What Is There For Supper? Remote Access to the Stock of Food in a Smart Kitchen

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***Abstract*—This article shows the first steps of a new remote access technology for a smart kitchen. With a mobile device and this technology the user will be able to remotely check the foodstock at home by using a smartphone application. Therefore, we firstly integrated a scale application and Radio–Frequency Identification (RFID) to measure the fill level of food boxes in the kitchen. This information is processed and stored by a specific component of an information system called *FillLevelCheck*, which is part of a smart kitchen project. By setting up a connected web server this information will be available online and can be requested by mobile web applications. This article describes the functionality of the information system component FillLevelCheck and the used hardware. In a next step, we will continue setting up the web frontend and the mobile application for remotely accessing the information. Altogether, this article presents a solution to measure fill levels of food boxes, which is more comfortable than other applications and acceptable for users.**

***Keywords*-Smart Kitchen; Information System; Remote Access;**

I. Introduction

The idea of the remote food access system is part of a smart kitchen project (UARKit- Ubiquitous Augmented Reality kitchen [7]). There a lot of different tasks occur, e.g., cooking a meal. These tasks are supported by tracking the user and showing him projected hints where an ingredient is located in the room and what to do with it. Beside the research concerning correct Augmented Reality projections for cooking steps, we set up a system component called *FillLevelCheck*. It collects information about fill levels in the meaning of storing the remaining amount of food (types) in the kitchen. For this task, we concentrate on the left amount of food not on the usability of the food like their durability or smell.

For UARKit, this information also enables different technical functions like projecting the amount of the next ingredient which has to be thrown into the cake dough (projection of coloured shapes on the butter for the amount of butter which has to be taken). Another use case is the presentation of suggested recipes which are possible for the current stock of food as a list.

The FillLevelCheck consists of two parts. The first part will be explained in this paper and concerns the hardware solution behind the measurement of the food (box) fill level. The second part is currently work in progress and only will be described as a draft.

For the target applications, e.g., recipe or buying list provisioning the measurement unit of every ingredient type will be its weight. The identification of the weighted objects is done by using RFID. This technology is of growing interest especially in the (food) producing and packaging industry. Beside the common barcode identification RFID has the chance to become a resistant method of identifying disposable articles such as food packages.

The following section gives insight into the measurement of physical contents of boxes. Section 3 describes the (proposed) functionality of the current system and its aim. At the end, a summary and a discussion will involve the comparison between the used and alternative technologies.

II. Measuring and Accessing Fill Levels

A lot of research has been done due to the topic of measuring fill levels especially in physically measuring the contents of tanks filled with liquids or granular material. Various patents for devices and methods exist. Current approaches use ultrasonic or electromechanical technologies for sensors which measure fill levels of liquids, such as water [1][2][8]. Here, a measuring device is connected to each tank that has to be monitored. These devices still are very big and expensive and cannot be used for the UARKit application of measuring disposable articles with the FillLevelCheck component. Additionally, the information about the content measured in various possible physical units is not necessary for this application. Because of the non existing restrictions for food box sizes, the data about fill levels expressed as a percentage can not be used for recipe provisioning.

However, with this work, we want to set up a measuring method which is based on the weight of the food. This statement is necessary for a system which is able to handle different food boxes with liquid or non-liquid contents at the same time. Weight, therefore, is the lowest common denominator for the entities gram, litre, and pieces. Furthermore, weight can be measured in a very simple way which is only barely susceptible to measurement errors. Additionally, the sensor technology should be inexpensive and must have an interface to integrate it in the smart kitchen hardware and software. This means that an ultrasonic sensor can not be attached to each food box the kitchen contains. The measurement has to be integrated in the furniture of the kitchen.

Different technologies are suitable to additionally identify objects. Possible are, e.g., barcodes combined with optical identification technologies. We cannot use this because a lot of food packing do have this code on the bottom or in an area where occlusions inhibit the optical identification. Another problem is the missing technical expandability. Barcode reader can only recognize one code per measurement. This means if the user has more than one object to put it on the shelf (typically two) he has to hold each in front of the reader one after another, whereas RFID reader can read up to 30 objects per second (measurement loop). Furthermore, RFID is not influenced by optical occlusions. But, because of the current little availability of RFID tags on food packing, for this project, we use boxes with RFID tags. The food has to be put in these boxes before they can be identified. The boxes, therefore, have to be initialized as connected to a specific food content like flour at the moment the system is launched.

