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# ELECTRONIC WHITE CANE FOR BLIND PEOPLE NAVIGATION ASSISTANCE

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ABSTRACT
In modern daily life people need to move, whether in business or leisure, sightseeing or addressing a meeting. Often this is done in familiar environments, but in some cases we need to find our way in unfamiliar scenarios. Visual impairment is a factor that greatly reduces mobility. Currently, the most widespread and used means by the visually impaired people are the white stick and the guide dog; however both present some limitations. With the recent advances in inclusive technology it is possible to extend the support given to people with visual impairment during their mobility. In this context we propose a system, named SmartVision, whose global objective is to give blind users the ability to move around in unfamiliar environments, whether indoor or outdoor, through a user friendly interface that is fed by a geographic information system (GIS). In this paper we propose the development of an electronic white cane that helps moving around, in both indoor and outdoor environments, providing contextualized geographical information using RFID technology.

Key Words: Blind Navigation, Accessibility, RFID, GIS

## 1. INTRODUCTION

People with visual impairment face enormous limitations in terms of their mobility and in today's world there is a lack of infrastructures to make it easier. 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, analyzing environment characteristics like footstep sounds or echoes and keeping on track through the memorized course until the destination is reached. A system that assists navigation and orientation in real time would be of great benefit to achieve this demanding task.

Nowadays, navigation systems are widely used to find the correct path, or the quickest, between two places, from saving disaster victims to guiding long range missiles. 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, so it is necessary to find another technology that allows accurate navigation in these kinds of environments. An indoor navigation system is important in several different applications, like tourist guidance in a museum, helping firemen facing lack of visibility to find a way out of a smoky environment and, of course, helping a blind person to move around in a building.

Several technologies have been proposed to make navigation inside of buildings possible. A radio beacon may emit a reference signal used to calculate the distance between the emitter and the receiver. An example is the use of Wireless Access Points to fingerprint a building's interior and then calculate a person's or object's location.

Another technology widely used in this context is the Radio-Frequency Identification (RFID). Tags are built-in with electronic components to store an identification code that is read by an RFID tag reader. 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 used in the guidance of people with visual impairment to move around in both indoor and outdoor environments, complementing the traditional white cane and providing information about obstacles, corridor or street walk width, doors, etc. This system is composed by RFID tags placed along hallways and street walks where blind persons may pass by and an RFID reader located inside the white cane. This work is part of a project named "SmartVision – Active vision for the blind", whose main goal is to develop a blind user navigation/orientation system that uses RFID technology, GPS and computer vision.

This document is composed by four sections. Section 2 presents an overview of related work using RFID technology to assist blind navigation. Section 3 starts by globally describing the SmartVision system and then detailed attention is given to the development of the RFID module. Finally, Section 4 presents conclusions about the work developed so far and makes some considerations about future work.

## 2. RFID TECHNOLOGY USED IN THE CONTEXT OF BLIND USER ORIENTATION

In this section, four projects that were used as guide to the development of the prototype proposed in this article will be presented. These projects reflect also the state of the art of development and application of RFID technology in blind person's navigation/orientation.

### *2.1 Projects - Related work*

The Department of Electronics Engineering of the Technology University North Bangkok developed a blind user navigation system (Project I) using RFID technology in building's interiors [1]. The system in composed by three subsystems. The navigation runway, which consists in pavement blocks with built-in RFID tags and whose function is to help in the user navigation; a communication module, a user interface module and a data module. Its task is to process the information obtained by tag readings. The reader reads the information contained in the RFID tag and sends this information to the microprocessor, via RS232 interface; a remote navigation server handles the task of calculate the route between the two places. The server receives information regarding tag ID and destiny location, and uses this information to calculate the quickest route and send it to the navigation device. The communication module interacts with the server using a GPRS connection only when the navigation has started or when the user gets out of course. In this case the user calculates a new route based on the information contained in the tags the user has read.

The kind of tags used in this system are low frequency RFID tags (134.2 kHz) and are planted along the pathway or, at least, in path intersections [2].

