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Using Smart Kitchen for grocery purchase prediction

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Abstract

Unlike the purchase of products with great value such as automobiles and houses, the grocery shopping is a repetitive and relatively unimportant activity which the consumers always don't have to take a deep consideration to make an "optimal" choice, but rather a satisfactory one. For such problems, the objective will be more like how to minimize the effort when making a satisfactory choice. This paper proposed a Smart Kitchen, which can sense and learn the user's daily usage and replenish behaviors through sensors, then analyze those data to track as well as predict the grocery demand. With the real time inventory level for each category of groceries, the Smart Kitchen can assist the consumers on the grocery shopping by providing the shopping list or even place the order online automatically, which will greatly facilitate the grocery shopping. Additionally, the historical consumption data can also be analyzed using statistical methods and valuable insights can be obtained for consumer behavior studies and healthy diet studies.

Keywords
repetitive purchase, grocery shopping, Ubiquitous Computing, consumer behavior

1. Introduction and Background

Grocery shopping is becoming a chore [2, 8] to more and more families, especially with the increasing proportion of double income families [2]. People feel distressed when doing shopping in the grocery store for various reasons including time consuming, parking problems and crowd of shoppers [8]. To avoid this stress of grocery shopping, many literatures have proposed using online shopping to eliminate the necessity of going to the grocery stores "physically" [16].

Plenty of benefits can be found out of online shopping, like the convenience of purchasing everywhere, free of worry about the transportation issues; while there are also enough reasons for the customers to reject the online shopping as a replacement of in-store grocery shopping. One reason is the extra delivery fee customers have to pay, which makes the purchase rather unpractical when the total amount is relatively low [8]; another major concern is the requirements for the target customers, since most of the housewives that consist of the main source of grocery shoppers are not so familiar with computers and Internet, the learning cost becomes a barrier for them to adopt the online grocery shopping [16].

Besides the shortcomings of general online shopping, the grocery shopping has more reasons for not going online. The repetitive characteristic makes the delivery fee a non-negligible factor for people who are economic sensitive; and the low importance among excessive alternatives of each grocery category also makes the operations of each online shopping tedious and tiresome.

Recently a new business paradigm, the subscription supply chain [17], has also been discussed and is taken into implementation in some online vendors like Amazon and Dunkin Donuts. This business paradigm allows the customers to subscribe a specific product from the vendors, which will deliver the product according to a chosen delivery schedule. This service always comes with some bulk discount to encourage the new customers to try it, and is a relatively improvement compare to the traditional business mode. While there are also complaints by some customers that the fixed schedule can't really make the shopping activity worry-free ever after, indeed either overstocks or out-of-stock occurs from time to time, thus making the customers have to modify the schedule manually. Actually this situation is rather natural to think of, since constant consumption only exists in ideal scenarios, not to mention the available schedules from the vendors are always limited due to cost considerations.

Since the demand for a grocery supply system is urging but not properly catered by any contemporary solutions, the call for a smart grocery supply system is rising. Thus we introduce a Smart Kitchen system in this paper, which proposes to solve this problem in a new way and aims to release customers from the burden of grocery shopping completely.

2. Literature Review

The process of decision making over a purchase is very different among different types of commodities, depending on several factors including price, purchase frequency, and the efforts customers willing to spend on acquiring information [5, 6]. Grocery shopping, unlike the Black Friday sales seasons when the customers are willing to push in the crowd and wait in long queue for some great deals [18], or some enthusiastic customers who are willing to "camp" hours for some hot products[4], the ordinary grocery shopping will not expect the customers to have such passion. People feel distress from various factors during grocery shopping, including crowd, waiting for checking out and difficulty in finding a parking spot [2].

