The Pervasive Fridge
A Smart Computer System Against Uneaten Food Loss

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***Abstract* — Food waste or food loss is food that is discarded or lost uneaten. The work presented in this paper is related to our researches in the field of pervasive and ubiquitous computing. Our "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, SMS (with no charge) and pop-up, to avoid uneaten food loss.**

***Keywords*-Application-oriented system; pervasive computing; ubiquitous computing; ambient intelligence; fridge; barcode scanner; voice interaction; SMS; android.**

I. INTRODUCTION

Food waste or food loss is food that is discarded or lost uneaten. Currently, in the world, according to the Food and Agriculture Organization of the United Nations (FAO), consumers waste about 1.3 billion tons of food annually. Consumers in rich countries waste about 222 million tons of food products [1]. People buy foods that are kept in fridge or cupboard and when products arrive at their deadline, they are thrown.

The work presented in this paper is related to our researches in the field of pervasive and ubiquitous computing. We are particularly trying to find some ways to help consumers avoid wasting food. Nowadays, the consumers, generally less attentive than by the past, often do not interpret correctly the dates of consumption, and/or do not care about the organization of the refrigerator and so, do not have the time to manage their products. Obviously, this leads to important food losses. Our goal is to reduce this waste of food. As this is mainly due to problems of "memory", we decided to work on solutions that provide easy and usable ways of doing this reminder's task, thanks to new technologies. We have decided to tackle two main parts of this problem by providing: (a) multiple ways to enter into the system data concerning the products, and (b) various notifications in order to remind important deadlines to users.

We believe that smartphones can be efficiently used in this fight against food waste. Indeed, they are natively equipped with hardware (camera, microphone) and software (barcode reader, automatic speech recognition, etc.) that can be combined and easily employed in order to collect data and also remind important deadlines to consumers.

The document is structured as follows: background and motivation of this project are explained in section two. Section three presents the related work on that domain. Section four gives an overview of our approach in order to tackle the emerging problems encountered. Section five describes a case study and our results using our developed prototype. Then, we conclude this paper and give our roadmap for future work.

II. BACKGROUND AND MOTIVATION

One quarter of the food produced on an international scale is discarded without being consumed, while more than 800 million people suffer from hunger in the world. To the question "*Why does so much food that could have been eaten get thrown away?*", the "Love food, Hate Waste" web site answers : "The main reasons for throwing away food can be grouped in to "cooking or preparing too much" (for example cooking too much rice or pasta and it gets left in the saucepan or on the plate) or "not using food in time" - for example having to throw out fruit and vegetables because they have gone off in the fruit bowl or in the fridge, or not eating food before it goes past its use-by date. We know that there are lots of potential reasons why food might not get eaten in time – our plans change, we forget what food we have in the cupboards, we forget to freeze or chill something to use at a later date, we lack the confidence or knowledge on how to use up our leftovers – which is where our website can help!" [2].

Loss and wastage occurs on all steps in the food supply chain. In low-income countries most loss occurs during production, while in developed countries much food – about 100 kilograms per person and year – is wasted at the consumption stage.

Our research interests include human-computer interaction in the context of ambient intelligence. The main goal of our research is to find a way to model, design and implement computer systems to facilitate human activities.

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Currently, our purpose is to cross these aspects with the notion of "green IT", allowing the user/consumer to obtain relevant information in order to take adapted decisions.

In this context, our motivation for this work is to look for solutions that can help consumers in avoiding the loss of uneaten food thanks to new technologies and smart devices. Thus, our research area is here clearly related to the field of application-oriented systems.

III. RELATED WORK

Trying to reduce the food waste is not a new idea. In the world, there are many applications that allow users to manage their food. In this section, we give some information about existing systems oriented toward this objective. We analyze the capabilities of each system, encountered during our study of the literature. We have listed below some characteristics of those applications.