Investigators from the University of Rome, in Italy, developed a system (Project II) that assists blind users to move around [3]. This system is composed by a tag network, a RFID tag reader and a PDA with a system specially developed for this project. The tags are buried in the floor, along the pathway to provide all the necessary information to the system. The RFID tag reader is installed in a plastic white cane, very similar to the ones used by blind persons and the antenna is placed in the cane extremity, moving very close to the ground. The antenna is connected to the RFID reader controller which, in turn, connects to the PDA using Bluetooth technology. The reader's power supply is a set of batteries that can provide autonomy of about three hours, continuously reading the tags. The PDA processes the information through software responsible for the navigation. The interface is done by audio signs, using headphones.

The RFID tag reader reads the tag ID, which is unique, and sends it to the PDA. With this information the algorithm generates an audio signal that is transmitted to the user through the headphones so that he stays on track, moves on the right way and avoids obstacles. To test this system the developers built a small path, shaped as 'L', with built-in tags on the pavement.

Tests were conducted with the participation of students and people with visual disabilities, in which the advantages and disadvantages of the system are discussed [3].

A group of investigators of the University of Florida proposed a system (Project III) composed by high frequency passive RFID tags, placed bellow the street walk pavements, building corridors and classrooms [4]. These tags provide information about the surrounding area and, therefore, no database or remote server is needed. All information is captured by a Skyetek RFID tag reader placed in the white cane and in one of the user shoes. The data is sent by Bluetooth to a PDA or Smartphone supporting JAVA.

In the case of outdoor environments, the tag will provide latitude and longitude information previously obtained by GPS. Each tag will have recorded information like details about a building's room, some objects found inside this room, and the user's location relative to the tag. All this information can be stored using XML format.

In the University of Science and Technology of China a system was proposed (Project IV) to address the orientation of the user giving information about his surrounding environment [5].

The system is composed by RFID tags, a RFID tag reader, a mobile phone and a remote server.

In terms of RFID tags, there are three kinds:

1. Information tags that contain the GPS location, pathway conditions, information about BUS or stores, or even distance from the current location to a point of interest.

2. Navigation tags, whose goal is to support the navigation of the blind users. These tags are placed near stores, BUS stops, etc. and will serve to alert the user.
3. Guide RFID tags, which are placed in specific places, like BUS stops, or serve as semaphores in crossings.

All tags have their own information stored, in XML format.

The RFID tag reader is built-in the white cane and connects to the mobile phone through Bluetooth interface. The mobile phone has installed software that translates the information stored in the tags into audible notifications. Software to store messages and other information is also installed. The remote server contains the tag database and a navigation system. The navigation server is responsible for calculating the best route between the current position and the user desired destination using tag information together with a routing algorithm [5].

### 2.2 Comparing the related works and the proposed project

All the presented projects use RFID technology in a similar way and all of them use passive RFID tags due to lower implementation cost. Projects I and II use low frequency tags placed along the pathway with short, but enough, reading range to the desired application since the antenna is placed close to the ground. This allows the system to get an exact position of the user coordinates, previously stored in the tag using GPS, and avoids the need to read more than one RFID tag in the vicinity. In Projects III and IV the tags are placed in specific locations and the use of higher frequency provides higher reading range. In this case navigation assistance is not intended, but only to provide information about the specific location where these tags were planted.

In project I the interface between the RFID reader and the mobile device is done using RS232 connection (wired), while in the remaining projects a Bluetooth connection (wireless) is used.