Another similar project already uses weight sensors and RFID [4]. They identify food ingredients and collect them to facilitate the choice of food or recipes for healthy cooking. Therefore, a similar sensor and identification platform is installed. But, in this project no remote access is possible or planned. In addition the user has to collect the food boxes he wants to take for his meal and must place them together on a so called counter. Our project wants to integrate weight sensors and identification in every furniture, to realize a hidden information system for all the food which is there. It should reduce the need of unusual user behaviour as much as possible. It also will help organizing the stock of food for a lot of different applications around this system.

Remote Access to smart home information (systems) is a well–defined research field and today also a huge market for consumer applications. Computer-based services at home can be monitored and controlled interactively from anywhere in the world via the Internet. This incorporates safety checks when the user is away as well as entertainment controlling from one room which has influence on every display or stereo in the whole house [3], [5].

Accessing the information about the left amount of food at home only involves another type of information and another relating database structure. We, therefore, will concentrate on using technologies which are highly flexible and fast, easy to develop and integrate, and with which we can setup a high data privacy level. This is of great importance because of the very private (and attractive) user data about what a user buys and eats.

III. Preliminary Survey

The usage of an additional information system for checking fill levels in a kitchen is connected to specific user behaviour. This is reduced to one step. Right after the food has been bought it should be put into a RFID box which is prepared for one food type. Figure 1 shows examples for these boxes and the intended content.

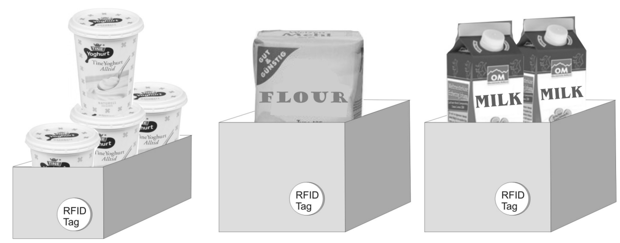

Figure 1. Examples for RFID tagged boxes and food content.

Because of the need for this unusual kitchen behaviour we did a preliminary online survey. We, therefore, asked 50 people (27 male, 23 female, average age of 30.58 years, standard deviation 6.6) online. The question was whether people would sort their food into these boxes to have an information system as described above. The online survey offered a short description of the proposed system and possible applications like the mobile usage of buying lists for specific recipes or the provision of recipes which are possible with the current stock of food. The description was closed with the picture seen in Figure 1.

The question whether the unusual behaviour is acceptable to have the system followed the picture. The answer possibilities were presented with a 5-level Likert scale in german analogue to the english scale with the options from ”strongly agree” (for analytic reasons connected to the number 5) to ”strongly disagree”(number 1) and the mid option ”neutral”(3).

Descriptive statistics. 50 participants answered the question. 5 of them had no preference and clicked ”neutral”. 8 % chose ”strongly agree”, 46 % decided for ”agree”, 32 % for ”disagree”, and 4% for ”strongly disagree”. The arithmetic mean is 3.22 (st. dev. 1.11) which shows the tendency to accept this task.

We did not ask for reasons for this decision because of its complexitiy. We already made this experience while making surveys for developping other smart home applications. The reasons in this case must be found out in further studies.

IV. The FillLevelCheck Component

A. FillLevelCheck System Setup

The system component for measuring and storing fill levels of food boxes consists of different hard- and software parts. The system setup is shown in Fig. 2.

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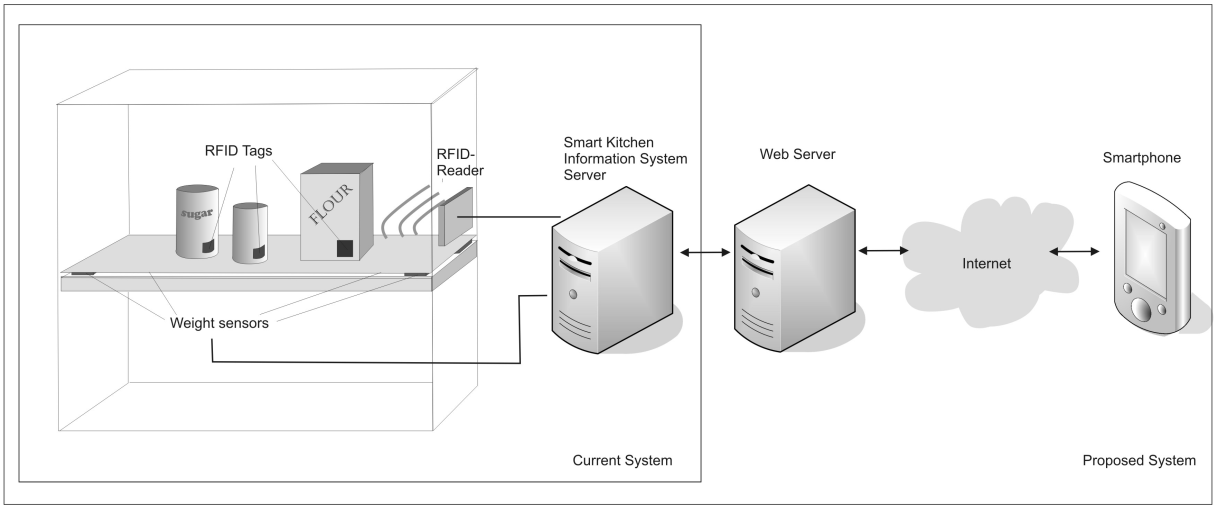