"**Consume Within**" (Iphone, 2.99$) is an application that helps households to reduce the amount of food they waste. Food items can be added to three different locations – fridge, freezer or cupboard – and their expiration dates set individually. Each entry can be accompanied by a photograph to identify when removed from storage. The application alerts users daily of the foods that are about to expire within the next 3 days and displays them by location or as a single list [3]. In the same way, "**Food Reminder"** (Iphone, free) keeps tracks of food expirations and provides reminders [4]. **"FoodScanner"** (iPhone, 4.99 $) allows using the camera to scan UPC barcodes on foods in order to track how many calories are eaten throughout the day by users [5]. By using "**Fridge Police**" (iPhone, 2.99 $), it is possible to obtain, after a barcode scan, some information about the products (i.e., manufacturer, brand, size, etc.) that will be logged along with the "opened on" date. The user is also prompted to take a quick photo of the item. Then, the item is placed in an alarm calendar, which can be accessed at anytime. As the items "use by" dates approach, users will get an automatic reminder [6]. "**Rz Fridge Reminder**" (Windows Phone 7, free) is an application available in English and Italian and could manage expire date of items stored in the fridge. Alerts are sent upon users choices (expire tomorrow, next week, next month, etc.) [7]. "**Fridge Manager**" is a Korean application (Android, free), that helps users in managing goods into their fridge with an alarm service [8]. With "**Fridge Friend**" (Android, 0.99 $), consumers can organize the groceries in their refrigerator and see which ones need to be used first. It is also possible to export data in a CSV (Comma Separated Value) file, which can be emailed to a particular destination [9]. "**Fridgician**" (Android, 0.99 $) is the same kind of inventory tracking system for home refrigerator. It provides features such as multiple accounts on the same phone, or view food sorted by date, expiration, and name [10]. "**LG smart Refrigerator**" (Android, free) is an application that works with LG DIOS Smart Refrigerators. The application connected to the world's first Smart Refrigerator using wifi provides convenience food management. Some particular features related to this refrigerator are available, such as management food list, location management and marking the expiration date, remote checking system of food list, recommended recipes, shopping list checking and monitoring conditions of the refrigerator [11]. This monitoring feature is often used to qualify intelligent refrigerators: "*An intelligent refrigerator is one which possesses self monitoring capability of food item or material with minimal or no human intervention.*" [12].

Other smart systems are now embedded into refrigerators. For example, the "**MMS Fridge**" by Electrolux, the "**Samsung's RF4289 WiFi smart fridge**" (3499 $), which can be connected to Twitter, Pandora, Gmail, Epicurious, etc. and the South Korea's **"LG smart fridge**" (4124 $), that suggest recipes, are available for consumers interested in those technologies.

Numerous studies were conducted around the notion of smart fridge. Some researchers are focusing on the ability to enhance health and enable better nutrition [13] while some others prefer focusing on the communication matters between the user and the device [14]. Among the main shortages of current smart fridges systems, listed by [13], we particularly agree with the following: "*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.*" and "*There is no uniformed bar code to record information such as expire date of the food.*"

Moreover, concerning the notification about expired goods, we noticed that all the systems that we have studied are conceived on a reactive mode. When the user asks the system for expired dates, it replies with a list of products. Obviously, if the user does not ask, he/she will never be notified. We are studying other ways to inform users about important events, and we are deeply convinced that smart systems have to be modelized on a proactive mode.

It is the system itself that has to push the relevant information to the users, by various ways, and not the opposite. But according to Mike Kuniavsky, "*Reviewing the history of the commercial fridge computer demonstrates both the idea's tenacity and its lack of commercial success.*" [15]. Indeed, it is not necessarily a good idea to propose always more capabilities if they do not match the user's needs. For instance, "*The intelligent fridge ordering food (M = 3.63, SD = 1.19) and the intelligent TV ordering products (M = 3.63, SD = 1.07) were found to be the least attractive.*" in a study presented in [16].

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Figure 1: Scanning the barcode and obtain information about the product with Pervasive Fridge

IV. OUR APPROACH

The main subject of this work is the modeling and implementation of a timely reminder of deadlines and validity of food stored in the fridge or cupboards. To avoid waste, we want to have a ("green") computer system to notify a smart home of the input and output of products into the fridge, via barcode, voice recognition or RFID tag, for instance. The system will also manage other aspects such as suggestion of recipes, depending on the ingredients available, allergic alerts, dietary advices, assistance to improve the conservation of food, etc.

One important difference between our system and the ones discussed in the related work part of this paper is that the database used by our system is managed externally (see Prixing) and takes advantage of a large community of consumers, that can add and comment a large set of products.

Our primary objective is to provide a useful, usable and low-cost system. We think that it is a good idea to use the capabilities of smartphones already daily manipulated by the consumers. Indeed, modern mobile phones and smartphones are equipped with barcode scanner, automatic speech recognition systems, SMS and instant message capabilities and could access the Internet network. So, we argue that the proactive mode of interaction that is predominant in our approach could be reached by the use of a pervasive system, in which the smartphone will be the core, for entering information and receiving notifications.