The information associated with the tags is stored differently in each project. In Project I the data is stored in the tags and a remote server, while in Project IV all the data is stored in the remote server. In projects II and III the concept of remote server is not used, discarding the need of GPRS connection. In Project II all data is stored in a database present in the mobile device. In Project III the data is stored in the tags own memory, in XML format, since these kind of tags have the feature of being able to store information. Table I presents a summary of all the projects studied and a comparison to the SmartVision project proposed in this paper. The RFID tags adopted are different from the tags used in the projects analyzed due to easier application. These tags will be covered in more detail in further sections.

| System characteristics | Project I | Project II | Project III | Project IV | SmartVision |
|---|---|---|---|---|---|
| Tag type | Passive | Passive | Passive | Passive | Passive |
| Operating frequency | 134.2 KHz | 134.2 KHz | 13.56 MHz | 13.56 MHZ | 125 KHz |
| Tag distribution | Along the path | Along the path | Points of interest | Points of interest | Along the path and points of interest |
| RFID reader location | White cane as antenna | White cane as antenna | White cane and shoe with built-in reader | White cane with built-in reader | White cane with built-in reader |
| Reader → System Communication | RS232 | *Bluetooth* | *Bluetooth* | *Bluetooth* | *Bluetooth* |
| Data storage | RFID tags and remote server | Mobile device | RFID tags (in XML format) | Remote server | Mobile device |
| Data transmission | GPRS | *Bluetooth* | *Bluetooth* | GPRS, *Bluetooth* | *Bluetooth* |

**Table I. System summary and comparison.**

## 3. SMARTVISION PROTOTYPE

The work presented in this paper is part of a project of wider coverage named SmartVision. The SmartVision Project's main goal is to allow the autonomous navigation of people with disability in two different environments: indoor and outdoor. As support to the development of the system, the Campus of the University of Trás-os-Montes and Alto Douro (UTAD) is being used, both in indoor and outdoor [6].

The technologies used in this project are: computer vision using a stereo vision system; RFID tags for location error minimization; GPS, for outdoor positioning; location by trilateration of signals from Access Points (APs) [7], for indoor positioning; a geographic information system (GIS) with data from the UTAD Campus [6]. The system is also composed by a web application for easy management and update of all the information in the GIS, and an interface module though audio and haptic actuators (Figure 1a).

These technologies are used with two distinct objectives. The first concerns the navigation of the blind user and the second concerns guidance by providing information about his surrounding environment (about 2 to 3 meters radius). Among other functionalities, the project implements the calculation and use of routes, indication and identification of points of interest like zebra-crossings, buildings or obstacles, etc.

Considering the limitations of each technology, data from different sources is condensed in one place. This data encapsulation allows a certain abstraction concerning the user's positioning, not being relevant if the user is in an indoor or outdoor environment. After getting the current position, through GPS, RFID or Wi-Fi, the system feeds the user with relevant information with the help of the GIS server, using Text to Speech software to transform text stored in a database into audio signs. To avoid overloading the user hearing sense, which is of vital importance in the case of blind users, some alerts may be given in the form of vibration, through the use of haptic devices, namely to alert the approach of street walk limits.

Although the data retrieved from the different technologies is condensed in one place and the fact that it shares common goals, some also have specific contributions.

In this system, computer vision is used to help the user keeping on track of defined trajectories, ensure his correct alignment with the street walk (through the use of haptic devices), object recognition and/or obstacle avoidance, among others.

In the case of GPS, its contribution is the ability to provide the current position and the associated error quantification.

Regarding the use of Wi-Fi, this technology is used to compensate for the lack of GPS signal in building's interiors. By obtaining the location of each *Access Point* location from the GIS server and using trilateration methods it is possible to know the user's current position, with an associated error margin, based on the APs signal strength. In this kind of implementation we assume the existence of, at least, three APs in range, in each moment. This way we obtain a location system very similar to the GPS system, and the same kind of information.

The objective of using RFID technology in this project is to correct the GPS error in the case of outdoor positioning, since each tag cluster is appropriately georeferenced (constant and well known latitude and longitude) and to correct the Wi-Fi location error, in the case of indoor positioning. This also allows the user to receive warnings and information relative to each specific point where the RFID tags are planted.

The SmartVision system works autonomously in a mini laptop, carried by the user, loading and updating the information required for the navigation/orientation from the GIS server through an Internet connection. All the remaining technologies will be connected to this processing unit. Figure 1b illustrates the SmartVision system running.