To solve this issue, many literatures have discussed using online shopping to replace the traditional grocery shopping, and the feedback from the online shopper proves there are indeed great advantages [13, 16]. While disadvantages and concerns about online shopping are also raised, like the time spent before the screen will increase and sometimes even exceed the traditional in-store shopping, when customers spend too much time comparing among the excessive candidate options [16]. Same thing may happen due to lack of experience in the online operations [16]. Due to this circumstance, some improved systems are proposed which will take the advantages of online shopping; while at the same time explore more possibilities on improving the customers' convenience.

A considerable amount of literature has been published on automating the grocery shopping activities using agent-based system [9, 11, 15], or use some new technology to track the customer's grocery inventory status for better management [1, 7]. The technologies used in these literatures include RFID [3], digital camera [7] and touch based tablet [1]. We can see those are very good technologies in tracking the inventory status of each grocery, and can detect the out-of-stock event once the inventory is used up. These methods can partially or theoretically solve the out of stock issue, but actually since most of the families don't do grocery shopping in daily basis, this kind of out-of-stock detect is not enough. A better inventory monitoring technique is absent, and that's why we propose to use load sensors to track the real time weight change of each grocery category, thus inventory out-of-stock event can be predicted in advance, and the restock order can be placed before the customers really encounter the inconvenience caused by out of stock. This method so far has not been discusses yet from our best acknowledgment.

3. Theoretical Model

The Smart Kitchen system we are proposing will essentially use some ubiquitous computing techniques to collect the consumption data in real time, analyze the customers' preferences as well as inventory level based on the data, and give reminds and suggestions whenever possible to facilitate the grocery shopping activity. The whole design architecture of this system is illustrated in Figure 1.

Though most components of the system are still in design phase, the philosophy behind this system is relatively consistent. So, the remaining content of this chapter will focus on discussing the 4 main features of this conceptual system instead of running into too much detail.

3.1 Ubiquitous sensing: Monitor the consumption data in real time

Sensing technology is becoming ubiquitous and prevailing in our daily life. Examples can be found in many surrounding cases like the accelerometer and gyroscope inside most of the smart phones, the throttle position sensor inside the air conditioner at home, and the infrared sensor in the restrooms flushing system[12, 14]. A sensor is a small self-powered node that gathers information and detects special events, and it can be served as a bridge between our real life and the Internet.

Sensors would play a vital role in our Smart Kitchen system as well. First we will use a pantry containing multiple rows and columns, partitioning this pantry into a matrix of compartments. Similar design of pantry can also be found by Hsu, C.F. [7]. The author in this literature used a camera to monitor the items in the pantry, which we think is not accurate enough, because only knowing whether an item is in the pantry or not will not provide sufficient data for the inventory control. Instead, in our Smart Kitchen system we would install a sensor, which can measure the weight of

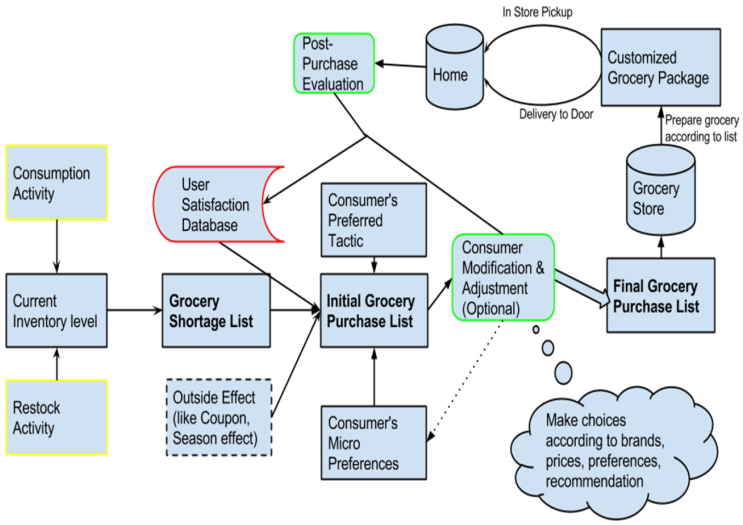

Figure 1: Theoretical model of the Smart Kitchen system

an item inside each compartment of the pantry. By doing this the weight of any item can be measured by those sensors accurately.