A. *Entering data about the product*

Our project name code is "Pervasive Fridge". It refers to the paradigm of pervasive computing and ambient intelligence, but does not mean that we are working on an intelligent fridge. The fridge of the users remains the same (i.e., classic, and not connected to Internet, without barcode reader, etc.). It is the application that we provide for smartphones that leads to the notion of pervasive and ubiquitous computing. Our system can be used in the supermarket, during the shopping or, at home, during the storage of the products in cupboards and fridge. The entering data task consists in giving to the system, for each food, relevant information for their future management. Thus, name, location, category, number of items, expiration date, and some optional data are asked to the user for each product and saved in a database.

This manipulation can be done, as traditionally, with the classic text/keyboard manner, but also with some more convenient ways with barcode/scanner, and voice/microphone of the mobile device. Figure 1 presents some screen captures of our prototype: (a) the user actives the camera of the device by a simple touch on the "scan" button, (b) the barcode of a product is scanned and detected, (c) the corresponding product is searched on an external database, available on Internet. Once the product is identified, the related fields of the form are automatically filled and the user enters the number of items, the category and the deadline (i.e., the expiration date). This could be done textually or vocally. On Android, the Google voice tools are used to do so.

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One of the key problems in such project is to choose between internal or external tools, in order to retrieve information based upon barcode data. EAN-Search [17] and UPCDatabase [18] are available on Internet, but they do not provide API (Application Programming Interface). So we decided to choose Prixing [19] as an external database. Prixing is a powerful system that retrieves the price of a product (not only food) according to its EAN code/barcode.

The API of Prixing is freely usable for developers and currently limited to 500 requests per day, per account. The database contains around 180.000 food references among 2.000.000 products. More than 700.000 products have been added in seven months by the people of the Prixing community; it represents almost 4000 products added each day.

In Pervasive Fridge, the deadline of the product can be entered by different means: directly by text or voice, or indirectly, with an estimated date, depending on the category of the product.

Figure 2: Identifying product by a photo

As illustrated on Figure 2, with Pervasive Fridge, it is possible to identify a product by taking a photo of it. This feature is helpful in situations where foods are not marked with barcodes (fruits & vegetables, some bread, etc.).

B. Notifying users about deadlines

As we can see classically on others applications, with Pervasive Fridge it is possible to display, on request, the list of the stored products and to mention the remaining days before expiration.

For example, we can see on Figure 3 that the Coca-Cola is still consumable within the next 9 days. The red color is used to indicated the expired foods ("original Collection" – Haagen Dasz – and "Ice cream smoothie" in our example) while green or orange colors indicate respectively products that are still eatable and products that have to be eaten very soon (see the colors used in Figure 4) .

An internal reminder is also activated each day at a parameterized hour, while a vibration is activated on the device, and a pop-up invites the user to see what products are expired.

Figure 3: List of managed products

Moreover, we decided to propose a more proactive notification that can be pushed to the user, even if his/her mobile device is not active. This is done thanks to reminders programmable via Google Calendar Agenda, as illustrated on Figure 4. Therefore, pop-up, Email, but also SMS notifications can be used with Pervasive Fridge, in order to push to the user important food deadline messages, every time it is necessary, everywhere on the planet, on a multichannel manner.

Figure 4: Google Agenda notification used with pervasive fridge

V. RESULTS

In order to test and evaluate the capabilities of our system, we used Pervasive Fridge within the following scenario. Thirteen different products were bought in a supermarket.

These products were composed of foods and beverages. We tried to use barcode, voice, photo and text to identify products and to enter expirations dates. Thirteen products have been bought the 21th of September 2011. Here is the list of these goods, sorted by expiration deadline: a piece of pork (23/09/2011), a Pack choy vegetable (25/09/2011), a pack of Kiwis (27/09/2011), a Chinese cabbage, some tomatoes and bananas (28/09/2011), 4 chocolate creams (29/09/2011), 6 eggs (13/10/2011), a bottle of milk (17/12/2011), a large bottle of Coca-Cola (30/12/2011), a pack of beer (25/10/2012), a bottle of mineral water (01/03/2013) and a rice pack (06/08/2013). Five products have been successfully identified by scanning their barcode and thanks to the Prixing database: the bottles of water and milk, the eggs, the beers and the rice. One product has been successfully identified by pronouncing its barcode: the Coca-Cola. This operation was a little bit longer because it worked after a few tries and by pronouncing the barcode numbers, three by three such as, for instance: 317 – 478 – 000 – 043 – 1.

