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Location based services for the blind supported by RFID technology

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Abstract

Nowadays, navigation systems are widely used to find the correct path, or the quickest, between two places. These systems use the *Global Positioning System* (GPS) and only work well in outdoor environment since GPS signals cannot easily penetrate and/or are greatly degraded inside of buildings. Several technologies have been proposed to make navigation inside of buildings possible. One such technology is Radio-Frequency Identification (RFID). In the case of outside environments, some hybrid systems have been proposed that use GPS as main information source and RFID for corrections and location error minimization. In this article we propose a navigation system that uses RFID as the main technology to guide people with visual impairment in unfamiliar environments, both indoor and outdoor, complementing the traditional white cane and providing information about the user's geographical context.

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Keywords: RFID, location-based, services, blind, navigation.

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1. Introduction

While assistive technology has contributed to the improvement of the quality of life of people with disabilities, with major advances in recent years, people with visual impairment still face enormous limitations in terms of their mobility. The task of moving from one place to another is a difficult challenge that involves obstacle avoidance, staying on street walks, finding doors, knowing the current location and keeping on track through the desired path, until the destination is reached. Most navigation systems are designed to be used by users without any major disability and are based on information systems which are mainly focused on road navigation (outdoor) and commercial and tourist destinations.

In recent years, several approaches have been made to create systems that allow seamless tracking and navigation both in indoor and outdoor environments.

This paper proposes a prototype which uses RFID technology to provide location-based services and navigation to the blind, or visually impaired. Section 2 makes an overview of previous work made in the context of systems developed to assist the mobility of blind users. Section 3 describes a prototype proposed by the team developing the Blavigator project, at the University of Trás-os-Montes and Alto Douro. Finally, in Section 4, the authors give some final remarks regarding the work done so far and perspectives for the near future.

2. Previous work

Location and navigation systems have become very important and widely available in recent years as a base for finding the quickest or optimal route to a specific destination or simply to retrieve contextual information about the environment and nearby points-of-interest (POI). Most of these systems use the Global Positioning System (GPS) and only work well in outdoor environment, since GPS signals are greatly degraded inside of buildings.

To address the task of finding the user location in indoor environments several techniques and technologies have been used such as sonar, radio signal triangulation, radio signal (beacon) emitters, or signal fingerprinting. All these technologies can be, and have been, used to develop systems that help enhancing the personal space range of blind or visually impaired users [1]. Another technology widely used in this context is Radio-Frequency Identification (RFID). RFID tags are built-in with electronic components that store an identification code that can be read by an RFID tag reader. In recent years some research teams [2][3][4] have developed navigation systems based on this technology. In the case of outdoor environments, some hybrid systems have been proposed that use GPS as the main information source and use RFID for correction and minimization of the location error. The research team at the University of Trás-os-Montes e Alto Douro (UTAD) has an extensive work in terms of accessibility and rehabilitation. In the last few years, the team has given major focus to visual impairment and on how existing technology may help in everyday life applications. From an extensive review of the state of the art and its best practices, two main projects have been developed: the SmartVision project [5][6] and Nav4B [7].

The main goal of the SmartVision project was to develop and integrate technology for aiding blind users and those with severe visual impairments into a small portable device that is cheap and easy to assemble using off-the-shelf components. This device should be extremely easy to carry and use, yet providing all necessary help for autonomous navigation. It should be stressed out that the device was designed to be an extension of the white cane, not a replacement, and to be "non-invasive", issuing warning signals when approaching a possible obstacle, a point-of-interest or when the footpath in front is curved and the heading direction should be adapted.

In this sense, the SmartVision prototype addressed three main applications: (1) local navigation for centering on footpaths etc. and obstacle avoidance, in the immediate surroundings, but just beyond the reach of the white cane; (2) global navigation for finding one's way; and (3) object/obstacle recognition, not only on the shelves in a pantry or supermarket, but also outdoor: bus stops, taxi stands, cash machines (ATM) and telephone booths.

The Nav4B project aims to create a small, cheap and portable application as an extension of the work done in the SmartVision project. The new prototype is built with the same modular structure as in SmartVision.

3. RFID Prototype

3.1. Infrastructure

In terms of the use of RFID technology to get the user location, the first prototype (SmartVision) used an electronic white cane that senses tags on the floor placed on a topology that consisted of connected lines and clusters [8]. This set of connected lines and clusters composed a network of safe paths and points of interest. The software was able to run offline on a mobile device using a local representation of the data present in a Geographic Information System, stored in a remote server [9], namely the tag identifiers, the corresponding geographic coordinates and the tag ownership (lines and clusters). The ability to run offline is an advantage when compared to previous works, since older systems relied on a central server to calculate the desired routes and provide information about user location, leaving the user somewhat 'alone' when there was no network coverage. Another advantage of this type of setup is that the user can be certain that he will stay on safe routes and locations, as long as he carefully follows the lines and clusters. However, when compared to normally sighted people, blind users still face some limitations in terms of where they can go while using the system.

To address these limitations a change in the topology from a network of connected lines and clusters to a mesh network of RFID tags was made within the Blavigator project (Fig. 1). This topology creates a layer that covers large areas and increases the places that the user can safely navigate.