Since all these weight data from the sensors can be transmitted to the server wirelessly, the server can keep track on the current inventory level in each compartment at a given frequency, like every 5 minutes. The weight data, together with the sensor index indicating the position of the compartment inside the pantry, will be sent to server and interpreted according to the mapping matrix (See Figure 2). By this means the server side can maintain an inventory level list for later use.

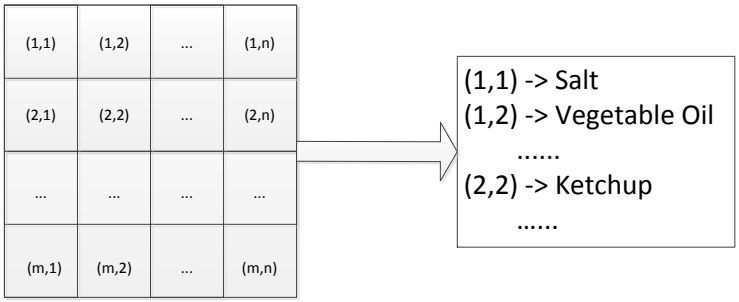

Figure 2: Smart Pantry mapping matrix

3.2 Smart supply: Manage the inventory level in a smart way

With the information obtained from the sensors, the inventory level of all categories of grocery products can be maintained in an inventory list from the server. Each time the server receives a new data packet from the sensors including the updated weight information, it will check the current inventory level of each category, and compare it to the corresponding threshold inventory level (Discuss later) stored in the server database.

Once a grocery category is running below the *threshold level*, a replenish item belonging to this category will be added into a shopping list. Among all candidate products belonging to this category, the system will decide which specific one to choose according to the customer's preference. This shopping list will grow longer each time a grocery category is running low. Once the total quantity of groceries reaches the threshold level, or one of the product is near the *critical level*, a restock event will be triggered, and the system will either notify the customer it's time to do the shopping, or place the order for the customer automatically.

3.3 Learn and become smarter: Machine learning to refine prediction

As described above, the system needs to be "smart" enough to understand the customer and make decisions for the customer, and one way to acquire this intelligence is through learning. Machine learning algorithms will be embedded in this system, which will analyze the historical consumption data and estimate the optimal threshold inventory level and critical inventory level.

The preferences of the customers on each grocery category are also obtained by analyzing the customer's choices. At the beginning, for each grocery category, there would be an initial preference scoring for each available candidate product, which means all candidates are preferred equally. After the first time the shopping list is prepared and the restock event is triggered, the customer will be presented with the list including all the candidate products. The customer doesn't have to make any decisions unless he would like to. For each category, if no choice is made, the system will make the decision according to the customer's default tactic, like price oriented, brand oriented, diet oriented, etc. Under this circumstance, the preference scoring distribution would remain unchanged. If the customer chooses some product particularly, this choice will dominate the system's current stored preferences and tactics, and will also be taken as a feedback to adjust the preference scoring distribution. The whole decision process is illustrated in Figure 3.

