IFCMS: Intelligent Food Consumption Mobile System for efficient and effective household food consumption

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Abstract
Nowadays, world food shortages are a common issue, even though household food waste was estimated at roughly 95-115 kg/capita/year for the United States and Europe for the year 2007. In comparison to South/South East Asia and Sub-Saharan Africa this figure is 6-11 kg/capita/year (Buzby 2012). It is evident that values of societies of developed countries face a serious problem. In this report we propose a system, called Intelligent Food Consumption Mobile System (IFCMS) which addresses fundamental issues related to these excessive waste figures for households. In order to address these issues, we have designed IFCMS to support mobile- and physical interaction between food we consume, the system and the user. One of the key findings of the design of IFCMS is that it provides means to raise awareness on individual's food consumption habits.

Introduction and motivation

Since the Great Depression in the 1930s, and probably earlier on, unnecessary food waste has been a controversial topic for organizations and consumers of developed countries. Food waste and world's food shortages are interrelated concepts which, when discussed, pose a morale dilemma. However, consumers in developed countries not often do individuals consciously consider this dilemma because it is relatively easy to waste large quantities of food.

According to Buzby, post-consumer waste is estimated at 22%, accounting for 118,570 million dollars, of the total food waste in 2008 in the United States (Buzby 2012). In 2007 the UK post-consumer waste was estimated at 25% of the total food waste[1] (WRAP 2009). Bio Intelligence Service (BIS 2010) give a broader view on food waste during different stages. BIS investigates the entire food supply chain from production waste to post-consumer waste. For the context of this report we will continue referring to household food waste instead of post-consumer waste.

WRAP is an organization from the UK which actively raises awareness towards governments and its citizens by researching and advising on food waste issues. WRAP categorized food waste into two categories, namely, edible and inedible food waste (WRAP 2009). The first category consists of 1) avoidable food waste and 2) possibly avoidable food waste. The distinction here is that possible avoidable food waste, such as bread crusts and potato skins are eaten by some but not all. The latter category consist of waste which arises from food preparation such as bones or egg shells (BIS 2010). Both categories make up for 8.3 million of tonnes per year in the UK (WRAP 2009) from which 5.3 million tonnes is avoidable food waste.

Several causes are presented in (BIS 2010, Buzby 2012, WRAP 2009) for the findings of their research on avoidable household food waste. Important causes are listed below:

1) lack of knowledge and awareness regarding edible food and food waste,
2) planning strategy issues which results in ‘buying too much food’,
3) confusion over ‘use-by’ and ‘best-before’ dates,
4) inappropriate storage for food,
5) personal attitude, socio-economic factors and preferences.

An important question for our motivation is why consumers should minimize avoidable household food waste. First, from a self-evident humanity perspective we should not throw away food which could have been used to feed others. Second, the amount of avoidable household food wasted is a significant amount of money which could have been spent otherwise by the consumer (Buzby 2010). Not only does the unused food account for money loss, but also the processing of the waste accounts for more money loss (BIS 2010). Third, processing of food waste can have a negative impact on the environment such as landfilling and green-house gas emissions (Hall 2009 & WRAP 2009).

In this report we propose an interactive intelligent mobile system called Intelligent Food Consumption Mobile System (IFCMS) for households to address and resolve the above stated causes. The main goal of IFCMS is to minimize avoidable household food waste in a manner that is appealing and unobtrusive to its users. From this main goals, and above stated causes, the following subgoals have been identified;

1) support food planning strategies for households for effective and efficient food consumption,

[1] The figure 25% food waste is based on the weight of the food.

2) provide relevant information regarding food and support knowledge on food related processes such as preparation techniques,
3) raise awareness of avoidable household food waste and change attitudes.

Since the widespread use and acceptance of mobile devices, IFCMS is designed towards interaction with mobile devices. Also, the explosion[2] of mobile phones equipped with Near Field Communication (NFC) technologies provides an interesting perspective for mobile interaction and context-awareness.

Related work

This section reviews related work with regard to context-awareness and mobile interaction. Based on the reviewed related work we argue our design decisions and implications further on in this report. The subsection related systems describes two systems which share similar purposes, but provide different (mobile) interaction scenarios.

Context-awareness

According to the online dictionary Merriam Webster[3], context is defined as "the interrelated conditions in which something exists or occurs". This definition is vague, broad and ambiguous, which presents reason why many authors elaborate on different definitions for context in computing (Chen & Kotz 2000, Bellavista 2012, Hervás 2010, Dey 2000, Hong 2009, Schilit 1994, Zimmermann 2007). From the reviewed research on context in computing, Dey's definition is probably the most widely accepted by the community:

"Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." (Dey 2000)

Chen & Kotz and Dey are prominent authors in the research of context-awareness and in their work they elaborate on context taxonomies (Chen & Kotz 2000, Dey 2000). Dey proposes primary context types which characterize the current execution environment of the system by defining the following types: *location*, *identity*, *activity* and *time*. Dey argues that all other relevant information are secondary context types since these are attributes of the primary types. Primary types of context act as indices for secondary types. As a result, multiple primary types can be combined to provide a secondary type. For instance, information related to the commute

[2] http://www.nfcworld.com/nfc-phones-list/ Many large mobile phone manufacturing companies have started to integrate NFC technologies in their newest devices. Currently there exist 100+ NFC-enabled mobile phones where the majority is from large manufacturers such as Google, HTC, LG, Nokia and Samsung.

[3] http://www.merriam-webster.com/dictionary/context

of the user from work to home (secondary type) can be provided by primary types *time* and *location*. Chen & Kotz target a more specific scenario, namely context in mobile systems. They provide a taxonomy of context types along the definitions provided by Schilit's work (Schilit 1994): *computing context* (nearby devices; computational resources, displays, printers), *user context* (user's profile, current location, nearby people), *physical context* (lightning, noise levels, temperature). They added a *time context* which maps to the *time* context type of Dey (Chen & Kotz 2000). Schilit's *user context* maps to Dey's *identity*- and, probably also to, *activity* context type because Chen & Kotz's *user context* also considers user tasks and goals. However, there is disagreement on Dey's *activity* context type because this is part of Schilit's *user context*. Also Schilit's *physical context* is not present in Dey's taxonomy.

