Indoor Navigation and Product Recognition for Blind People Assisted Shopping

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Abstract. Achieving blind people autonomous shopping in a supermarket is a real challenge. Without help from another person is very hard or impossible for them to reach to a specific supermarket section and browse through its products. Besides, once there, they cannot identify the products and their features (e.g. price, brand and due date) to decide whether they want to buy them or not. This work presents BlindShopping, an RFID and QR-code based mobile solution to enable accessible shopping for blind people, only demanding inexpensive off-the-shelf technology and limiting the deployment effort from the supermarket.

Keywords: Blind, Navigation, Mobile Computing, QR codes, Web-Services.

1 Introduction

Although technology seems to be invading every aspect of our lives, it is still having limited impact on those social collectives which most need it, i.e. dependable people due to sensorial impairments or advanced age. Ambient Assisted Living (AAL) aims to address this gap by using ICT technology to enhance the daily activities of dependable people, e.g. blind or deaf people.

The PIRAmIDE project[1] aims to approach the AAL vision by exploiting smartphones' potential –mobile phones equipped with continuously increasing computing, communication and sensing capabilities– as sensorial complements for disabled users'. It enables the smartphone-mediated interaction of a user with the ecosystem of services populating an environment (e.g. home or supermarket). Thus, it allows disabled people to perform daily life tasks autonomously and independently of their disability (e.g. blind, deaf or elderly people). In essence, through PIRAmIDE, mobile devices are transformed into sense enhancers giving a 6th sense to those who already enjoy their five functional senses, but more importantly, complementing those which have some sensorial impairment.

One of the concrete application domains targeted by PIRAmIDE is overcoming the difficulties blind people usually encounter whilst they are shopping autonomously, as if they could see, without the help of someone else. The focus of this work is to describe an inexpensive easily-deployable solution addressing this issue, entirely based on off-the-shelf technology (mainly smartphones).

Comparative studies [3] on research for blind people assisted shopping support consider that an ideal assistive infrastructure should address the following functional and non-functional design requirements:

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- *Eyes-free product selection and browsing*. The capability of allowing blind people to easily select or browse through the available range of products, just before she initiates her purchasing process. The idea is to give blind people the chance to easily plan their shopping by knowing and selecting what products are on offer.
- *Free navigating within the store.* Once a blind person has prepared a shopping list (*planned shopping*) or rather prefers to go to different supermarket sections to browse and choose products (*opportunistic shopping*), the blind person must be offered support to navigate through the supermarket and reach to the wished section.
- *Product search and navigation*. Once the user is in the area where a product category is located, the blind person must be able of locating the concrete products types of her interest, and select the actual units she wants to purchase.
- *Utilization of existing devices*. A blind person carries with her a white cane and a mobile phone. Therefore, if any, those are the elements that may be modified or enhanced in order to allow a blind person to safely and effectively carry out her shopping. Only inexpensive off-the-shelf already known technology by the blind should be considered to ensure acceptability.
- *Minimal environment adjustments*. Supermarkets are reluctant to introduce complex changes in their internal information management systems. Furthermore, only simple low-cost easily maintainable physical instrumentation of their premises including aisles and shelves is acceptable. Any feasible solution should leave products as they are, i.e. it must be able of recognizing and deal with standard UPC barcodes utilized in worldwide retail. Hence, it is a must that accessible shopping systems operate in real supermarkets with all their restrictions.

Our proposal, namely BlindShopping, addresses the above mentioned requirements to provide an inexpensive and feasible solution in order to ensure wide deployment from blind people and supermarket organisations. A remarkable feature of our solution is that blind people will follow the conventional shopping behaviour somebody without visual problems follows.

2 Related Work

Robocart [4], developed by Utah State University, gave place to a robotic supermarket assistant, in the form of a custom-built market cart equipped with a laptop, a laser range finder, and an RFID reader. For navigation, it uses the RFID reader attached to the cart and passive RFID tags scattered at different points in a supermarket. Furthermore, a wireless barcode scanner is used for product search and identification. The biggest drawback of this system, in contrast with BlindShopping, is its use of additional non-conventional costly and complex to manage devices.