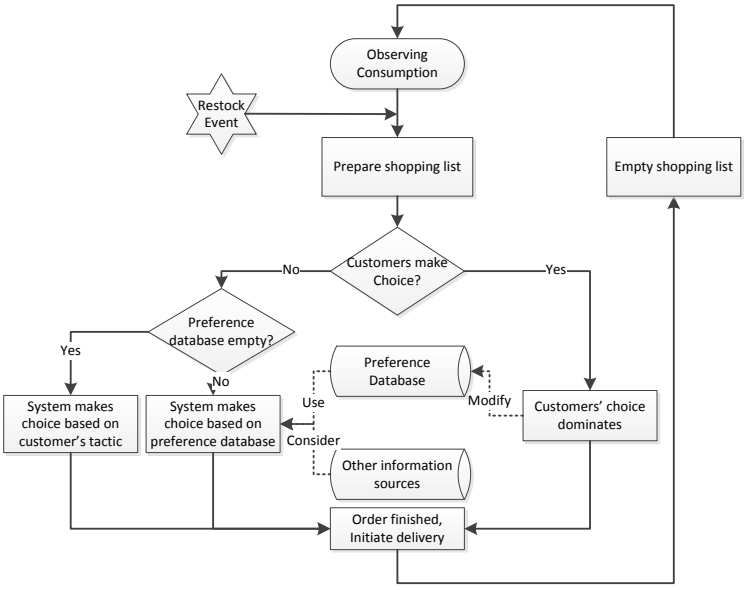

Figure 3: Flow chart of decision making on grocery product candidates

For all following restock events other than the first one, the system will have a recommended product for each grocery category, based on the preference database. Unless the customer never made any choices, there would be unbalanced preference scorings among those candidate products, thus we can assume confidently that the decisions made by the system would also be acceptable by the customer.

As mentioned above, the preference database is a crucial component for this Smart Kitchen system. It needs to consistently refine itself by collecting as much customer preference data as possible. In order to do this, not only the choice input after each restock event is necessary, a post-purchase feedback from the customer would also be very helpful. After the grocery inventory is replenished, the system can randomly select purchased product and ask the customer for feedback. The feedback should require minimal effort from the customer; otherwise it would violate the basic principle of releasing the burden of tedious unimportant choices. One possible method of feedback would be through the Smart Pantry itself, which can provide the "like" or "dislike" button on each compartment, allowing customers to easily click one of them whenever the light on one of the compartments flashes and reminds the customer to give a feedback. Of course, the customer can always choose to ignore it if he/she doesn't feel like to do that. Another alternative is to use the apps from the smart phone, which gives notifications for similar feedback questions with the product picture and other detail information together, asking the customer to give a positive or negative review about the product.

Besides the preference database that is generated only from the customer's feedback and decision activities, other information sources which may also affect the customer's choices need to be included into this decision making process. Such information sources may include the limited time coupon or discount information for some products, seasonal or special event related variations (recommend turkey combo when Thanksgiving is approaching), or some healthy recommendation if the customer's current nutrition portfolio is considered unbalanced by the system.

3.4 Multi-optional delivery: Adapt various needs

Some people would prefer time saving a vital factor [8], while some people would consider economic benefit a non-negligible factor and consider shipping expense as the main reason that stops them from shopping online.

In this system, this problem can be solved by providing multiple options after the shopping list is determined.

- Option 1: In store shopping
  For conservative customers, they can choose their shopping old habits, and use Smart Kitchen merely to provide the shopping list that aids their in-store shopping. The shopping list can be sent to the customer's cellphone through email or by SMS text, or it can be printed out and carried along by the customers.
- Option 2: Online purchase and delivery to door
  For online shoppers who prefer minimal outside activities, they can use Smart Kitchen system as an automatic online shopping tool, and complete all the shopping activities online. The grocery vendor can prepare the package according to the shopping list received from the Smart Kitchen system, charge the payment from the customer, and deliver the grocery package to the customer automatically. Of course, an extra delivery fee will be charged over the original grocery amount, so this method will only be chosen by the customers who think the saved time justifies the extra expense.
- Option 3: Automatic purchase and in store pick up
  There is another option in this Smart Kitchen system that acts more or less as a compromise between the first two options. The shopping list generated from the Smart Kitchen can be sent to the vendor, and the vendor can prepare the grocery package accordingly just like the option 2. Instead of delivering the package to the customer's address, the vendor can hold the package in the warehouse near the store, and remind the customer to come to store and pick up the package when the order is ready. The customer can plan his schedule and arrive at the store whenever convenient, which will save a considerable amount of time compare to shopping in store and waiting for checking out. The time for parking can also be saved if the layout of the store can be modified and add a drive through lane outside the store warehouse. Note that this option would expect to be adopted easily, since in store pick up is a service that can already be found in many grocery stores, thus integrating this new feature into their current system would not be an issue.