In (Zimmermann 2007), he rightfully points out that a major issue in defining context, and therefore context taxonomies, fail to provide justifications for its definition. Zimmermann agrees with Dey's taxonomy but elaborates on an operational taxonomy by adding a *relations* context type, exchanging the *identity* context type with an *individuality* context type and elaborates further on subcategories for *individuality*. Zimmermann argues that the addition of a *relations* context type is of importance, because related entities of a particular entity may convey relevancy for context.

From above stated definition of context, context-awareness defines system activities such as sensing, interpreting and adapting (to) context. Moreover a system is context-aware when it provides relevant information, where relevancy depends on the user's task (Dey 2000).

Reflection

For humans, making sense of context is essential to adapt to our ever changing (chaotic) environments. Most humans are able to sense, interpret and adapt to very specific contexts in matters of milliseconds. From elaborated definitions in presented work, context is a generic concept resulting in issues when defining a taxonomy for context. Bellavista argues that many of the proposed definitions pose an issue related to the specific scenarios of researched context-aware systems (Bellavista 2012).

Context is everywhere and may involve everything if relevant, making it cumbersome to elaborate on these taxonomies for generic scenarios. However, we agree that spatial and temporal context types are straightforward to represent in a taxonomy, hence many authors share these types in their work. The different definitions presented by authors lack limits to what context captures. Therefore we agree with Bellavista that these taxonomies dependent on specific scenarios of the context-aware system. For now Zimmermann's taxonomy provides a good foundation for the design of our system because it captures the essential context types for our scenarios well.

An interesting statement put forward by Dey is that explicit context should be considered to be part of context-aware systems as well (Dey 2000). To illustrate, deducing whether a user is has diabetes, probably can be achieved by implicitly gaining that information. However, gaining that information explicitly does not mean it is not part of context. Moreover, there will be cases where gaining relevant information is much easier, and possibly more convenient for a user, when it is gained explicitly.

Mobile interaction

Mobile devices has become an essential part of interactions in our daily lives and therefore covers a broad research area including mobile interaction research. The ubiquitous aspect of mobile devices presents opportunities for persuasive technology anytime and anywhere (Chittaro 2010, Hong 2009, Savio & Braiterman 2007). However, considerations regarding mobile interaction should be taken into account. In this section we will first elaborate on these considerations. Second, we elaborate on a more specific area in mobile interaction research, namely mobile- and physical interaction. We argue that this research area is of most interest for the design of our system for its interactions.

Considerations for mobile interaction

In (Tarasewig 2008, Chittaro 2010) several mobile interaction design considerations are presented. Tarasewig and Chittaro agree on aspects of mobile devices which present possible issues for interaction, such as limited computing and connectivity power, form factors, always changing context and simultaneous occurring user tasks (Tarasewig 2008, Chittaro 2010). The latter is an important aspect of their work since it defines how the surrounding changing environment (context) has an effect on performance of used modalities in mobile interaction.

Chittaro categorizes these effects into the levels *perceptual* (physical parameters of mobility), *motor* (user's mobility can decrease ability of user's controlling voluntary movements or taking postures), *social* (certain modalities are not socially accepted in a particular context) and *cognitive* (devotion of human attention to the mobile device and the interactions it exposes). Chittaro argues that most modalities, or a combination of these modalities, can facilitate the *perceptual*, *motor* and *social* levels well. However, the *cognitive* level poses a more careful approach towards selecting the right modalities for interaction. Following from his work on the *cognitive* level, Chittaro provides guidelines for designing mobile interactions which pose a minimal amount of *cognitive* load by designing interactions which 1) provide quick and easy processable information to one or more human senses, 2) have appropriate combinations of modalities and 3) use context-awareness to minimize necessary attention and thus decrease *cognitive* loads (Chittaro 2010).

In (Tarasewig 2008) several guidelines are presented as well, which coincide with Chittaro's guidelines of the *cognitive* level, namely *top-down* interaction (displaying information in a hierarchical fashion), *eyes-free* interaction (provide modalities which do not require attention of sight) and consistent use of interfaces (Tarasewig 2008).

Mobile- and physical interaction

Humans are good at touching and pointing at things, and we do so to communicate concepts and ideas to others. These physical interactions are natural to us and we start to do this at a very early age. Trends in technology such as the explosion of RFID and NFC-enabled mobile devices, provide new opportunities in designing natural mobile interactions with our physical environment (Falke 2007). The research domain of mobile- and physical interactions elaborates on the use of a tagged physical objects to act as a physical user interfaces in mobile interaction (Broll 2010, Falke 2007, Riekki 2012).

In (Rukzio 2006) a distinction of *touching*, *pointing* and *scanning* is presented, and a user study based on a prototype is conducted to provide insights on these three types of physical interactions. *Touching* and *pointing* imply the mobile device should touch or point to a physical object. Findings from the user study indicate that *touching* and *pointing* were experienced as natural interactions, intuitive, felt error-resistant and produced less cognitive loads. *Scanning* however, implies discovery and presentation of physical objects available for interaction. An important difference of *scanning* in comparison to *touching* and *pointing* is that the user does not have to be aware of the augmentation of the information or services related to the physical object. An issue for *touching* is that users have to be in the vicinity of the physical object. Although *touching* is dependent on location, it suffers least from cognitive loads and is widely experienced as natural.

NFC-based mobile- and physical interaction use *touching* since the NFC standard specifies that the maximum distance between tag and reader can only be 10 centimeters apart due to security considerations (Broll 2010, Falke 2007, Riekki 2012).

In (Broll 2010) a user study is carried out to evaluate different mobile- and physical interactions. Broll presents several prototypes which implement either complete mobile interaction, various types of hybrid mobile- and physical interaction, or complete physical interaction. Each of these prototypes is evaluated in the user study in terms of 1) task completion time, 2) task complexity and 3) attention shifts from mobile device to physical environment. Mobile application features such as, *selection* of items, *navigation* through application and *combination* of items were mapped to each scenario (completely mobile-, hybrid- and completely physical interactions). Findings of the study suggests that more physical interactions result in faster task completion (Falke 2007, Riekki et al. 2012) and less attention shifts, and therefore lesser cognitive loads (Rukzio 2006). However, Broll points out that choosing a scenario depends on the purpose one is trying to achieve. Therefore Broll states that physical interactions can complement mobile interactions, and more importantly, relieves the user from *cognitive* loads.

