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RiBOMS: RFID-Based Object Management System for Home Environments

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Abstract—**In this paper we introduce a RFID-based object management system, RiBOMS, for home environments. The system has an easy to use pictorial user interface aimed at older adults with associative memory impairments. The system technical correctness was successfully tested in a lab environment.**

I. Introduction

Population ageing in developed countries presents several challenges to society and to the scientific research community. Several studies commissioned by government institutions reveal that population ageing will continue to grow in the coming years. According to a study made by the Administration on Ageing of the US Department of Health & Human Services, in 2010 the population over 65 consisted of 13% of the total US population, while this figure is expected to rise to 20.2% in 2050 [1]. According to another study performed by the United Nations Department of Economic and Social Affairs, there were 737 million people over 60 in 2009 worldwide, equivalent to 11% of the entire world population [2]. The same study forecasts 2.008 billion people over 60 in 2050, which would represent 22% of projected worldwide population.

Several studies have been published related to memory problems in older adults, specifically associative memory impairments. In a study published in [1], the older participants demonstrated disproportionate difficulty with the recognition of associations, when they did not show problems with other memory tasks, and learnt associations slower than younger adults. Another study [2] concludes that older adults are especially deficient in memory tasks that require the merging of different aspects of an episode into a cohesive unit. The research published in [3] also concludes that the elderly have more problems than younger adults in associative memory tasks. Finally, the work described in [4] concludes that older adults learn slower than younger adults and exhibit greater short-term forgetting when a material has not been well learned.

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RiBOMS uses passive RFID technology to manage the location of every day objects. The relative location of each object is associated to a landmark in the environment (e.g. table or shelf). Using passive RFID technology, we can provide very high position accuracy of the objects at low cost.

There are two key entities in the system: the objects and the landmarks. The objects are defined as any mobile item such as glasses, keys, pillbox, etc. The landmarks are any place where the objects can be left such as table, drawer, chair, shelf, etc. The object location will be chosen from the set of landmarks. The objects and landmarks are tagged using passive RFID tags. The user carries a glove with custom electronics and a Bluetooth enabled Smartphone. When the user tries to find an object, the location of the object will be requested using the Smartphone and it replies with a picture of the landmark where the requested object is located.

The user, or an assistant, can deploy the system and update it without the need of a professional operator by using the application designed for this purpose.

RiBOMS first prototype focuses on the object finding functionality, but different applications could be created such as alarm triggering in case an object is left in a dangerous or not common place. The integration of other sensor networks can add more functionality such as activity recognitions and behavior patterns learning.

The paper is organized as follows. In the next section we introduce related work and in Section 3 we describe the system overview. Section 4 describes the smart glove and Section 5 introduces the system software. Section 6 introduces the experimental results and Section 7 concludes the paper.

II. Related Work

Very few systems have been developed to manage objects location in home environments. An active RFID based object management system is described in [5]. The system uses active RFID tags attached to targeted objects and active RFID readers (four per room) which are located on the ceiling. Using signal strength measurements the algorithm can determine an approximate distance between the reader and the object. Since such readings are noisy, the system

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also employs floor pressure sensors used to assist in the position estimation.

The system can locate the objects accurately in an absolute 3D position in the room rather than in a relative position (e.g. "on Table"). However, the system presented in [5] has following drawbacks: 1) high cost: it is expensive due to the use of active RFID technology both to tag each object and in the dense deployment of the active RFID readers in the environment. Moreover, pressure sensors are deployed on the floor, fact that increases the system cost. RiBOMS that uses passive RFID technology has significantly less cost. 2) the system requires professional skills in order to install the active readers, the pressure sensors on the floors and obtain the signal strength readings required to calibrate the algorithm. RiBOMS does not require professional installation. The authors in [5] do not describe the user interface.

III. RiBOMS OVERVIEW

RiBOMS architecture depicted in Figure 1 consists of the following system components:

Environment: it includes objects and landmarks.

Object: any mobile item whose location is likely to be requested by the user. Passive RFID tags (R-tags) are attached to each object. Proximity of 2-3 cm is required to transfer data from the R-tag into the reader. Other reasons for selecting these R-tags were their cost and the fact that they do not need any power source.

Landmark: any place where objects can be placed (object location will be chosen from the set of landmarks). R-tags are attached to each landmark.

The tagged objects and landmarks are depicted in Figure 2.

User: The user carries a glove and an Android based Smartphone.