4. System Architecture

From the features of Smart Kitchen described above, this system will require the accurate monitoring of the weight change of each item in the pantry, the smart recommender system to predict the grocery choice for the customer, and the communication as well as coordination between the server side from the vendors, and the client side from the customer's kitchen. This architecture is illustrated in Figure 4.

Since most of the vendors will have their own management information system, there is no reason to assume those systems would be unified. Thus it is important that this server side system can be compatible with heterogeneous platforms. To achieve this purpose, a universally accepted communication protocol is necessary. The implementation details for this communication protocol will be discussed in the next chapter.

Different from the server at the vendor side, the client side can be assumed as unified, and use the ordinary home PC or some other cheap equipment like system-on-a-chip system [10]. This client will also act as the server for the load sensors and the cellphone app. The weight information collected by the load sensors in the Smart Pantry will be received and analyzed by this server, and the notifications to remind the customers from certain events are also sent from this server.

5. Implementation Details

To implement this Smart Kitchen system, all features mentioned above are required to be in position. This includes the load sensors which are installed inside each compartment of the pantry, the user side server containing the receiver

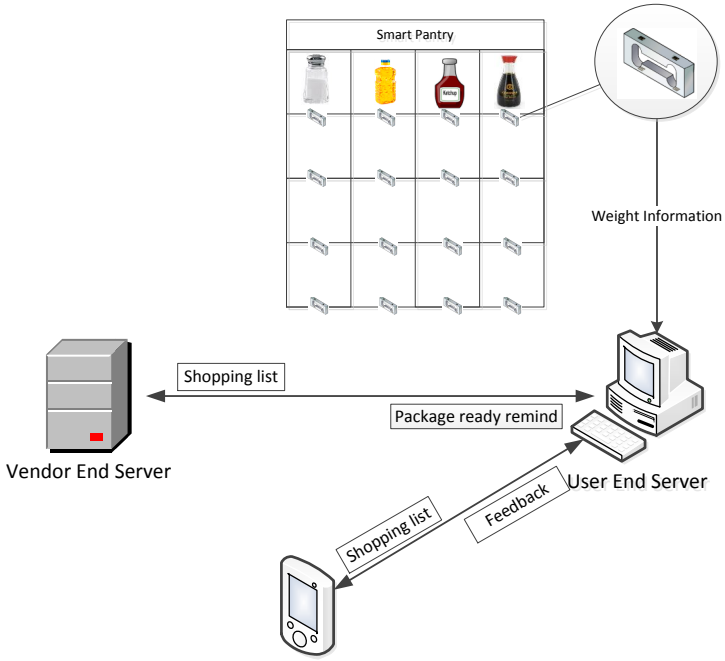

Figure 4: Smart Kitchen System Architecture

application for the weight data, the database that stores the user preferences, the protocol to communicate with the vendor's backend server, the output function to export the shopping list to the customer (If customers choose option 1 delivery), and the settlement function to complete the order as well as the payment (If customers choose option 2 or option 3 for delivery).

Since this Smart Kitchen system needs to install a load sensor for each compartment, in this solution we will use the ordinary low cost load sensors (See Figure 5)with only the ability of measuring the weight of the object. Those sensors can be wired with the cheap hardware that can read the analog signal from those sensors and convert it to digital data for later use. This kind of hardware can also serve as the user side server and provide other functionalities like analyzing the consumption data and communicating with the vendor. The system-on-a-chip hardware currently on market can be a very good choice, like the Beaglebone Black (See Figure 5) and the Raspberry Pi. Those system-on-a-chip hardware have the advantage of compact size and low energy consumption, thus can be mounted easily behind the pantry.

The preference database and the refining algorithm would be a relatively independent components in this system. A unified input and output interface will be defined, which guarantees that the database and the algorithm that accesses this database can be replaced without customer's perceiving. This would be very useful for later online system upgrading, which will make sure the customers always get a good algorithm for accurate prediction and the external information are also up-to-date.