In (Riekki 2012) aspects of advertising NFC-tags to users are presented and discussed. Since the *touching* interaction is very natural to us, we might not consider touching our mobile device to a very specific area on a NFC-tagged object. Riekki therefore elaborate on a system which uses a graphical information visualization to communicate interaction possibilities with

NFC-tagged objects. Important elements of this information visualization are 1) getting *attention* from user, 2) *instructing* how to use the tag, 3) present which *action* is carried out by interacting and 4) what area should be used for *interaction*.

Reflection

An interesting observation from the reviewed literature on considerations of mobile interaction, is that context has a prominent role in designing usable mobile systems. Moreover, the notion of mobile context is intrinsic to the purpose of these devices which provide mobility to a user and thus pose highly dynamic contexts (de Sá 2010). When referring to context, all relevant information for the current execution environment should be taken into account whilst designing these interactions. In context of mobile- and physical interactions, relevant information therefore includes physical objects in this environment. Therefore these physical object should be considered a part of the whole interaction (Riekki 2012).

Related systems

An inspirational project for ICFS is Nutrismart. Nutrismart is a system which can identify food and therefore can provide relevant information such as nutrition values, healthy meals and more. Unfortunately, the project does not provide a system description, but does provide a promotional trailer[4] which shows features and interaction scenarios. Similar to IFCMS, Nutrismart proposes the use of identification technology in food. A major difference however, is the use of plates which can sense what kind of food is placed on the plate. In our system, we propose the use of a mobile device capable of doing exactly the same without having additional hardware. We agree that the use of this additional hardware can provide different interaction scenarios and can overcome issues currently affecting our system. We elaborate on this more in the discussion.

Albert Heijn, a major retail chain in the Netherlands, introduced a new way of shopping in some of their stores in urban areas[5]. Upon entering the shopping area of the store, consumers identify themselves with their personal Albert Heijn-card and grab a device with a monochrome display, bar code scanner, four buttons and a trigger. Before putting products in their physical shopping cart, consumers *point* the device at the bar code of a product and pull the trigger to confirm adding it to the virtual- and physical shopping cart. The display shows all, or a selection, of products in the virtual shopping cart and their accumulated price. Removal of products is achieved by selecting a product with two navigational up and down buttons, and a remove button. After the consumer is done shopping, the device is handed in. Thereafter at a payment system, the personal Albert Heijn-card is identified again, and the virtual shopping cart is retrieved by the payment system. After payment with a bank card, a receipt is printed of the transaction and must be kept in order to open the gates to exit the store.

4 http://vimeo.com/24332950

5 http://www.youtube.com/watch?v=05emMr2sKs0 (in Dutch)

Albert Heijn's system poses several critical interaction issues. First, there are, at a minimum, five physical objects involved during the end-to-end interaction of a user completing its task at a store. These physical object are; 1) an Albert Heijn-card, 2) a virtual shopping cart device, 3) a product, 4) a bank card and 5) a receipt. Having that many objects in the whole interaction relate to higher cognitive loads on the user. Second, the virtual shopping cart device is bulky and therefore may result in clumsy body movements whilst scanning the bar codes, especially for people with smaller hands (Chittaro 2010). Finally, the system does not consider context, such as user goals or relations between products. Moreover, the system is aimed at one goal only; to (hopefully) provide quicker means to shop.

Methods

Interaction design

IFCMS enhances our everyday interaction with the food we consume. From the stated goals in the introduction, we argue that IFCMS should promote effective and efficient consumption. Therefore we need an interaction design which describes our everyday food related tasks to propose more efficient and effective ways to perform these tasks.

In this section we present these tasks and how this translates into a interaction design. First, we will introduce scenarios and elaborate on the identified user tasks and goals. Second, we visualize the abstracted scenarios in a system-user interaction flow for better comprehension. Third, we elaborate on possible occurring exceptions. Finally, we present on mobile interface designs.

Scenarios

In order to communicate the interaction design of IFCMS, we present scenarios as narratives on the core food related tasks in this section. After each scenario we summarize Zimmermann's context types for the current scenario.

Scenario 1: shopping for food with IFCMS

James (aged 32) usually buys small quantities of food but had to buy more for yesterday's dinner with friends. In most occasions James walks from his commute back home to the grocery store to gather ingredients for his dinner.

When he enters the store, he launches IFCMS from his mobile device. IFCMS retrieves the current household inventory. Based on his location IFCMS switches to food shopping mode and visually proposes several recipes for tonight's dinner. James reviews the recipes and selects one he likes, IFCMS puts the missing products into IFCMS's shopping list. The shopping list *contains items which complement left over, still edible, items to yesterday's dinner to form a healthy dinner for tonight.*

James found the first item on the list and he lets his mobile device touch the item. IFCMS confirms this interaction by providing tactile feedback through the mobile device and thereafter displays information related to the item and automatically adds it to the virtual shopping cart. James wants to bake an apple pie for his mother's birthday and therefore needs six apples. Since these are not on IFCMS's shopping list, it is considered a spontaneous action. Again, when he gets to the fruit department, he lets his mobile device touch one of the apples, IFCMS provides confirming tactile feedback, but also produces a warning sound. Instead of related information on the apple, the mobile device displays a warning message stating that he already has two apples still edible back at home. James dismisses the warning message, IFCMS displays relevant information of the apple and adds the apples to the virtual shopping cart.

Now that he gathered all the items on the IFCMS shopping list, he is ready to pay and go home. There is no cashier, but a payment system. When James lets his phone touch the designated contact point of the payment system, IFCMS provides a tactile confirmation, the current IFCMS shopping cart is retrieved by the payment system and upon completion a confirmation sound is produced. Thereafter a visual confirmation message containing the price details is displayed on the mobile device. James agrees and confirms payment. IFCMS transfers the bought items into his household inventory.