The same research group developed ShopTalk [5], an alternative more wearable solution. In this case, it requires that the user carries a barcode scanner and a Ultra-Mobile Personal Computer (UMPC) in a backpack. A barcode scanner aided with two plastic stabilisers to enhance usability is used to read MSI barcodes placed in product shelves. Verbal route instructions were issued through a headphone connected to the UMPC at the blind person's backpack. Although the supermarket does not need to install and maintain any hardware, the system requires access to the supermarket's inventory control system. In contrast, BlindShopping only requires blind users to carry a lightweight smartphone equipped with a camera to read QR [2] codes attached to product shelves and to navigate through the supermarket with the aid of a white cane augmented with an RFID reader at its tip.

Another interesting assisted shopping solution is GroZi[6], which focuses on using computer vision software for detecting products. Visually-impaired people use a hand glove with a small camera and vibrating motors that provide haptic feedback. A small wearable device carries out image processing and generates haptic feedback in the two dimensional plane of the shelf for product localization and verbal feedback for identified product description. Again, BlindShopping is more easily deployable, economically and technically, since it uses a "common" device such as a smartphone and the standard white cane used for guidance.

Tinetra[7] presented at Carnegie Mellon University, offers the possibility of detecting products via a barcode or RFID reader, and then it obtains related information via GPRS from the server. However, it does not include a guiding system as BlindShopping. Interestingly, the system advocates, as in BlindShopping case, a mobile platform for accessible blind shopping. It handles both barcodes and RFID tags. Similarly to us they use a Baracode Pencil2 and a Baracoda IDBlue to scan barcodes and RFID tags, respectively.

Fig. 1. Navigation system (left), UPC code recognition (middle) and QR-code recognition

iCare[8] relies on an RFID[9] reader embedded in a hand glove to detect products and query information from a server via Wi-Fi. The user has to move her hand along the shelf, so the system gives indications such as "passing dairy section". This system seems more intrusive than ours, where the user still uses her white cane, enhanced with an RFID reader. The usage of RFID is very promising, but it presents problems from the technical and industrial side. Tags attached to liquid low-end products with metal cases refract and reflect RF waves. Manufacturing costs for tags and readers remain prohibitive for tagging all but high-value products. Technical problems, environmental hazards and consumer perceptions of trust, privacy and risk, mixed with fear remain significant acceptance barriers to RFID item-level tagging.

3 The BlindShopping Platform

Our solution aims to offer eyes-free technological support for blind people to shop around as if they saw, without altering conventional shopping patterns. It is designed to avoid overloading the visually-impaired person with additional new gadgets and enforcing a supermarket to go through heavy and costly, both in price and time, installation and maintenance processes.

Fig. 2. User drawing a "P" (left) on Motorola Milestone, Nokia 6131 NFC to read HF RFID tag for navigation and supermarket mock-up for testing (right)

The assumptions taken by BlindShopping regarding a supermarket organization are as follows. First, it is considered that all products are grouped into different product categories (e.g. drinks), and these are divided into product types (e.g. drinks/cola) which again are divided into concrete brand products (e.g. Pepsi can). Apart from that, the supermarket area is divided into cells of two main types: cells containing a shelf and passageway cells. Thus, internally, BlindShopping maps the IDs of the RFID tags within a cell to navigation and product location information such as the type of a given cell, its neighbour cell types, and in case of being shelf type cells, the product category, types and concrete products located in that area.

BlindShopping offers infrastructural support for the whole purchasing process within a supermarket, which we understand as a four-step cyclic process: *1—product category navigation/2—product search/3—product identification/4—product selection*. Such cycle stops when the user decides to go to the cash till to pay for her purchases. Consequently, BlindShopping offers a *navigation* component driving the user through voice messages to the aisle where a product category previously dictated to her smartphone is located. Once there, BlindShopping also offers support for *product recognition* by either shelf section identification or product own identification by means of embossed QR and UPC scanning, respectively. Note that QR codes redundant encoding allows for efficient recognition even when a blind person slowly passes her mobile camera over the embossment where the code is.