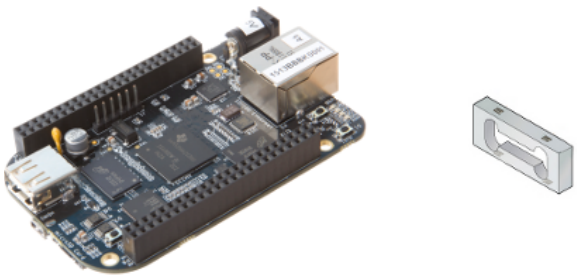

Figure 5: Beaglebone Black (left) and Load Sensor (right)

```
<?xml version="1.0" encoding="utf-8"?>
<CustomerInfo>
      <CustomerID>
      0001438123
      </CustomerID>
      <CustomerAddress>
      4377 High Oak Cove, White Stick, TN, 37185-1129, US
      </CustomerAddress>
      <CustomerTel>
      (615) 625-5920
      </CustomerTel>
</CustomerInfo>
<ShoppingList>
    <GroceryCategory>
        <Item ID=90001234181 Type="Salt" ProductID=000245 Qty=1>
        </Item>
        <Item ID=90001234181 Type="VegeOil" ProductID=000255 Qty=1>
        </Item>
        <Item ID=90001234181 Type="Ketchup" ProductID=000262 Qty=1>
        </Item>
    </GroceryCategory>
</ShoppingList>
......
```

Figure 6: Shopping list and customer information in XML format

The communication component is used to send shopping list to the vendor server. Since the system may need to be compatible with all kinds of vendors' heterogeneous systems, it is necessary to use some common protocol that is universally accepted. A practical solution is to use email service for this communication. Every time a shopping list is formed, the client will prepare the shopping list along with the customer's information formatting to the XML-like style (See Figure 6), and send all these data to the vendor's email address. On the vendor side, since the data in the received email is well formatted, it can be easily interpreted and stored into any kind of information management system under minimal development. Since the data is sent via email, even if the cooperating vendors don't currently have the ability to interpret the email message directly, the order can be processed by the employees manually. This will in further enhance the robustness of the system a lot.

6. Conclusion and Discussion

In this paper, we propose a new business paradigm that can change the grocery shopping business tremendously, and bring huge convenience to the customers.

Grocery shopping is tiresome and repetitive, which is a huge waste if time in people's daily life nowadays and can be considered as non value added activities. With this Smart Kitchen system, we are trying to release most of the grocery shoppers from this low importance chore, and save a great of time and trouble from their daily trivia. A system framework along with the features and implementing details are discussed in this paper. The Smart Kitchen will use the ubiquitous sensing technology to collect information from the customer's daily activities in kitchen, help to keep an eye on the inventory level for each grocery category, and utilize the recommender algorithm to predict the customer's preference before finally placing the order for the customers. Also, various delivery options are discussed in order to best cater different type of customers. During this whole process, the customers don't have to spend any time worrying about the grocery shopping or supplying except giving some simple feedback and confirmation to the system.

This Smart Kitchen is currently still in the prototype phase, which means there would be more than one possibilities on how the final product will be implemented. But the principle behind this system will always remain consistent, which is, to minimize the time and effort spent on the whole grocery shopping process, and authorize the intelligent algorithms to make the decision for the customers. There will be a tradeoff between the optimality of the solution and the time and effort saved by taking an acceptable solution. In the realm of grocery shopping, we assume the optimality of the solution is unnecessary, thus taking the automatic solution would be well justified.

7. Future Direction

This paper is proposing a promising business paradigm that would bring great change on how people are participating in grocery shopping activities. The system framework as well as many implementing details are also discussed with certain depth. One big challenge remains undeveloped would be the cooperation and interaction with the current grocery vendors. How to build a pilot case and convince the participating vendors to realize this win-win business opportunity would be objective of the next step.

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