Context types to consider

1) *Location* → grocery store,
2) *Activity* → selecting a meal, gathering ingredients for a meal, paying groceries,
3) *Entities*
    i) *Human entities* → James' food preferences, allergies, budget, regular appetite,
    ii) *Natural entities* → apples,
    iii) *Artificial entities* → prices, payment module

Scenario 2: dinner preparation with IFCMS

Sam (aged 27) is at home and he is planning what to prepare for tonight's dinner. His partner Lisa (aged 29) is still at work but will arrive home in about one hour. They live together in the center of Amsterdam. Sam launches the IFCMS from her mobile device. Based on his location, IFCMS switches to home mode, and based on the current time switches to dinner preparation mode.

Earlier that day Sam already did groceries with IFCMS, and planned to make pumpkin pie. Based on the recipe, IFCMS displays which items should be retrieved from storage. Sam goes into the kitchen and gathers all necessary ingredients and cooking gear. Once he completed this task, he wonders how he has to prepare the pumpkin for the pie, since he never prepared a pumpkin before. With his mobile device he touches the pumpkin on, IFCMS provides confirming *tactile feedback, and displays basic information of the pumpkin. He now touches an item preparation tag on the kitchen which starts a video tutorial on preparing pumpkins for a pie. After following the tutorial, Sam was able to correctly prepare the pumpkin.*

During further preparation of the meal, Sam regularly checks instructions of the recipe which is displayed by IFCMS separately from the previous necessary ingredients. Lisa just got back home and they both enjoy a nice pumpkin pie.

Lisa is in charge of cleaning the kitchen and disposing left over parts of the dinner. When she approaches the bin to dispose the food, the touches the tag on the bin. IFMCS displays the current recipe they just had for dinner and asks Lisa to give an relative indication how much has been wasted from the prepared dinner. Lisa gives an indication by using a slider on the mobile device's display and submits the indication. Thereafter she disposes the left overs.

Context types to consider

1) *Location* → home,
2) *Time* → end of afternoon, ie. 17:00,
3) *Activity* → item retrieval, item preparation technique discovery, dinner preparation from recipe,
4) *Entities*
   a) *Human entities* → Mandy and Sam's food preferences, allergies, budget, regular appetite,
   b) *Natural entities* → pumpkins, bell pepper and tomatoes,
   c) *Artificial entities* → oven to bake the pumpkin pie, refrigerator as storage.
   d) *Group entities* → the pumpkin pie itself consists out of multiple *entities* which form a meal and are described in a recipe.
5) *Relations*
   a) *Social relations* → Sam and Lisa form a household,
   b) *Functional relations* → Sam prepares the pumpkin pie, and both Lisa and Sam eat the pie.

User goals

From the above presented scenarios we have identified the following user goals;

1) Create a shopping list based on missing ingredients for a recipe (at grocery store),
2) Add and remove products from shopping list (at grocery store),
3) View shopping list (at grocery store)
4) View shopping cart (at grocery store)
5) Retrieve related information (depending on the location) of a product (at both locations),
6) Get instructions for a recipe (at home) and
7) Learn to prepare a particular product (at home)

System-user interaction flow

System initialization

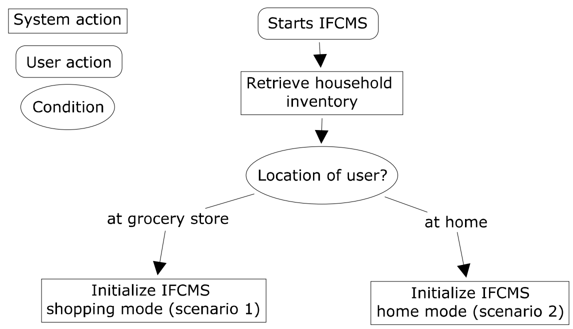

Figure 1. System-user interaction flow describing both scenarios.

Scenario 1: IFCMS shopping mode

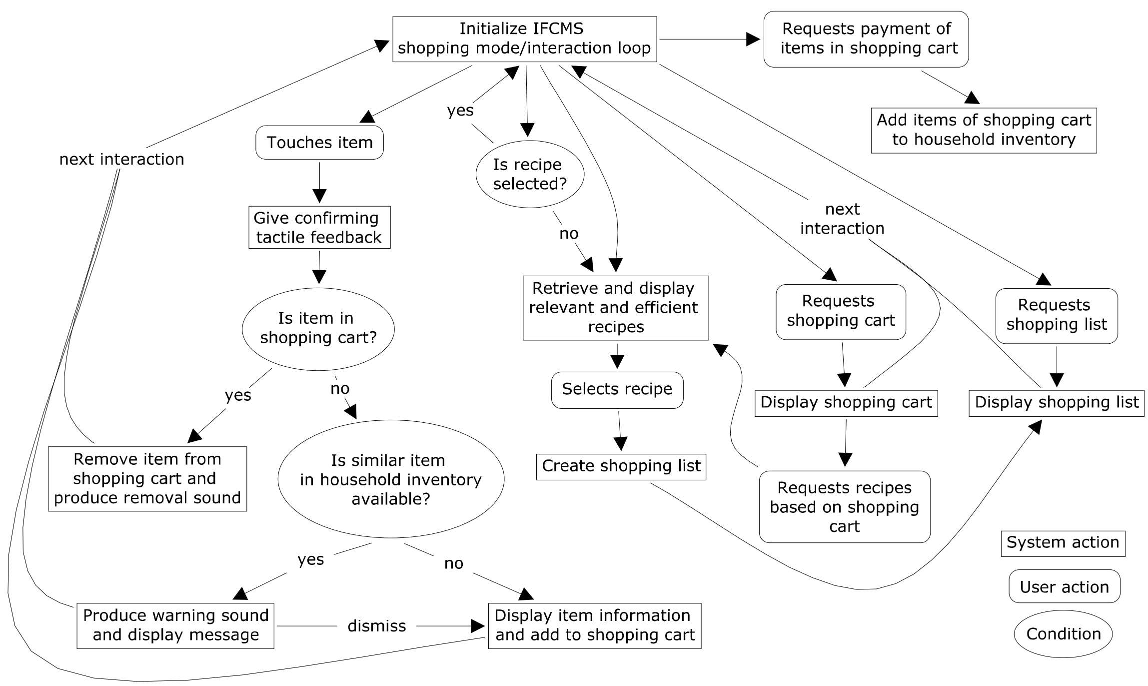

Figure 2. system-user interaction for IFCMS shopping mode.

