Improving Mobility of Pedestrian Visually-Impaired Users

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Abstract

Objective In the present paper the study, design and prototyping of a mobility aid system for visually impaired persons in outdoor scenarios is presented. The application scenario is autonomous mobility in urban context, and, in particular, the living of outdoor public places of tourist/cultural interest and urban routes.

Main Content The basic idea behind the project is to realize a safe path that can be followed by the user thanks to a tactile vibration provided by a modified white cane (Smart Cane), potentially usable also as a traditional one; a smartphone provides the user with additional information about the route. The basic guidance function on a safe path is suitable also in an indoor scenario, e.g. in exhibitions, museums, public buildings. Final users were involved in the definition of mobility requirements and during system tests. The safe path is composed by tracks, branch points and points of interest, and is implemented by means of an electrical circuit generating a magnetic field detected by a receiver on the white cane tip. The Smart Cane is equipped with an electronic device (Smart Cane Controller) managing cane functions. The path electrical circuit may be buried in several kinds of ground or placed on ground surface. The user follows the path sweeping the white cane in front of him/her and perceiving a tactile vibration when the Smart Cane tip is in the range of a few tens centimeters from the track centre. The smartphone brought by the user is wirelessly connected to the Smart Cane Controller and to a small portable GPS receiver. The user queries the mobile phone by means of a switch-based user interface on the cane; thanks to GPS positioning information (strict positioning accuracy not needed), the mobile phone provides vocal information about possible destinations, directions and about points of interest.

Results The system electronics and the firmware and software applications were completely developed and tested both in lab and in real operating conditions. For the test and Demonstration phase, a bastion on the Walls of Lucca city, Italy, was selected, and the system was tested also with final users. A second run of trials with other users is foreseen in late Spring and Summer 2011.

Conclusion The proposed mobility aid system was completely designed, developed and partially tested. A Demonstration phase will allow final users to further test and validate the system, providing hints and feedbacks for a possible engineered future version.

Keywords. Mobility aid, visually impaired people, assistive technologies.

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Introduction

The present work describes an extension of [1], and it deals with the study, design and prototyping of a mobility aid system for visually impaired people in an outdoor urban scenario. The system was conceived so that the basic guidance function on a safe path is suitable also in an indoor scenario, e.g. inside public buildings, exhibitions, museums.

1. *The Context*

1.1. The Mobility Need

For people with visual impairments, autonomous mobility, while being an undoubtedly important need, often turns out to be difficult or impossible especially if not restricted to well-known contexts (e.g. the home or its surroundings), due to the difficulty of recognizing the current position and orientation and to avoid obstacles and dangerous situations (holes, ditches, crossings, etc.). The consequence is a lowered quality of life, due to lacking or reduced autonomy, self-esteem, social integration.

According to statistical data about visual impairments [2], in Europe about 30 million people are affected by visual impairments including blindness. In Italy, visually impaired people are about 350.000, and 60.000 of them are blind [3]. Mobility issues could therefore affect a large number of people.

1.2. Urban Mobility for Visually Impaired Persons: the White Cane

Since several tens of years, the white cane is a chance for autonomous mobility outside home. Fundamentally, the white cane is used to perceive the environment in two ways: detecting obstacles and recognizing objects and places along the route. Before facing a route alone, a blind person generally need to preliminarily create a mental map of the route containing recognizable reference elements, typically trees, house corners, lamps, traffic lights, etc., to be used while walking to recognize one's position. However, moving safely with the help of the white cane is not easy: specific training courses should be attended before a person can walk alone. In some cases, the white cane turns out to be anyway useless, for example in case of obstacles not laying on the ground (e.g. an open blind jutting out on a sidewalk). As a matter of fact, people with severe visual impairments, when alone, often have to stay at or near home.

1.3. State of the Art in the Field of Mobility Aids

As an aid to autonomous outdoor and indoor mobility, different solutions based on different technologies and working principles are available, both as commercial products and at the prototype/research state. Each detection technology and/or device/solution has its own advantages and issues.

Obstacle detectors are electronic devices mainly based on infrared [4,5], ultrasound [6], LASER [4,5] technologies able to signal the user the presence of obstacles in front of him/her. Such devices, anyway, do not work in all situations, mainly due to the very different physical properties of obstacles (composition, shape, etc.).

Other mobility aid systems exploit the GPS (Global Positioning System) signal transmitted by the GPS satellite constellation; some of them also make use of terrestrial enhancement signals to improve positioning accuracy and of specialized service centres [7,8,9]. As a consequence of GPS relatively poor accuracy and precision (a few meters at best, but even tens meters near buildings, trees, etc.), such systems are not completely suitable for blind pedestrians mobility in an urban scenario. Moreover, such systems cannot be used inside buildings, where the GPS positioning signal is lacking.

Another proposed mobility aid is represented by a guidance system based on a path implemented by means of buried RFID tags, a cane mounting an RFID reader and a portable user terminal providing indications downloaded from an online map [10].

Paths equipped with suitable guide tiles (Loges and Apice tiles [11,12]) provide the user with a safe route inside buildings (e.g. a train station, a subway) and/or outdoor; however, the user should have a preliminary knowledge of the route.

Finally, dog guides may present some issues for the user, as he/her must establish a very strict, continuous and engaging relationship with the dog [13].

2. The Proposed Mobility Aid System

The basic idea behind the present project is to realize a guidance system trying to overcome some issues presented by other mobility aid solutions, realizing a safe path that may be followed by the user thanks to a tactile vibration feedback provided by a Smart Cane handle while the user is on a predefined safe track.

