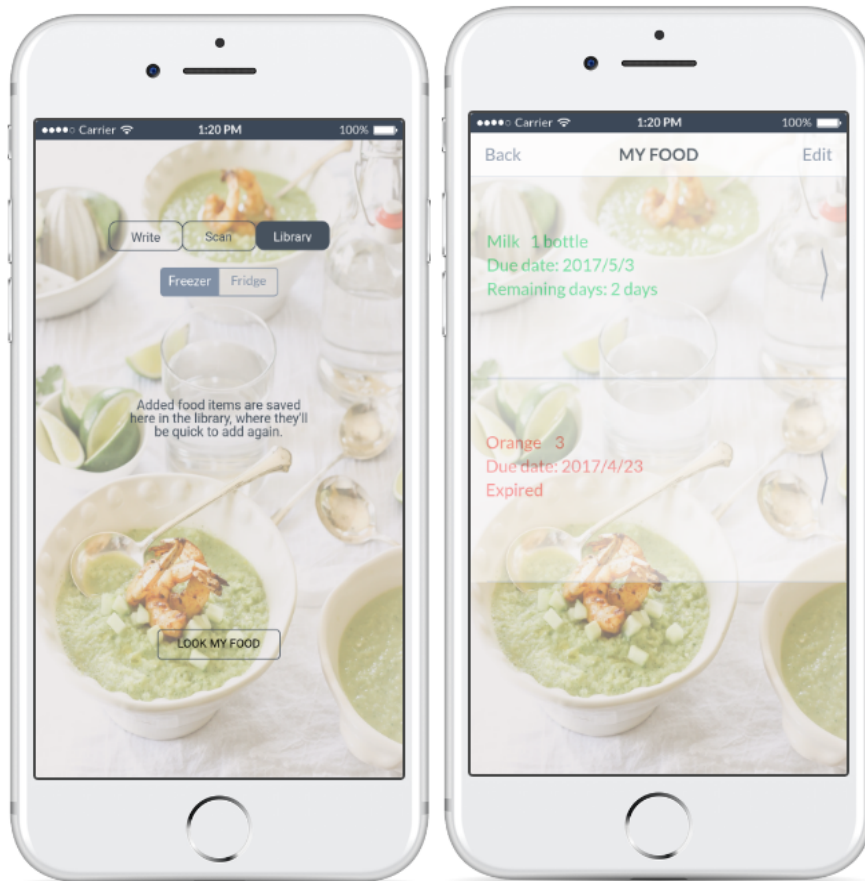
(3) Press the Add food to the Freezer or Fridge button: Choose write, new a food item with times, then press DONE to the next step.
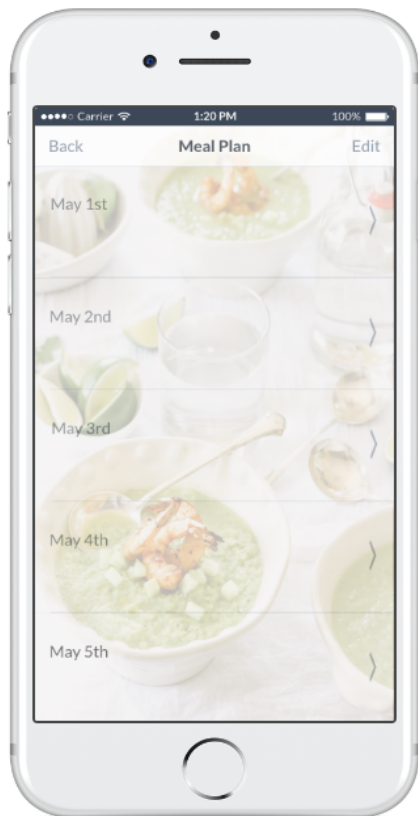