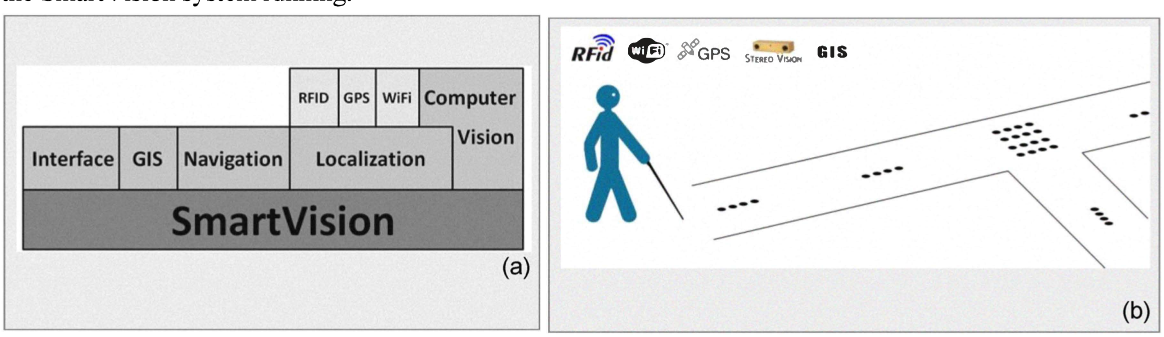


**Figure 1. SmartVision project. (a) Diagram of the SmartVision project. (b) SmartVision project with RFID tags in the ground.**

The presented work concerns the RFID module, working in outdoor environment. In this article the adopted solutions are described, as well as the developed prototype for future testing in UTAD Campus.

### *3.1 White Cane Prototype*

The first solution consisted in using an RFID tag reader in the extremity of a white cane, similar to the ones used by blind people, and connecting it to a computer or PDA via USB connection.

This solution was implemented by manufacturing a white cane prototype to test tag reading and cane usability. The white cane was made of light PVC and its length was established according to the specification standard for a white cane used by blind people. The length depends on the user height and must be long enough to reach the user sternum [8]. The RFID tag reader used in this solution was from the manufacturer Phidgets [9] and was mounted in the extremity of the white cane (Figure 2b). The choice of the Phidgets tag reader comes from the ease of implementation and previous knowledge of its functioning. To create an RFID path prototype the tags must be very resistant to the surrounding environment threats, like water and erosion, since they are planted in the street walks. The chosen tags were of the passive type, having a working frequency of 125 kHz and compatible with the chosen tag reader. The tags have the shape of a wood nail, and the electronics are fixed inside a hard and resistant plastic encapsulation. The tags are 2,5cm long and 4mm wide [10] (Figure 2a). The connection between the reader and the processing unit was made through an USB cable, coming out from inside the cane, near the user's wrist. A small cut was made to the cane in order to give the user the notion of the orientation of the white cane relative to the ground. After some preliminary tests a small wheel was placed under the RFID tag reader in order to avoid contact between the reader hardware and the ground, during its utilization. This measure was taken for protection considering that the blind user constantly tries to feel the path he walks in and there is constant contact between the white cane and the ground.

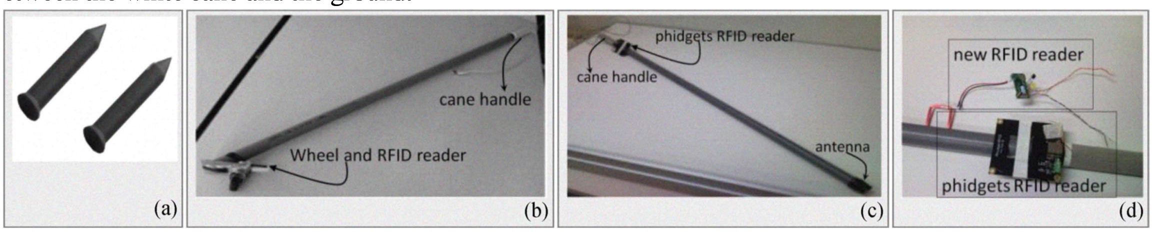


**Figure 2. White Cane and RFID Tags. (a) Tags RFID. (b) White Cane with RFID reader at the bottom. (c) White Cane with RFID reader on top. (d) Electronic to embedded in third version of White Cane.**

After running the first tests it was verified that the use of the tag reader in the extremity of the white cane reduces sensitivity while trying to detect some objects, ground texture or sidewalk limits, while at the same time easily damaging the tag reader.