Scenario 2: IFCMS home mode

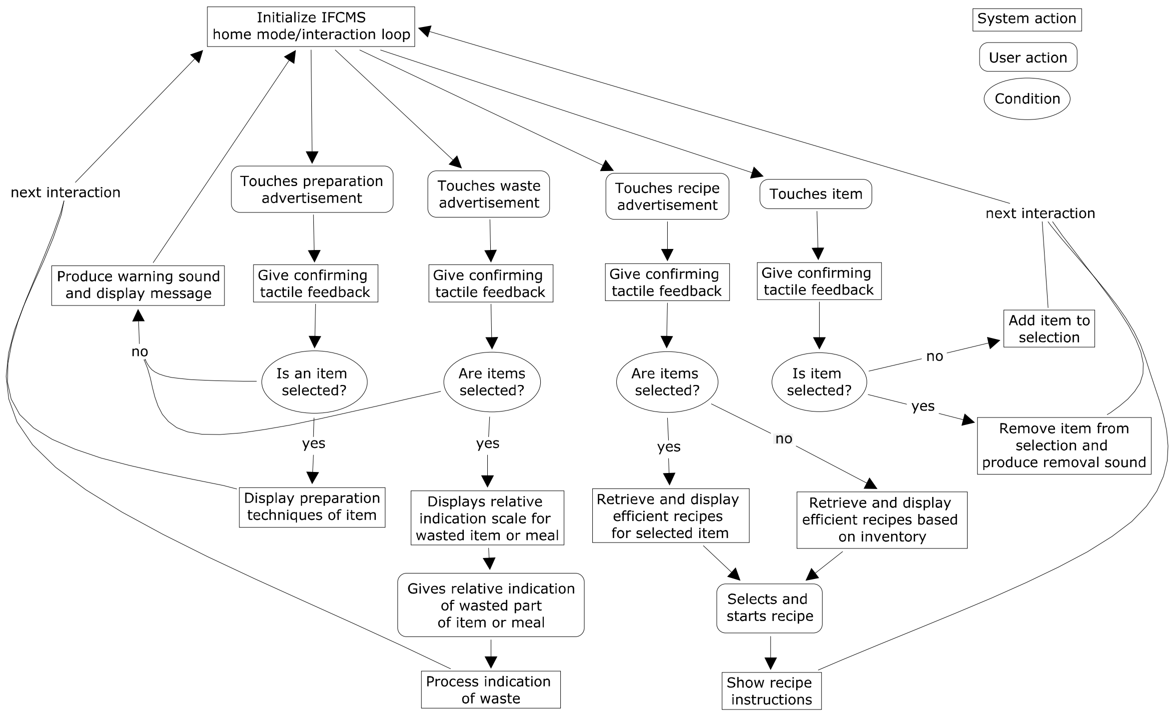

Figure 3. system-user interaction for IFCMS home mode.

User Interfaces

NFC-tag advertisement

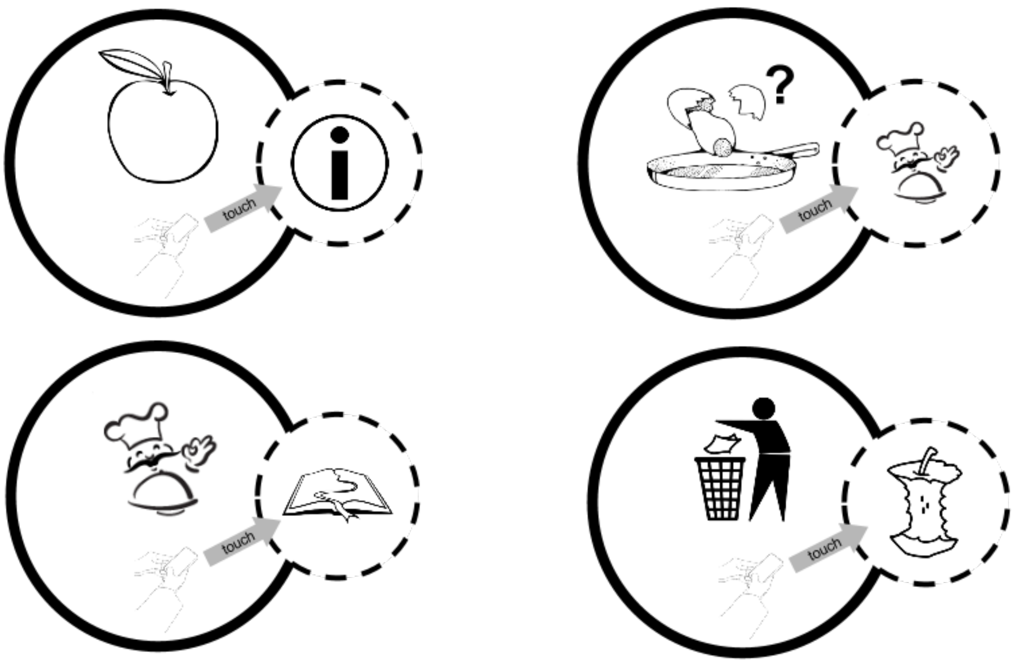

Figure 4. NFC-tag advertisement to raise user's attention on interaction possibilities and actions (Riekki 2012). Upper left is advertisement for food tag. Upper right is tag in kitchen to request preparation techniques based on the selected food product. Bottom left is tag in kitchen to request recipes based on selected food products. Bottom right is tag on every bin in home to request an indication of waste of the selected item.

Managing user profiles

Figure 5. mobile user interface for managing user profiles

Food shopping mode (scenario 1)

Figure 6, mobile interface for shopping scenario

Home mode and dinner mode (scenario 2)

Figure 7, mobile interface for home mode scenario

System description

Hardware

IFCMS's hardware consists of a NFC-enabled mobile device, NFC-tags and a server. We thrived to design a system which keeps the hardware at a bare minimum.