Besides, BlindShopping does not only offer a working technical solution for assisted shopping, but it provides an affordable, usable and easily-manageable solution for blind people. *Affordable* since the cost of the platform deployment is relatively reduced. The supermarket must install a server and a wireless network (Wi-Fi) in the shopping area. In addition to this, RFID tags must be distributed throughout the floor (see left hand side of Fig. 1). On the other hand, the visually impaired customer must carry a smartphone, a very common device nowadays. The most significant investment would be the acquisition of RFID readers attachable to blind people's white canes bought by the supermarket and lent to its clients.

Usable since the application is adapted in a way that blind people can make an independent use of it. It includes a gesture and voice-based interface, which allows selecting among the different functionalities by drawing strokes on the smartphone screen with a finger or issuing voice commands (see Fig. 2). The rest of the interaction is done through speech synthesis and recognition. The blind user says the supermarket section where she wants to go, and the system uses speech synthesis to give routing indications or product information. Once the user is located in front of product type section (e.g. daily product/milk), she can locate specific products by pointing her phone camera in the direction where an easily recognizable embossed 2-D code (e.g. Carrefour's semi-skimmed milk) has been stuck on a shelf. Those codes are stuck on the typical plastic tags including name and price for each product distributed through the shelves of a supermarket.

Easily-manageable since the BlindShopping navigation and product type management web-based client (see Fig. 3) offers an intuitive interface to configure the RFID-tag based navigation system and the QR codes assigned to product types attached in front of the shelf portion where those products are located.

Fig. 3. BlindShopping Management Tool

4 BlindShopping Architecture

Fig. 4 shows the distributed component architecture of our solution, composed of the following three components:

1. *Navigation system*. It is in charge of guiding the blind user inside the supermarket, by giving her, through a headphone connected to her smartphone, simple verbal navigation instructions. Such component combines a white cane with a portable RFID reader attached to its tip, a set of road mark-like RFID tag lines distributed throughout the corridors of the supermarket (see left hand side of Fig. 1 and top part of Fig. 5, respectively) and a smartphone application

processing the RFID readings received though Bluetooth and generating user navigation verbal commands as result.

2. *Product recognition*. Once the user reaches the target product section, she fetches some of the products there, see Fig. 1, or better points with her camera phone to an embossed QR or UPC code attached to every section of a shelf where a different type of product has been placed. The smartphone camera recognizes that code and then informs verbally about the product main features. Note that a QR code can encode up-to 4296 alphanumeric characters, and its redundancy makes successful reading possible even when partial images of them are captured. Details about the recognized products may be encoded in the codes themselves or retrieved from the back-end.
3. *System management*: BlindShopping includes a web front-end for BlindShopping RFID and QR code infrastructure management. It allows the registration of the collection of RFID tags scattered though the supermarket floor and the QR-codes attached to shelf sections. For that, it offers a RIA (Rich Internet Application) interface which is very usable from any web browser without requiring specific technical knowledge (see Fig. 3 for more details).

4.1 Implementation and Usability Issues

A Nokia 6131 NFC has been used for reading RFID tag floor markings. A Java ME application has been developed which continuously reads RFID tags and sends their codes through Bluetooth to a mobile Android application (see Fig. 4). An easier, lighter, cheaper and more robust solution can be achieved by attaching a portable RFID reader such as a Baracoda Tagrunner[1] to the tip of the white cane. In fact, we have already created a version of the system which operates with Baracoda's ID Blue device (see centre of Fig. 5) – a more old-fashioned device with the important drawback of demanding a button press every time an RFID tag wants to be read.