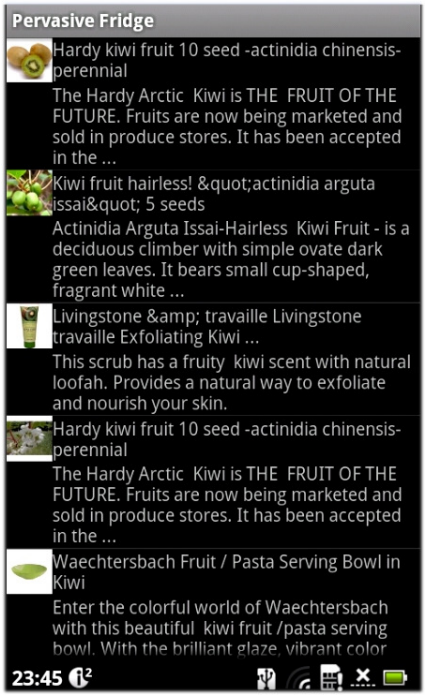

Figure 5: Kiwis, identified by a photo of the product

One product has been successfully identified by taking a picture of it: the pack of kiwis, as illustrated in Figure 5. The image recognition took a long time (around 40 seconds) compared to the barcode scanner method (around 2 seconds). After this image recognition phase, the system proposes a list of possible matching products and the user chooses among them the more representative, compared to the targeted one. The field “barcode of the product” is not filled, but the other fields of the form such as the name of the product, the category or the estimated relative deadline are automatically filled, if available. The six others products have been entered in the system by typing their barcode with the virtual keyboard of the Android device.

In the following lines, we give some information about the reactive and proactive received notifications in this experiment. The reactive notification way is traditional in this kind of applications. It means that the user ask voluntarily the system about the expirations date of the food stored in the system. In reply, the application indicates to the user, with a graphical internal reminder message (see Figure 6) and a vibration of the device.

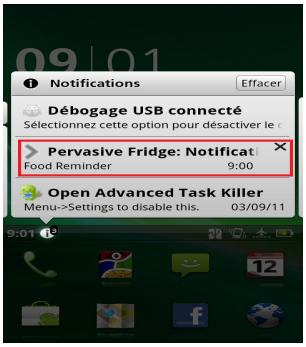

Figure 6: Internal reminder of Pervasive Fridge

For instance, in our tests, the 22th September of 2011, the Pervasive Fridge indicated two products to be eaten soon: the piece of pork (23/09/2011) and the Pack choy vegetable (25/09/2011). We see with this example that the system uses a notification parameter of 3 days for the vegetable category. The user can freely change all the notification parameters, and this will indicate to the system how many days before the expiration date he/she like to be notified.

Figure 7 is an example of proactive notification event created automatically by our system in the consumer's Google Calendar. We used the Google Calendar Agenda API to indicate the channel (window pop-up, Email and/or SMS reminder) and the timing chosen by the user.

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Figure 7: A Google Agenda reminder event created by Pervasive Fridge

Thus, we provided the possibility to push some important information to the user, even if the Pervasive Fridge application is not activated at the appropriate moment. Finally, Figure 8 presents a screen capture of a SMS notification received freely by the user on his/her phone. We strongly believe that these kind of proactive messages, emanating from our Pervasive Fridge system, are very useful in the fight against uneaten food loss.

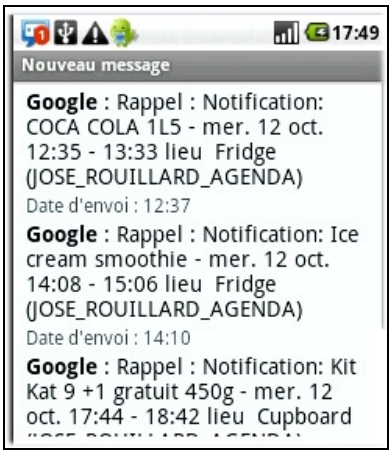

Figure 8: SMS Notification for Coca-Cola, Ice Cream and Kit Kat

VI. CONCLUSION AND FUTURE WORK

The goal of this paper was to describe the Pervasive Fridge system, and to explain how we can facilitate the fight against uneaten food loss by using ambient computing strategies and technologies. Our results shown that a proactive system is technically feasible, and that it can freely and easily push appropriate reminders to the consumers. Pervasive Fridge is an application-oriented system that can be used in a multimodal way (keyboard or voice) and with different technologies (camera barcode scanner, voice and image recognition). We tested our system with an experiment. It showed that Pervasive Fridge helped in (a) entering products information into the database, and (b) receiving relevant reminders across multiple channels of interaction. Our future work will be oriented toward the possibility to propose recipes according to the foods managed by our system. We are envisaging to propose relevant manners (with augmented reality for instance) to measure the necessary quantities of food to buy and cook, in order to avoid loss and wastes of uneaten food.

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