NFC-enabled mobile device

Nowadays, the industry is pushing the integration of NFC technology in mobile devices (Falke 2007, Riekki 2012). Therefore we assume that in the near future all mobile devices are equipped with NFC technology and therefore have the requirements to integrate in IFCMS. Since we want to make IFCMS available for all consumers, we cannot elaborate on a specific mobile operating system to do the implementation on. Based on this report, we provide a guideline for mobile application developers. Since these developers probably target a specific mobile operating system, it is up to them to implement all necessities for IFCMS.

Most current mobile devices (ie. Figure 8) have the required capabilities other than NFC technologies for the scenarios of IFCMS. These required capabilities include, a GPS sensors, speaker and microphone, tactile actuator, a relatively large touch display and Internet connectivity via WiFi, 3G or 4G.

Figure 8. Google Galaxy Nexus, NFC-enabled mobile device running on Android

NFC-tags

As followed from the interaction design section, we propose food products to have a NFC-tag attached. There are limits to what extend tags can be attached to all food products. For instance, attaching a tag on every peanut for a bag of 100 grams is a cumbersome and costly activity. Next to that, physical interaction with that many tags poses issues for the overall experience of interaction due to tag interference (Papapostolou 2011). Therefore there should be made clear considerations to what extend tags are attached to food products. We elaborate on this in our discussion since more practical and ethical issues arise from this considerations. For now we assume that tags are attached to either packaged (ie. rice, coffee beans, peanuts) or single larger products (ie. tomatoes, crops of lettuce, cucumbers).

Passive NFC tags (see Figure 9) are used to minimize cost and removes the issue of energy power for the tags to work. The tags must comply with the Near Field Communication

Interface Protocol-1 (NCIP-1) defined by ISO/IEC 18092. NCIP-1 provides a passive mode which defines transport protocol, initialization and target selection (Falke 2007). Available passive NFC have several memory sizes ranging from 48 to 1024 bytes. For our purpose, we suffice with a tag memory size of 144 bytes to encode the food resource identifier (see software section) of a food product.

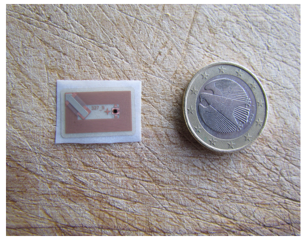

Figure 9. a passive NFC tag capable of storing 144 bytes with a size of 19mm x 12mm

Server(s)

Since NFC-tags are not able to store large amounts of information, we require a server to relay related information and services from NFC-tag to the mobile device. This server should act as a gateway to relevant information and services in the context of mobile- and physical interactions.

Using a cloud service, such as Amazon Cloud services[6], Windows Azure[7] or other, is an interesting and promising alternative instead of buying and installing a dedicated server. Several advantages for using this type of service are the provisioning and maintenance of hardware by the cloud reseller, scalable if needed and avoidance of costly hardware investments upfront.

The IFCMS server(s) will be mainly used for the exchange of information via HTTP(S) from and to mobile devices. Therefore, we propose the use of a reliable web server such as Apache[8]. A stable OS is a must, although most cloud services provide good fall back scenarios if a virtual machine (VM) containing the OS, or the OS itself crashes. Currently, one of the most popular Linux distribution for the web is CentOS[9]. Most cloud services today provide VM installation kits for various OSes, including CentOS.

Software

In this section we elaborate on the software components of IFCMS. Most of these software components reside in the previously proposed cloud service to minimize computational on the mobile device, and to provide easier scaling of the IFCMS when necessary.

6 http://aws.amazon.com/
7 http://www.windowsazure.com/
8 http://httpd.apache.org/
9 https://www.centos.org/

Architecture

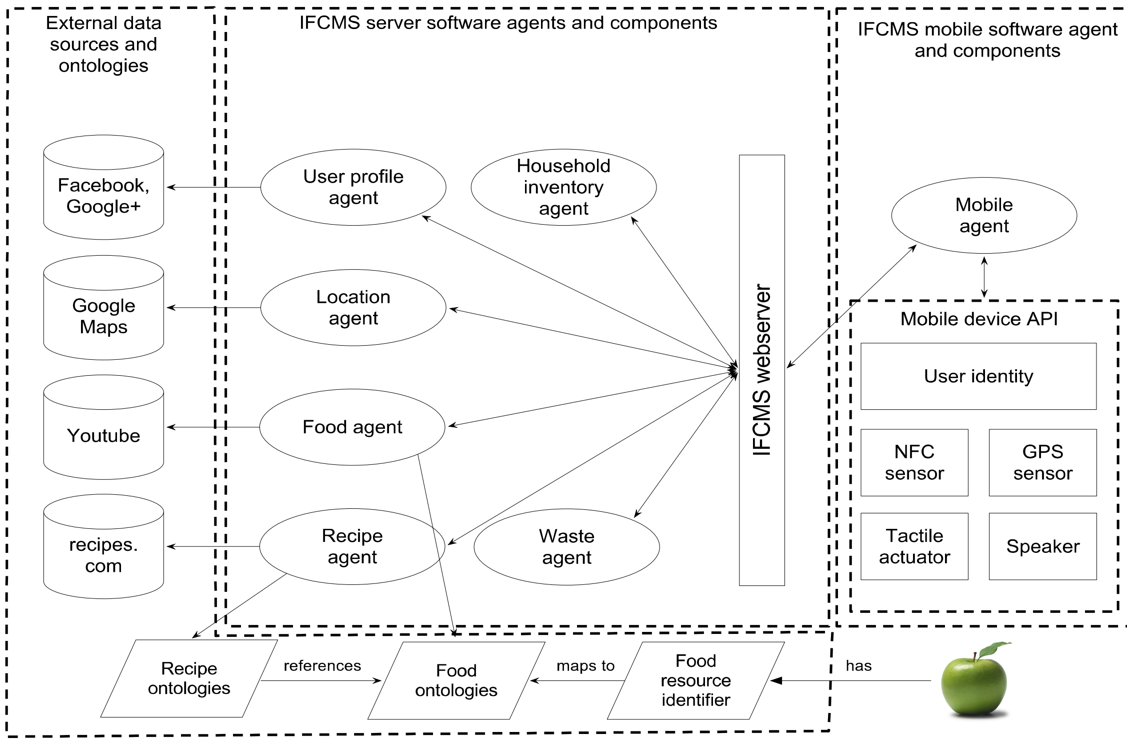

Figure 10, IFCMS's software architecture[10]