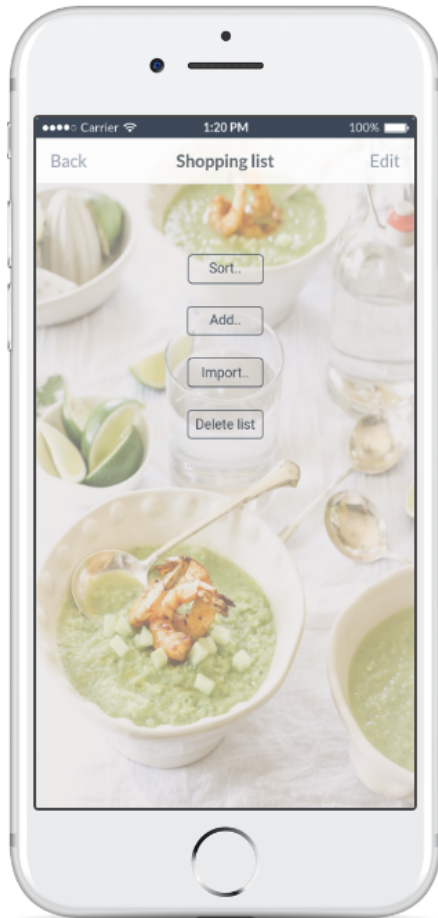(4) Or scan your food with camera:

(5) Library: A function can quick to add again. MY FOOD will provide the list you added recently.
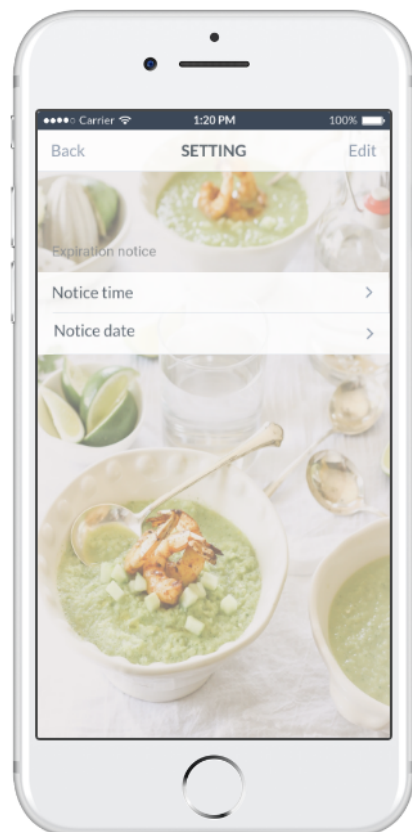
(6) Meal plan: Add food you want eat.

(7) Shopping list: Make your own shopping list.

(8) Setting: User can set time and date to notice them.

Here is the prototype:

Evaluation Methodology

To prove the results from our solution, we can set several experiments and use the comparison data from them, then we can get the conclusion that if the solution is better than else. To make experiments convictively, we need to find what kind of data can show that our solution is truly helps people to reduce the quantity of food going bad on their refrigerators. Thus, we set experiments of choosing the best method to be the insurance inside of the fridge, and that is used to avoid some unpredictable situation like the wrap was broken to shorten guarantee period. We have formal experiments from three aspects to test our application, and they are sensor detective part, software recognition part and the comprehensive application part.

When choosing the insurance method, we have three different sensors as the candidates and they are: air content sensor, laser detective, and color-changing plastic foil. Air content sensor can detect the concentration changing of different gas in the air. From the related research, we know that when vegetable and protein deteriorate, ethylene and sulfuretted hydrogen will be released; laser detective technique is to use laser beam detecting bacteria on the food surface, then use specific camera to record and analysis the change of bacterial plaque excited by laser beam; color-changing plastic foil is a kind of plastic opal film and it is a new plastic. It uses light refract different color between photonic crystals to measure the fresh degree of food, so we can see the color to judge if the food is fresh.

In order to select which one is the best for this product, we need to consider the overall of their sensitivity, cost and the convenience to use. The procedure of experiment is: we set three group A, B, C corresponding with three different sensors. A is air content group; B is laser group and C is color-changing plastic foil group. We assume three groups has same quantity and same kinds of food, then we observe the variation of them, for group A, we record the changing of air content, until the curve changed in short period, that shows there is food start to go bad; for group B, we'll see the bacterial changing situation, until the area enlarged to the warning line of deteriorate we have set before; for group C, we need to see

when the color of film change to the 'deteriorate color'. After the experiment, we consider the composite factors and we choose the air content sensor finally because it is sensitivity, cheap and really easy to use for everyone.