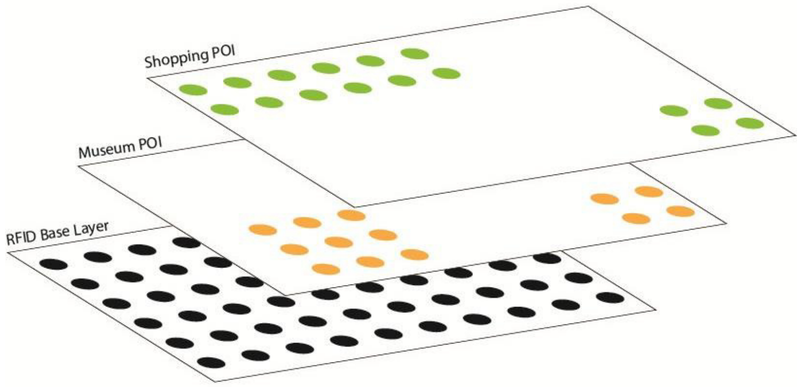

Fig. 1 – Mesh network of RFID tags and example layers of points-of-interest.

The base layer is the actual infrastructure of individual RFID tags and their geographic location in terms of absolute coordinates. On top of that, it is possible to create an infinite range of layers that can be used to provide location-based services to be shared by both blind and normally sighted users. By clustering some of the tags it is possible to create points-of-interest that can be categorized (layered) according to the needs of the actual location owner or promoter, much like traditional navigation systems, and the path between these POIs can be dynamically calculated using routing algorithms and the RFID base layer.

The contextual information stored can range from the cultural and intellectual promotion of places or events, such as navigation in museums, to commercial advertisements in shopping areas. At the same time, it is possible to extend the coverage area of the system, reducing the gap between the places where blind and normally sighted people can safely navigate.

3.2. Software modular structure

The interaction of the user with the hardware infrastructure is supported by a software application developed in a modular structure. All the modules were designed to work independently, exchanging information and being controlled by a central decision module (Fig. 2).

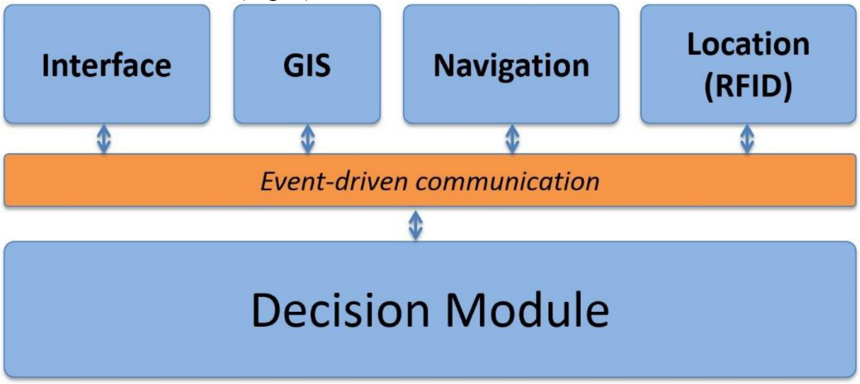

Fig. 2 – Modular structure of the software prototype

The prototype is composed by five of the SmartVision/Blavigator modules: Interface, Geographic Information System (GIS), Navigation, Location and the central Decision Module.

The Interface Module is responsible for the user interface. The system outputs information through vibration (haptic actuator present in the electronic white cane) and through text-to-speech technology (per user request or in the presence of relevant contextual information).

The Geographic Information System keeps a local representation of the data stored in a dedicated remote server supported and maintained by the Blavigator project. This module provides all the geographical data to the prototype according to the user's current location. The user location is estimated using the Location Module and the RFID mesh infrastructure exposed in the previous sub-section.

The Navigation Module, by request of the Decision Module (and user input), uses data from both the Location Module and the GIS to calculate the optimal route to a specific destination (point-of-interest), to guide the user through the calculated route and to provide contextual information about the user's surroundings.

3.3. The electronic white cane

The Location Module uses the RFID infrastructure exposed in sub-section 3.1 to determine the user's location with high precision. To sense this infrastructure, an electronic white cane has been developed which uses an RFID reader to read the tags placed on the floor (Fig. 3).

Fig. 3 – Electronic white cane of the Blavigator project.

Every time an RFID tag is sensed in the floor, the white cane vibrates alerting the user that he is in a safe area. Then, the tag ID is sent to the mobile device via Bluetooth, to be handled by the Location Module. To determine the user's location based on the tag ID, the Decision Module queries the GIS module about the coordinates of that specific tag. This way, the user is able to know his location within the mesh infrastructure.

When an RFID tag is sensed, the mobile application (software) can handle this input in one of two ways (or modes) according to the user's requirements: Navigating or Touring. If the user wants to navigate to a specific point-of-interest, the system uses the current coordinate and the destination coordinate to calculate a route between the two points. Then, each input from the Location Module triggers the Navigation Module to keep the user on his track. On the other hand, if the user wants to stroll around, as if sightseeing, the system uses the current coordinate to query the GIS Module about relevant features (points-of-interest) in the user's surroundings. There is an 'alert' level within the software that can be modified by the user to filter the types of alerts he wants to be warned about. This is a support system that must not be intrusive neither an obstacle by itself, overriding the will of the user.