External data sources and ontologies

An important part of the IFCMS are ontologies (see lower part of external data sources and ontologies in Figure 10) which provide IFCMS' agents with semantics on food and recipes. We propose the use of Semantic Web technologies to achieve this. To connect food products to IFCMS, we propose the use of a food resource identifier which basically is a HTTP(S) address for a RDF document. Once these identifiers are presented to the system they should be persisted and made available to all agents. These *food resource identifiers* are formatted as follows;

http://ifcms.net/*<producer- or processor name>/<food identifier>* or could be

http://myveryhealtyapples.com/*<food identifier>*

An advantage of using this type of references for a product is that RDF is an interoperable format, which in turn can then can map to ontologies so machines are able to infer about the provided information provided by the RDF document.

[10] For the sake of clarity of the architecture diagram, we have not elaborated on storage for data produced by all software agents in IFCMS's server part. In the description of each software agent section we elaborate how data is retrieved, processed and send on to storage. We also did not provide links between all software agents. However all agents are able to communicate with each other. Details are presented in each section regarding the communication between software agents.

Other data sources presented in Figure 10 provide input for the agents. For instance, the *location agent* uses the Google Maps API to provide translations from GPS sensor to an annotated location. This retrieved annotated location can then provide better means to determine in what mode IFCMS has to operate.

IFCMS server software agents and components

User profile agent & location agent

The *user profile agent* and *location agent* are responsible for managing context information for IFCMS. In (Heckmann 2007) GUMO, a General User Model Ontology is presented which uses Semantic Web technologies to provide a decentralized approach to exchange relevant information regarding user preferences and profiles via HTTP(S). This ontology is interesting for modeling context information regarding user's food preferences, diets and other relevant information. A limitation for GUMO in the context of IFCMS is that it is specificly geared towards *user modeling*. We want to capture other context types as well.

In (Hervás 2010), COIVA (Context-aware and Ontology-powered Information Visualization Architecture) a system which also employs Semantic Web technologies is presented. COIVA is a context management system which provides context types such as *user context* and *environment context*. It provides several features which are interesting for IFCMS such as, 1) distinguishes between information sources, 2) quality of information and 3) ownership of information (privacy issues).

For the IFCMS the *user profile agent* and *location agent* we envision a similar architecture to COIVA. However, we argue that COIVA is a relatively large architecture for the purpose of context-awareness aspect of IFCMS. Here we would like to refer to Bellavista, who points out that many context-aware systems provide very specific models and means to manage context information (Bellavista 2012). From the above stated, we argue that IFCMS should have its own context information management for providing *user*- and *location* context types to match our scenario.

Household inventory agent

The *household inventory agent* is responsible for keeping track of the household food inventory by keeping references to *food resource identifiers*. For instance, after a completed shopping task, the *mobile agent* sends the *household inventory agent* identifiers and their quantities held by the shopping cart. The *household inventory agent* should therefore be able to update the current household inventory. This also applies when the *waste agents* performs its activities.

Another important task of the *household inventory agent* is that it must provide the *recipe agent* with food which result in a optimal solution for a recipe proposition. Therefore, a negotiation algorithm between these two agents should be implemented.

Food agent

The *food agent* is responsible for handling requests by the *mobile agent* with regards to information related to the food. Also, the *food agent* is able to use the YouTube API to query for videos on food preparation for the particular food the *mobile agent* is interested in. Query patterns can be constructed rather easily; *how to prepare a <name of product>*[11].

Recipe agent

The *recipe agent* has a crucial role in IFCMS since it provides the *mobile agent* with recipes relevant for the current context of a household. As stated earlier, the *household inventory* acts in concord with the *recipe agent* to provide relevant recipes for the current inventory. Since relevant recipes should be targeted at a household, the *user profile agent* should be considered as well for the proposal of a recipe. Therefore, a recommendation algorithm should be implemented in the *recipe agent* which should cover data retrieval from the *user profile agent* and *household inventory agent*. The result of this recommendation algorithm should be a collection of recipes along with their missing ingredients. The *waste agent* can also be considered as input for the recommendation algorithm to provide means of estimating whether the recipe should be adjusted if a household, for example, consistently wastes food from the proposed recipes.

Waste agent

The *waste agent* is responsible for tracking relative quantities of food waste provided by the interaction of a user disposing food. The *waste agent* therefore is provided with a *food resource identifier* and a relative indication. From this input, the *waste agent* can estimate weight and other valuable information of the disposed food. The output of the *waste agent* can be reused by the *recipe agent*.

IFCMS mobile software agent and components

As discussed in the hardware section, we do not aim for a particular mobile platform, but provide guidelines for mobile software developers. Therefore the mobile device API will differ on each platform. In IFCMS, the mobile device provides all sensing and interactions between the user and the system. The *mobile agent* describes the mobile application which is running on the mobile OS. An important design aspect to consider for the *mobile agent* is that the NFC-sensor, tactile actuator and speaker provide near real-time processing of information and activation. Moreover, for these modalities, lag is considered harmful for user experience.

The *mobile agent* communicates via the web server with all other agents. Input provided by the *mobile agent* to other agents generally is the *food resource identifier* and the desired action to perform on one of the agents.

[11] http://www.youtube.com/results?search_query=how+to+prepare+a+pumpkin

The implementation of the shopping cart and shopping list (not present in Figure 10) should be done in the *mobile agent*. We argue that keeping track of the shopping cart in IFCMS' server would, for now, prove no additional value. However, the shopping list can be considered an interesting extension of the IFCMS' server.