After studying different possibilities to overcome these problems, and in a way to make the prototype lighter and more resistant, an option was taken to separate the antenna from the tag reader, placing the antenna at the bottom of the white cane and the remaining hardware near the handle. To do this the original antenna was disconnected from the reader hardware and a new antenna was built by manufacturing an inductor with equivalent inductance to the original antenna (Figure 2c). These modifications turned the white cane into a lighter and user friendly tool.

Both white cane solutions use USB to establish communication with the processing unit.

In a third stage a new RFID tag reader unit was developed using Bluetooth to transmit data, with dimensions suited to be incorporated in the inner part of the white cane (Figure 2d). Two new components were also developed: a power source that allows battery recharge and a small vibrator placed near the handle of the cane. This actuator will alert the user each time a tag is detected allowing the user to know its relative position to the tag.

### *3.2 Tags distribution in the test path*

In this stage, experiments were made both in laboratory and in the outside of the Engineering Building of UTAD Campus in a way to find the best RFID tag layout.

Initially the tags were distributed all over the pathway, along three parallel tag lines: two lines to mark the path limits and one line, in the middle, to give alerts like obstacles or direction change. This configuration may be observed in Figure 3a. In a second configuration, a single line was placed in the ground and the white cane's vibrator gives a notion of the path that the user must follow (Figure 3b). This solution has proven to be very functional, leaving only the need to define the tag spacing. Following this need, tests were made in order to determine the success percentage of different tag spacing. The results may e observed in Table II.

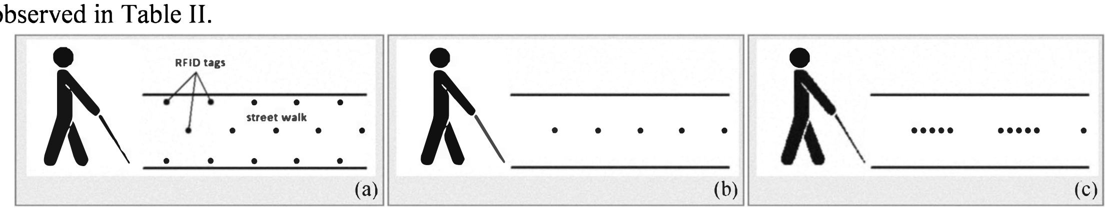

**Figure 3. Tag distribution in the test path. (a) Tags distributed in lines. (b) Tags distributed in one line. (c) Tags concentrated in line Clusters, with 5 tags each, distributed in one line.**

After analyzing the results it was clear that the number of hits was very low in all cases and, from all the experiments, Case 3 of Table II was the one with higher success (30%). This happens because the tag reader has short reading range (10cm) in order to provide good location precision. Thus a new configuration was implemented, using groups of inline tags, called “line clusters”. This layout can be observed in Figure 3c. The presented configuration consists in using clusters composed by 5 inline tags, with 5cm spacing between each tag and 100cm spacing between each cluster in straight paths. In corners the distance between clusters must be shorter, and this spacing varies according to the corner nature. In the first experiments this configuration proved that the line clusters are detected, although extensive tests must be undertaken in different environments to better evaluate this configuration.

| Case | Tag amount | Spacing (cm) | Hits | Success (%) | Average spacing |
|---|---|---|---|---|---|
| Case 1 | 5 | 100 | 0 | 0 | -- |
| Case 2 | 10 | 50 | 2 | 20 | 1 |
| Case 3 | 20 | 25 | 6 | 30 | 1,5 |
| Case 4 | 40 | 12,5 | 10 | 25 | 1,25 |

**Table II. Results of the preliminary tests taken to determine tag spacing.**

Together with this clustering concept, bigger clusters were created (matrix clusters) in critical points in the pathways (POI – point of interest). The most common matrix cluster is composed of 16 tags. Placed in POIs like zebra-crossings, stairways, building entrances, obstacles, crossings, etc. The matrix clusters placed in POIs of UTAD Campus may be seen in Figure 4. This option assures that all POIs are detected when the user passed by them, feeding him with detailed information about the POI where he is located.