Figure 2. System setup

For the object identification, we use RFID-Reader and tags which are fixated on each food box. Therefore, we applied passive transponder at the frequency of 125 kHz with inductive power supply. This ensures a maximum reading distance of up to 30 cm. The advantage of these tags, compared to usual tags using the frequency at 13,56 MHz, is, that the range of the reader is large enough to identify the boxes while being small enough not to read the information from other shelfs (no reader overlap). This reduces data collisions if more than one reader is installed in one shelf. Additionally difficult climate conditions can be handled with these tags like a high humidity because they have a robust design (plastic jacket). Furthermore, if only small numbers of tags should be red by one reader but a lot of those reader have to be installed the costs for the expensive tags at 125 kHz but cheaper reader pay off for the kitchen application.

For the measurement of weight sensors are attached under an additionally installed shelf base above the normal base (see Fig. 2). For a later installation of such a system this is an easy way of incorporating sensors and cables.

Both of these hardware parts are connected to the information system server which is implemented using Java. It handles a lot of components like optical user tracking and information presentations which are adapted to the used display (different types are used in the kitchen) and the shown information (navigational hints to a searched object or presentation of recipe step).

Measuring and storing the fill levels is solved within two steps for later accessing the whole stock of food in the kitchen.

The first step is the identification of all objects which are available on one shelf. Therefore, every object has to be recognized by the RFID reader. This happens automatically if the object tag gets into the reading distance of the RFID reader. But, every object has to pass the reader actively (the user has to hold the object in this way once) if the dimensions of the shelf allow greater distances than 30 cm between objects and RFID reader. The information about all currently available object IDs (up to 30 object IDs per second) is used for the data integration of object identifier and current weight difference.

The second step involves a weight measuring loop which provides the weight of the whole shelf base for the information system and for the database. This means that if one object is taken away or put into the shelf the difference between the past weight and the current weight are compared. If the box (and the content) is taken away (difference in ID list from step 1) the database holds the old weight value for this ID. The appropriate value 'weight' will be updated if the same object (ID) is recognized again and the weighting loop result shows the difference. If the object is new, a new entry is generated with the current weight difference. The measurements provided by the weight sensors are currently requested every 200 milliseconds (adaptable).

Afterwards, the database contains the frequently updated information about which food boxes are there and which weight they have. This database will be requested by the remote access system. This will enable the information provosioning of at least possible meals by knowing the amount of ingredients which are necessary for suggested meals (from a stored list) and which are available in the kitchen. Also a buying list can be created for a proposed recipe or a weekly purchase.

B. *FillLevelCheck Functionality and Open Issues*

The measurement of shelf base weights and the identification of objects are designed fit together. More precisely, a cause of measurement and database failure can only be generated by these two components and a measurement time overlap of the two parts.

Figure 3. Three screenshots of an exemplary fill level measurement by using a scale and RFID (stucked on the shelf)

Despite the investigations of an optimal loop duration for the weight measurement it is still possible that a user is able to put more than one object on the shelf within 200 ms. In this case typically two objects are put on the shelf because the user has one object in each hand. This results in the described unclear assignment of the weight differences for both food boxes in the database.

The system, therefore, can only handle one object per 200 ms. From our experience a user is not able to place two objects in that way that the measurement identifies both objects and measures the different weight for both so that it is unclear which weight belongs to each of the boxes. Nevertheless, if two objects or more are put back into the shelf the calculation can not assign the taken contents to the database entries and throws an exception.