Glove: The smart glove (Figure 3) is responsible of reading and delivering the R-tags identifiers to the Smartphone. The Smartphone which runs our application interfaces with the glove and with the user (see Figure 3). The user wears a glove on the hand used to move objects. This Glove allows the user free use of his hand as well as the ability to scan the R-tag. The user will first find the tag attached to the object and locate it on his palm to read it while it is being moved. The glove communicates to the Android based Smartphone using Bluetooth technology. After the user places the object on a landmark, he will read the R-tag placed on it. As in the object case, the glove communicates the identity of the chosen landmark to the Smartphone. More details on the glove implementation are provided in the next section.

Smartphone: We use the Android based Droid Incredible. Several built-in hardware components and applications are used to assist the development of our application. The Bluetooth module of the system is used to exchange data (R-tag unique identifiers) with the glove. We also use the built-in Text to Speech engine which is used to interact with the user (e.g. Object picked up, object left, or object location). The software developed on the Smartphone is described in Section 5. An example of user interface is given in Figure 4.

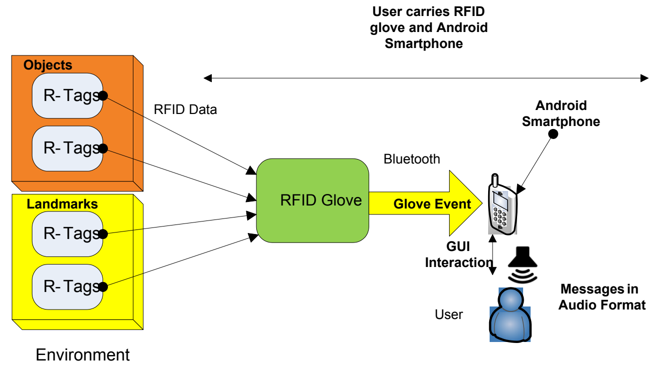

Figure 1. System Architecture

Figure 2. R-tags embedded in the environment (landmarks and objects)

Figure 3. Gloved hand holding an object (back and front)

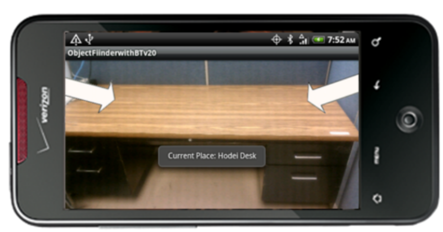

Figure 4. User interface on the Android based Smartphone

IV. SMART GLOVE

The SMART Glove (Figure 3) allows the user free use of his hand as well as the ability to scan the R-tag. The R-tag is scanned by placing the palm on top of the R-tag. The glove communicates the unique ID represented by the R-tag using Bluetooth technology to the Android Smartphone. The glove system (Figure 5) which is incorporated into a weight training glove includes an Arduino Microcontroller, RFID Module and Antenna, Bluetooth chip, a set of buttons, Rechargeable Battery, and a Power Regulator. The Arduino microcontroller is used to keep track of all the events occurring in the glove. On scanning the R-tag, the RFID module and Antenna send the R-tag data to the Arduino microcontroller. The Bluetooth chip is used to exchange data from microcontroller to the Android Smartphone.

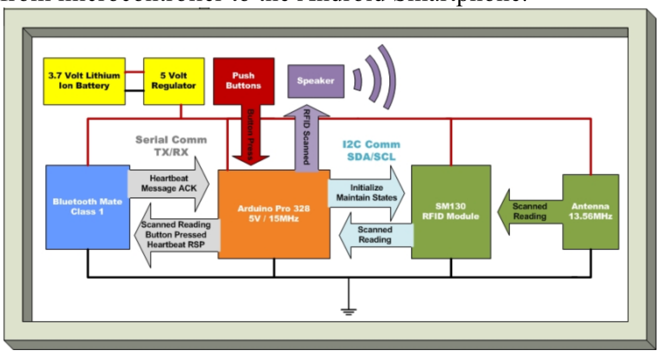

Figure 5. SMART Glove Schematics

V. RiBOMS Software

The software architecture is depicted in Figure 5. We implemented the following components in the Android Smartphone:

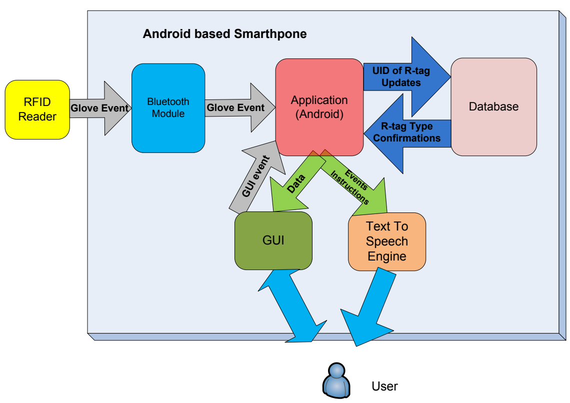

Figure 5. RiBOMS Software Architecture

1. Bluetooth Module: This module is responsible for exchanging data (e.g. R-tag scan) between the Android Smartphone and the glove.

2. Application: this application differentiates among various events i.e. R-tag Scan Events and GUI events. For R-tag Scan Event, the Unique Identifier of an R-tag is received and the application acts differently depending on the identifier and the status of the software. The GUI events are referred as pressed buttons or manual introduction of data in the GUI. The output is displayed on the screen or converted into an audio form using the Text to Speech Engine. The algorithm includes the following three states: Idle, PickedUp and Left (see Figure 6).

3. Database: The database stores the environment data. It is located on the SD Card of the phone. The database is implemented using xml files to store data. Each xml file corresponds to a table of the database. Storing the data in xml files provides to the developer the possibility of reading, analyzing and editing the values of the database using a computer. Hence, the correctness of the values on the database can be faster and easily checked during the application development. In addition, the use of the database implemented in xml files makes it easier to migrate from the Smartphone to a server for future development.

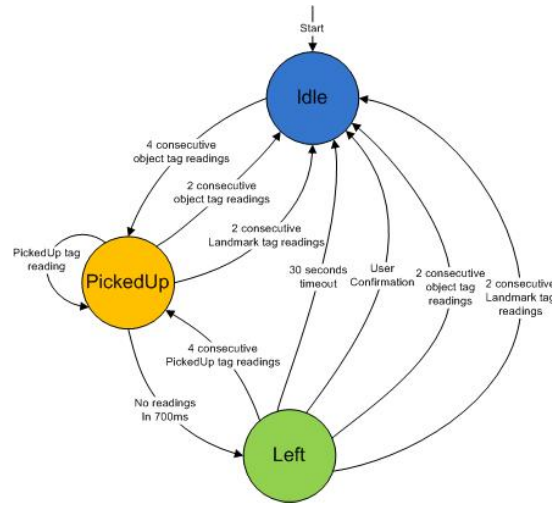

Figure 6. Event Detection Algorithm

4. Text To Speech Engine: The system interacts with the user both in graphical and audio format. The Android Smartphone provides a built in Text To Speech engine to convert the textual instructions for the user into audio format.

5. Graphic User Interface: The designed graphic user interface is simple and easy to use. It provides the user the means to introduce data, confirm some situations and interact with the system. The graphic user interface is implemented for the touch screen Droid Incredible Smartphone. Only the necessary buttons are shown and the navigation trough different screens is avoided because the user can get lost.

In addition to the components cited above, the application also uses the camera built-in application when it requires a picture of the landmarks and objects introduced in the system.

A. System Deployment Module

The system deployment module is first used in the initial deployment of the system, when the vast majority of the objects and landmarks will be introduced. This module also provides the user with the necessary means to add or delete objects and landmarks or add new tags to existing landmarks (notice that one landmark can have multiple R-tags attached while one object will have only one R-tag). One of the main advantages of the entire system depends on this module. There is no need of professional skills to deploy and maintain the system. The user or a relative can deploy the system using this application.

The main functionality of this module is to update the database after adding or deleting objects, landmarks or

R-tags.

Adding an object: The name is introduced in the home screen of the GUI writing in the box between the text "Name" and the button "Get Landmark" (Figure 7a). When the "Take Picture" button is pressed the built-in camera application is opened (Figure 7b) to take the picture, and once it is taken, the picture name appears next to the button. And, finally, when an R-tag is read the unique identifier is printed next to the text Tag to notify the event to the user. When the button "Save as Object" is pressed the data is introduced in the database and the user is notified by an audio message.