Discussion

Cost, effort and conflicting agendas

To achieve all stated goals of IFCMS, we argued that, to some extend, all food should have an NFC-tag attached for identification purposes. But, who will pay for this tag on the food? Ultimately, we believe, the consumer will pay for these kinds of new technologies. Although this seems not very promising, we argue that the result of a higher product price due to the NFC-tag in combination with IFCMS eventually will pay off. However, we should consider (how much) do food producers, food processors and food retailers care about consumers who efficiently and effectively buy and prepare their food? These companies care about their revenues, which makes a consumer who wastes more, and thus buys more, a better supporter to their money-making cause.

Food producers and processors who distribute their products to food retailers have to attach the NFC-tags. But, these companies also have to put an effort develop systems which can publish the food information to the web.

Accuracy of food waste captured by the system

One of our goals for designing IFCMS was to keep the additional hardware components at a bare minimum to keep costs down. We believe we succeeded by only adding the necessary NFC-tags next to all existing hardware. However, since IFCMS does not include other ways of sensing food, other then sensing its relevant information, an issue arises that IFCMS is only able to capture an estimate of the food used and wasted. With the presented design these estimates are based on the input of the user and on the household software inventory agent and therefore lacks accuracy. Especially the first poses an issue, since users pro-actively have to interact with IFCMS to provide this feedback. However, we do believe that concerned households who use IFCMS will elaborate pro-actively and more accurate on their used and wasted food.

To partly resolve this, we focused the design more towards prevention of food waste instead of accurately keeping track of the food wasted. To completely overcome the above presented issue, IFCMS needs more sensors. For instance, intelligent packaging which can provide information (ie. temperature, weight, humidity) of the current content of the package. The consideration not to elaborate this in the design is that intelligent packages increase cost significantly.

Robustness of the use of NFC-tags attached to food

Since IFCMS relies on the NFC-tags attached to food products, we have to consider that tags can get detached as well. For instance, during the preparation of a product, the tag can come off, but the product is only used half and the user would like to put it back into the system. Does the user have to put the tag back on the product, and more importantly, what happens if she does not? The first question poses an issue if answered with yes, because it means an extra physical interaction is needed to restore the system. No, again poses an issue because IFCMS assumes a NFC-tag is attached to the product, else it cannot identify the product. The latter question poses the same previously mentioned issue. To resolve this robustness issue, other modalities should be considered. Vision for instance; image processing can help identity the type of food, and therefore can fall back to a default *food resource identifier*. However, we argue that this is not an optimal solution.

Healthy usability

Not only does the size of the human thumb pose a problem in designing usable mobile interactions. During the design of the system we noticed that mobile interaction during a user cooking a recipe and following preparation instructions can pose a serious issue. While preparing dinner, the hands of humans get exposed to all kinds of by-products of the food. For instance, consider a user preparing raw chicken with her bare hands and thereafter, without washing her hands, interacts with the mobile device again. First, the touch display of the device gets dirty with grease and water, making the conductance of the thumb different and therefore results in strange touch interaction behavior. Finally, raw chicken poses a great risk to human health, especially when grease and other fluids aren't cleaned up afterwards. In the current design we have not resolved this issue, but we regard this as a serious issue.

Ethical issues and privacy

Probably the most important aspects to consider are ethical issues, privacy and trust, because these have greatest impact on humans general feeling of well-being (feeling secure, respected, valued). All technology poses a shift in our ethical belief system, because the technology itself holds and exposes certain values to us.

An interesting question related to IFCMS and ethical issues is; to what extend will we go to try and minimize waste? Is attaching edible tags to food and putting sensors just before our stomachs to measure very accurately what food is actually used ethically right? Technology-wise the latter is possible today. It proposes a radical alteration to the human body and is therefore widely considered ethically wrong. For IFCMS, the use of NFC-tags attached to food could be considered radical too. However, we argue that current widely accepted technologies such as bar code scanners present similar possibilities. The important security feature of NFC is that communication between a mobile device and NFC-tag can only be established at very small ranges; *touching* range.

Although, nowadays, we cannot seem to live separately from technology, new technologies which track us or objects closely related to us, are highly likely to be considered to have a negative impact on our privacy. Questions which arise are what will happen to the data related to households and its users? Is the data safe at the cloud service reseller? We can't elaborate on a clear solution for this, but we regard this as important security related aspect of the system.

Conclusion and future work

In this report we have proposed a mobile system which promotes effective and efficient household food consumption to its users by addressing reasons for avoidable food waste. By using the system, consumers can save money, possibly time, minimize environmental pollution and gain knowledge regarding the food they eat. Moreover, the most important outcome is that consumers become more aware of their behavior regarding their food consumption habits. Although these habits differ per individual, they can be addressed at core aspects related to effective and efficient food consumption, namely knowing what food (not) to buy, knowing what food is already available to you, and knowing how to prepare food effectively. We tried to incorporate these values into the mobile system by using context-awareness and mobile-interaction.

For the future of this mobile system we envision cooperation with food producers, food processors and food retailers to create the end-to-end interaction we propose with our system. As discussed in the previous section, there are different, conflicting agendas to get there. The cooperation we aim for is the creation of standards with regards to publishing information and knowledge to the web about food products. As discussed, this preferably would be according to the Semantic Web standards. Strict laws are already in place stating what information of food should clearly be published on a package. This does not apply strictly for fresh foods. However, we argue that in the near future, digital information should also be made available next to information on a package.

We argue that for the designed interaction of the system, user studies have to be carried out to evaluate how cognitive loads are distributed across the different interactions of the system. In this user study, and important group is evaluating how elderly- and disabled humans experience the proposed mobile- and physical interactions with the system. These user studies should be based on a prototype implementation. Both locations, grocery store and at home should be considered for evaluation. Various prototypes should be created to exchange modalities with other modalities. For instance, the issue regarding dirty hands during dinner preparation and recipe instructions could be solved by providing text to speech synthesis and speech recognition. This changes the interaction drastically but may improve the experience for that particular activity.

We find that technology can provide humankind means to change his environment and behavior for the better. An important step to move towards the actual implementation and effective use of IFCMS, or a similar system, is putting in place standards which, by law, or rationale, provide means to digitally share information related to food.

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