The first experiment is to use the air sensor to detect the content changing of sulfuretted hydrogen gas and ethylene gas. As we know, the most of vegetable and fruit are always release the ethylene with their breathing, this kind of gas can not only ripen these vegetables but can also causing them to spoil faster. In addition, when the protein going bad, it will release sulfuretted hydrogen. When the content of these two kinds of gas changed quickly in short time, that means some food is start to deteriorate and we can judge that one is vegetable or protein.

To certificate this method is useful, we set the comparison experiment. We have two group A and B with the same refrigerator and same quantity of vegetable, fruit and pork. The whole period is two weeks, we use the fresh food to substitute the food of group A, and never substitute the food of group B. Then use the sensor to record the content changing of sulfuretted hydrogen and ethylene. We keep eyes on the data, when the content changing rapidly in short time, we pause the experiment and use the chemistry method to detect if which food of which group begin to deteriorate or not and see if it consists with our theory. To reduce the errors, repeating the same experiment ten times.

Tab. 1　Current value of hydrogen sulfide　μA

index	time			
	3:00	9:00	15:00	21:00
the 1st day	–	3. 95 ± 0. 01 a	3. 96 ± 0. 01 ab	4. 04 ± 0. 04 b
the 2nd day	4. 10 ± 0. 01 bc	4. 14 ± 0. 02 c	4. 24 ± 0. 02 d	4. 39 ± 0. 01 e
the 3rd day	4. 48 ± 0. 06 f	4. 73 ± 0. 05 g	5. 05 ± 0. 11 h	–

The second experiment is to test the accuracy graphic and character recognition system of our application. For this goal, we choose 50 kinds of common vegetable and fruit in bulk and 100 kinds of food with printed expiration date. We do not choose the frozen meat because frozen meat can be stored for really long time, and for that kind of fresh meat and seafood we don't want it to be freeze, we just need the system to recognize it as 'meat' or 'seafood', these kinds of food need us to eat them as soon as possible.

When we take the photo of the target unpackaged food, the system compare the photo with the database and match them, then it will show the name of the target food. If the showing answer was right, we record the result as 'hit' and if it was wrong, we record it as 'miss', then we calculate the accuracy. To reduce the errors, we choose different individual of one kind of unwrapped food.

For the testing of character recognizing, we use the similar way of testing unpackaged food. First step is taking photos of the printed expiration date, then transcode the date in pictures to the characters into system database. Finally, we will check the data by ourselves. If the data was right, we record the result as 'hit' and if it was wrong, we record it as 'miss', then we calculate the accuracy and do the repeating test.

And the final test of whole application is that we separate 50 people to two groups A and B, and each group has 25 people. The goal of this part of experiment is to test if our

application can become the daily app of users to change the wasting situation, so we follow the steps below. First, we provide same kind and quantity food, include vegetables, fruits, meats, milk and eggs, to each person in each groups every week because most of people like to go to the supermarket on each weekend. The test period is 1 month as a stage. We don't tell group A, the purpose of the experiment and we want to simulate their daily lives as normal as possible. They can use any food in their fridge and substitute the spoiled food with fresh food, then we record how many foods they wasted. For group B, we told them this is a test of our new application, and we wish they can use it every day, as well as group A, we substitute the spoiled food by fresh one. We will count this wasting data up to check if our application is useful.

Effective
We can see the result from the last experiment, if the wasting quantity of group A is more than group B, it proves that our application is useful and effective and if the result shows that the wasting quantity of group B is more than group A, that means our work failed. According to us simulation, the probability of success is pretty high because group A don't know the purpose of the experiment, if nobody told them what they should pay their attention, they had almost no conscious to concentrate on the food in their fridge, like everyone else. While group A use the application every day, and it will build a kind of consciousness in their mind that makes them pay some attention on the food-wasting problem. Then group B can see the fresh level of food, that also can help them to arrange their daily recipe more reasonable and consume those foods more efficiency. So, we could get the conclude that the application can help to reduce the problem of food wasting and can let people know how many foods they need per week indeed.