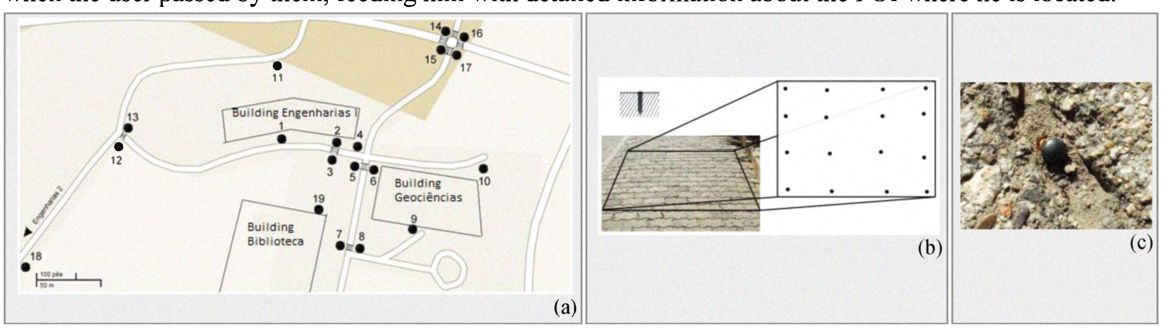


**Figure 4. Tag application in UTAD Campus. (a) Cluster geographic distribution. (b) Tag cluster distribution. (b) Tag planted in the ground.**

This matrix and line cluster solution has proven, so far, to be the best tag distribution in outdoor environment. The user interface is done through the vibrator present in the white cane handle, vibrating only once each time a line cluster is detected and twice each time a matrix cluster is detected. In this last case, information regarding the associated POI is also transmitted to the user through an audio interface.

### *3.3. Path Management Software*

A path management software application was developed, using C# programming language, which is able to run in two modes: path configuration mode and navigation mode. When running in path configuration mode it is possible to add new tags, connected as clusters, saving the tag identification code and its corresponding cluster GPS coordinate. This application is vital to set up new clusters and perform tag maintenance. After creating new clusters, all this data is loaded into the UTAD Geographic Information System (GISUTAD) developed for this infrastructure [6]. At the moment, data relative to the clusters already installed in UTAD Campus may be downloaded from the GISUTAD, in XML format, and used by the application in navigation mode. Although a laptop is currently being used, a similar PDA application was already developed and tested using the MIO A710 PDA. In navigation mode, this application uses the data from the GISUTAD to provide contextualized information about the user’s current location.

## 4. CONCLUSIONS AND FUTURE WORK

The study of the related works revealed to be very important in the initial specification of the RFID module prototype. Likewise, the analysis and respective evaluation tests of RFID tags and RFID tag readers gave relevant information to the choice of the RFID tag reader and the working tag frequency used in our prototype.

The SmartVision's RFID module prototype developed so far presents promising results. We foresee the use of this module in two objectives: a first one, related to autonomous operation providing only information regarding the clusters detected, and a second one, in which the RFID module helps the SmartVision System complementing the user's location information given by the Location Module and the Computer Vision Module.

After creating a set of test messages, now it is necessary to improve the specification of the information to be delivered to the user. An example is the case where we want to deliver different information according to the direction the user is moving.

After this stage, a set of tests will be carried out with blind users to adjust the system to the special need of the users that the system is designed to. The interest already shown by blind persons and leaders of Portuguese cities for implementation in their city streets leads us to believe that I the next few years we will be able to conduct tests in urban environment.

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