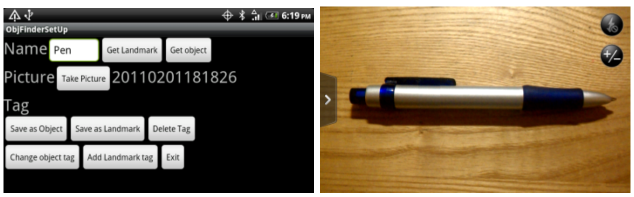

Figure 7: (left) a. Home screen of the GUI
(right) b. Built-in camera application

B. Object Location Module

This module updates the database with the location of the objects in the environment. As described above, the system requires that the user will move the objects using the hand with the glove. Once the moved object is placed in a new landmark, the user has to read the R-tag of this landmark to notify the system where the object has been placed. Even though it is slightly more complex than leaving an object without being worried about the association, we believe that the added inconvenience will not cause rejection of the system.

This module also informs the user about the location of the objects. The user interface is presented in two levels: the GUI and the audio messages. Some screenshots are shown in Figure 8. To find objects, the button "Find objects" has to be clicked (Figure 8a). Once it is clicked, a list of the introduced objects appears in the screen (Figure 8b). After an object is chosen from the list, the system shows the landmark it is associated to (Figure 8c).

When the user requests the location of an object pressing the find button the list of the introduced objects is shown. If the object is not associated to any landmark, the application shows a screen with the last landmark it was associated to and the user can request also the most common places as in the previous case.

VI. Evaluation

The testing of the RiBOMS prototype focused on the technical correctness of the system which we define as the percentage of times that the user finds the object with the information provided by the system. It was tested in the lab environment and two members of the lab staff were the users. The users received explanation of how to use the system.

We tested the system in different scenarios varying a number of parameters:

Objects' size: we tested the system with small (i.e., a pen) medium (i.e., a cup) and large objects (i.e., 50 CD box).

Landmarks visibility: we tested the system with very visible landmarks – Category A (i.e., desks and shelves at eye level), less visible landmarks – Category B (i.e., high or low shelves) and not visible landmarks – Category C (i.e., drawers or cabinets).

Combining the different size objects and landmark visibility we have 9 types of experiments. For each type of experiment we performed 8 trials. In all 72 trials all the objects were found.

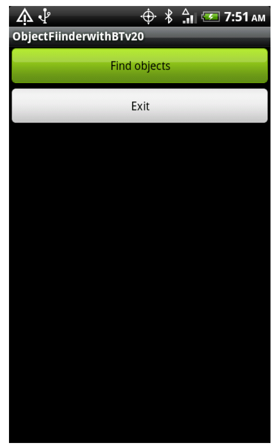

Figure 8a: GUI

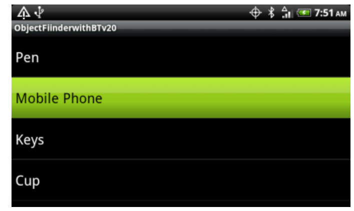

Figure 8b: List of objects

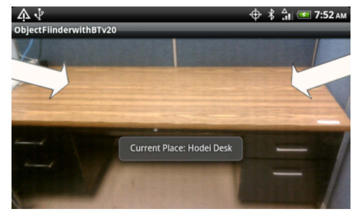

Figure 8c: Object Location

VII. Conclusions

In this paper we presented RiBOMS, a RFID-based object management system for home environments aimed at adults with associative memory decline. This is the first low cost user friendly object management system for home environments which has a pictorial user interface that displays the location of the object in the environment. The system was successfully tested for technical correctness in a lab environment. Our next step is to deploy the system in homes and test it with adults with associative memory decline.

References

[1] C. Bastin, M. Van der Linden, "The Effects of Aging on the Recognition of Different Types of Associations", Experimental Aging Research, 2005, 32:1, 61-77

[2] M. Naveh-Benjamin, J. Guez; "The associative memory deficit of older adults. Further Support using face-name associations", Psychology and Aging,2004, Vol. 19, No. 3, 541–546

[3] D. Alan, F. Castel, I.M. Craik; "The effects of aging and divided attention on memory for item and associative information", Psychology and Aging, 2003, Vol. 18, No. 4, 873–885

[4] J.E.Fisk, P. B.Warr, "Associative learning and short term forgetting as a function of age, perceptual speed and central executive functioning" Journal of Gerontology: Psychological Sciences, 1998, Vol. 53B, No. 2, PI I2-P121

[5] T. Mori, C. Siridanupath, H. Noguchi, T. Sato, "Active RFID-Based Object Management System in Sensor-Embedded Environment", Future Generation Communication and Networking 2007, 25-30.