The interface between the user and the mobile software application is bidirectional (Fig. 4).

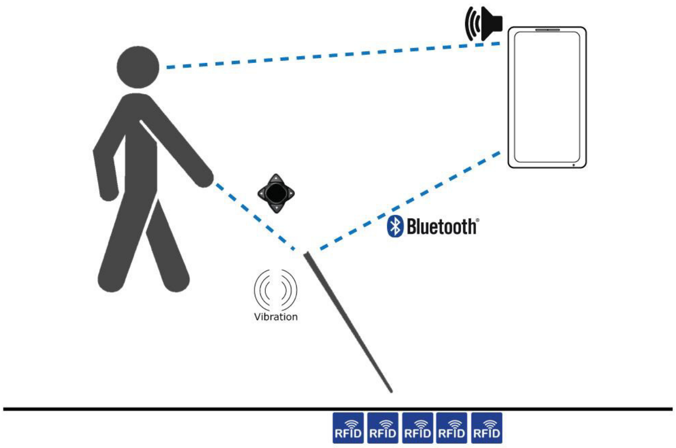

Fig. 4 – User interface with the prototype

The user interfaces the software using a small joystick placed conveniently in the white cane. The joystick works in four directions and has a press button as well (a total of five switches). This joystick is used to navigate the software application and the inputs are sent via Bluetooth, much like in the case of the tag ID.

When the software needs to provide feedback to the blind user, text-to-speech technology is used. This type of audio cues is used only at specific locations (such as dangerous areas or important points-of-interest) or by user request, if he feels the need to know with more detail the contents of his surroundings.

No interface is made with the mobile device itself, directly. The mobile application is designed to be interfaced exclusively using text-to-speech and the joystick.

3.4. The Geographic Information System (GIS)

As it has been explained in previous sections, the knowledge and details about points-of-interest to relate to the user location, providing contextual information and ways to determine optimal routes to specific locations depends on an accurate and complete representation of the RFID infrastructure and real world features. The mobile device keeps its local representation of this data, for offline use. However, the source of this local representation is a central server, designed to be maintained and updated according to the changes that may happen over time in the RFID infrastructure and in the real world itself.

The Geographic Information System (GIS) stores data about all the RFID tags, points-of-interest, layers, etc., in a MySQL database. All the required CRUD (create, read, update and delete) operations are available through a web application interface (Fig. 5).

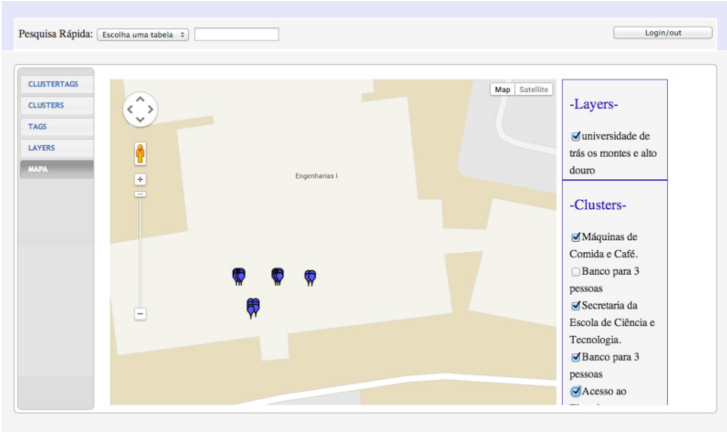

Fig. 5 – Web interface to the Geographic Information System.

Every major update to the server's database affects (increases) its version number. Major releases are defined by the system's administrators and, this way, every change made in the central GIS is replicated to the user terminals, via internet access. The data is transferred from the server to the mobile terminals using JSON files, which are interpreted (parsed) locally and used to synchronize the prototype's database.

4. Final Remarks

This paper proposes a prototype which uses RFID technology to provide location-based services and navigation to the blind, or visually impaired.

Previous work, cited in Section 2 of this paper as led the team to the conclusion that the line/cluster topology, while keeping the user on safe paths, lacked some of the versatility that normally sighted users had while navigating. Moreover, as the geographic location of the points of interest varies over time and the tags are embedded in the floor, the mesh topology has arisen as a natural evolution. Using a mesh infrastructure optimal routes can also be calculated, reducing the overall distance that the user must travel to reach the desired destination.

Regarding the user interface with the system, audio cues and alerts are used only in specific point or per user request. Blind users rely very much on the hearing sense, and the system mustn't be an obstruction. The inputs made via a small joystick, so the user can naturally navigate through the software menus.

Currently the campus of the University of Trás-os-Montes and Alto Douro is being used as a test scenario, with the help of real blind users from ACAPO - Blind and Partially Sighted People Association of Portugal. Some connections have been made with private and public partners to extend the geographic area covered by this system.

Results of the tests being made at the moment will be publish later, on future publication of the Blavigator project team.

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