One obvious solution could be the shorter loop duration to avoid the time overlapping processes of putting two (or more) objects in the shelf. But, in this case situations are still possible where the user puts objects into the shelf at the exact same time (equal up to one millisecond). The minimal possible time range of uncertainty or time overlapping relates to the computers capacities because of the implementation methods and latencies of opening serial ports for reading the values of the weight sensors. These durations have influence on the minimum loop duration. Thus, the risk of getting a database error varies between systems.

In our tests the system measurements had been correct for taking weights of the objects and identifying them for a weighting loop duration of 200 ms.

Another problem is the possible existence of different food boxes (and tags) for the same or very similar contents, e.g., sugar (normal sugar, powdered sugar, brown sugar, etc.). The tags we use are associated only with one numerical identifier. These identifiers have to be associated with a special ingredient (category) once they are new in the shelf to avoid the described problem. At this point of work, the user has to sort the object into the right box (right after he or she has bought it). Currently, there is no possibility of recognizing objects automatically because of the missing RFID tags in the food industry. If this application is established in the future this information can be stored in the tag and must not be determinded by the user anymore. Also other interactive identifying technologies like barcodes are suitable for this purpose.

With an automatic identification of the box contents the information system implementation has to be changed in that way that a category order sorts the ingredients by their contents or categorial relations. This avoids that recipe suggestions only relate to one box with sugar and misses other boxes where also sugar can be found. But it also enables automatic substitution suggestions if one specific ingredient is missing but another very similar ingredient is available, e.g., oregano is missing, but marjoram is there. However, the appropriate sorting techniques may have any degree of complexity relating to the purpose. For our proposed system the apriori assignment of the user is the knowledge base for the applications 'buying list' and 'recipe suggestion'.

The left risk of not recognizing each food box on its own and reading collisions for (two or more involved) RFID reader with more than 30cm radio distances also is an open issue. But, the usage of low frequencies for the RFID tag technology and user instructions avoid this problems nearly hundred percent. The recognition only fails if the tag (or food box) is moved by the user with too much distance to the reader. Beside the web application development we therefore will incorporate a feedback sign (visual or acustic) to give feedback about the correctness and amount of recognized food boxes.

V. Remote Access

The system component, so far, is able to manage and provide valid values for the available weight of foods in the (shelf of a) kitchen which are stored and accessed via

 ISBN: 978-1-61208-232-5

a database. No simple user interface is available yet. The planned additional component of a web server will make these data available online especially for mobile devices (see Fig. 2). The appropriate application will suggest recipes for the left food or can answer the question what to buy if the user is in the supermarket and does not know his stocks of food at home.

Therefore, a web and a mobile application will be implemented in the next step of our work. We will use the play! framework [9] to first set up the web application. This framework enables quick and easy application development on the basis of the model, view, controller–pattern. Thus, the information provided by the database can be accessed by simply calling the website via a browser and using a personal login. Therefore, we incorporate projects like play–siena–user [6].

The next step will be to develop this access via a native mobile application for smartphones. This intention is related to the trends of interactive applications where smartphone hardware is integrated in web search processes. In our case, this for example could be a recipe suggestion generation by scanning a barcode of a food box or recognizing a RFID tag in the supermarket. The customer benefit would be that if, e.g., the substitution application of the information system at home already knows that a similar product is available there he or she does not need to buy the new product.

VI. Summary and Discussion

In this article, we described the state of work concerning a new system which enables the remote access to the stock of food in a smart kitchen. Beside different other system components in the kitchen like user tracking this system measures and stores fill levels of food boxes. In the next step, we will develop a smartphone and web application with a user interface to access this information by, e.g., having a buying list for a specific recipe or suggestions for at least possible meals with the available food in the kitchen. The current system setup incorporate RFID and weighting techniques for a storage of data in a database which will be accessable via web.

The system, in general, is designed to also help people with handicaps or the elderly. Therefore the system provides simple diplayable lists for the existing stock of food. The user must not search the shelfs. The application of appropriate recipe suggestions for the left food also allows a greater variety of meals (also for specific nutrition schedules) with avoiding (vicious) eating habits. Nevertheless, the system helps to avoid unnecessary purchases and trips to the supermarket.

The open issues for such a system are the measurement loop durations for the weight sensors and the approriate identification performance to generate only valid data without unclear database assignment states. Also, the problem of needed tasks, instructions, and feedback signs in a user interface should be designed in a user friendly way.

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