The selected Android devices for our tests were a Motorola Milestone with Android 2.1 OS and an HTC Desire device with Android 2.2. With them, a blind person chooses an action by means of a gesture or by issuing a voice command. Concretely, the navigation system operation is requested by drawing an "L" or issuing the "Location" voice command (see Fig. 2). This launches the supermarket navigation system, which initially asks the user to touch a floor RFID marking or the QR code attached to a nearby product shelf to figure out where the user currently is. Next, the application requests the user to dictate the product category or type where she wants to go. Note that the smartphone maintains a Bluetooth connection with the RFID reader to keep track of where the user is at every time. As the visually impaired walks on, the android application will give verbal navigation indications ("go straight on", "turn left", "turn around" and so forth) until the target section is reached. Observe that whenever the blind person follows a wrong route, the system automatically detects it since the blind person keeps touching the floor RFID markers as she moves. Both product information and the route to be followed are obtained from the server by invoking web services accessible through a Wi-Fi connection.

Drawing a "P" or issuing a "Product" voice command, the user accesses the product recognition component that allows obtaining information about a product.

[1] http://www.baracoda.com/baracoda/product/p_48_TagRunners.html

The system then asks the user to point the smartphone to the shelves, so that the camera will recognize an easily detected by the blind person embossed QR or embossed UPC code (see middle and right hand side of Fig. 1) and obtain either the product details directly or the ID of the product from which its details can be retrieved from the BlindShopping back-end. By using speech synthesis, the application informs the user about the product details, e.g. its name, manufacturer and price.

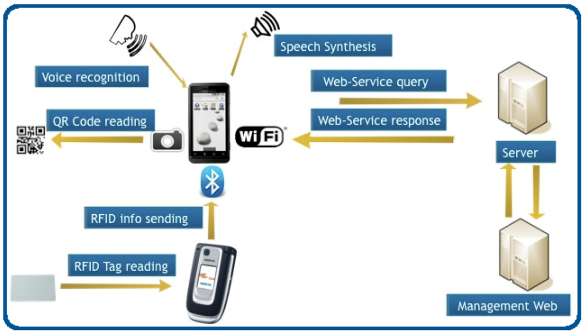

Fig. 4. BlindShopping Distributed Architecture

Fig. 5. RFID tag marking (top), Motorola Milestone and HTC Desire Android devices (left), Baracoda's Pencil2 barcode recognizer and IDBlue RFID reader (middle), NFC 6131 NFC device (right) and QR-Code and standard UPC barcode (bottom centre)

5 Usability Study

A basic usability study with a blind person was conducted in order to validate the usability and accessibility features of our navigation and product identification subsystems. The blind person was requested to navigate through different sections of our emulated supermarket surface by using her white cane with an attached BT RFID reader and an Android application on an HTC Desire (see Fig. 1, left hand side). Her main comment was that navigation was very intuitive since locating the RFID tag markings was very easy due to their different texture and small relief, and the navigation vocal commands were very useful to reach the desired target.

The blind person was requested to assess whether locating embossed UPC barcodes through a Baracoda Pencil2 (see centre of Fig. 1) was easier or harder than using the Android phone camera to point to embossed QR codes (see right hand side of Fig. 1). After 10 product recognitions with each alternative, she judged that the second approach was much simpler. Besides, QR code recognition using a camera phone was found to be much faster and reliable. The redundant encoding of information on embossed (easily found by touch) QR-codes allows their identification even when only a partial image of them is captured.

6 Conclusions and Further Work

This work has shown a low-cost easily deployable solution for blind people assisted shopping constituted of two main components: a) an RFID and mobile phone based indoor *navigation system* and b) a mobile QR-code based *product recognizer*. It is important to note that although the chosen scenario was a supermarket, the platform can be easily adapted to any other self-service shopping scenario.

Further work will expand the BlindShopping Android mobile application with GPS reading capabilities, so as to guide the user from her home to the supermarket. Although the RFID reader has been implemented with a Nokia NFC as a proof of concept, it will soon be replaced by a dedicated Bluetooth RFID reader. A fully fledge evaluation in a real supermarket carried out by a statistically significant group of blind people will also be carried out to thoroughly assess the suitability of the proposed solution.

The prototyped solution can be seen online at Youtube[8]. This work has been supported by project grant TSI-020301-2008-2 (PIRAmIDE), funded by the Spanish Ministry of Industry, Tourism and Commerce. We want to thank Mercedes Mata for evaluating the system.

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