The Smart Cane is a traditional white cane equipped with electronic devices, and can potentially also be used as a traditional white cane. In addition, during the route the user is provided with vocal information by means of a mobile device (smartphone), wirelessly connected to the Smart Cane and exploiting the GPS positioning signal.

In a preliminary phase, also thanks to some users' contribution, a study was carried out on aspects and user requirements concerning mobility, autonomous mobility scenarios, the control of an electronic mobility aid device and the kind of route information expected by end-users. The identified mobility scenario was outdoor urban mobility, in particular living an outdoor public place of tourist/cultural interest and walking on urban routes. The chosen project demonstration scenario was identified since the first steps in living the Walls of Lucca city, Italy, surrounding the city historical centre. Near the top of the Walls, a pedestrian/bicycle lane of a few kilometers allows people to enjoy a tour, to access, sit down and relax in several "Bastioni" (bastions), green areas along the Walls with benches and internal lanes.

User requirements concerning the control of an electronic device and the more suitable feedback signal to the user were studied. In particular, on one hand, we deemed it appropriate to provide users with an unobtrusive feedback so as to make them aware of the presence of the path: to this aim a tactile vibration was selected. On the other hand we judged it convenient to enable the user to control the functions supported by the mobile phone through a number of controls placed directly on the cane, so as to avoid using a dedicated hand just for controlling the mobile phone. Such controls (as we will see later on, a joystick and a slider) act on the mobile phone through a wireless connection. Finally, the kind of information contained in messages provided by the system was chosen according to user needs, for example details in the description of the surrounding environment suitable to the need of following a mental map.

3. System Implementation

The mobility aid system was designed and realized as a prototype. The system architecture is shown in Figure 1.

System elements are a virtual path, a traditional white cane equipped with an electronic Smart Cane Controller and path detector and an input interface (mini-joystick and slider), a mobile device (smartphone), an external Bluetooth GPS antenna.

Figure 1. System architecture.

3.1. The Path

The path architecture identified for the chosen mobility scenarios is composed of the following elements:

- Tracks;
- Branch Points;
- Points of Interest (POIs).

In Figure 2 a schematic representation of a sample path is shown.

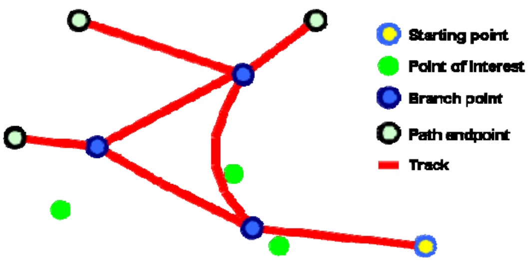

Figure 2. Path architecture.

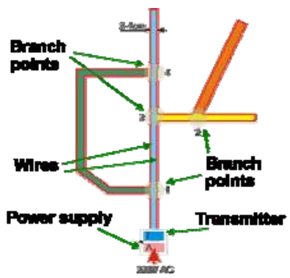

Figure 3. Virtual path circuit.

Tracks are path segments that may be followed by the user thanks to a tactile vibration provided by the Smart Cane when its tip is within about 0.25 m ÷ 0.5 m from the track center. Tracks are not necessarily straight. In branch points, three or more tracks join together; in the surrounding circular areas with a diameter of about 1 m ÷ 2 m, no feedback is provided to the user. The user, following a track, detects the arrival at a branch point as he/her stops receiving feedback, and then queries the system by means of a switch-based user interface on the Smart Cane; thanks to GPS positioning, the smartphone provides vocal information about branches and where they take to, and/or provides information about the presence and description of Points of Interest along the tracks (as an example a bench) or in the surroundings (as an example an historical building, a panorama view). To be noticed that, even if the GPS accuracy/precision may be in the range of some meters in the specific outdoor area, branch points are placed far from each other about 15 m ÷ 20 m or more, and therefore GPS accuracy/precision is not a fundamental issue. Some of the announced POIs along the route, as an example benches, may be recognized by means of the white cane itself.

The virtual path is implemented by a couple of electrical wires in which a transmitter injects a proper low-voltage signal, generating a variable magnetic field that is detected by a receiver mounted on the Smart Cane tip. Wires are placed a few centimeters far from each other (distance is not anyway a critical value), and the whole electrical circuit identifying the path must be a closed loop (see Figure 3). It is easy to modify the path adding/removing tracks and/or enabling/excluding existing path segments. In the branch point areas, each couple of conductors belonging to a path segment is twisted to cancel the magnetic field.

For a permanent installation, wires may be buried at a deepness of about 10 cm ÷ 30 cm. At the used signal frequencies, non-metallic ground, both wet and dry, does not shield the magnetic field, and therefore the system is suitable to be used with concrete/asphalt/ground soil. Wires may also be placed just on the ground surface, and the system is therefore suitable also for use on existing floors; as an example, with minimal installation costs and issues (e.g. using a pre-existing carpet), the system may provide a guidance function in a public building (without exploiting GPS signal).

3.2. The Smart Cane

The Smart Cane is equipped with an electronic device (Smart Cane Controller) connected to the path detector on the Smart Cane tip. When the path signal is detected, the controller actuates a vibration motor in the stick handle producing a tactile vibration. The smartphone is not strictly needed for the Smart Cane to work, but in this case the only information available to the user is path detection. In Figure 4 the Smart Cane architecture is reported. In Figure 5 the Smart Cane prototype is shown.

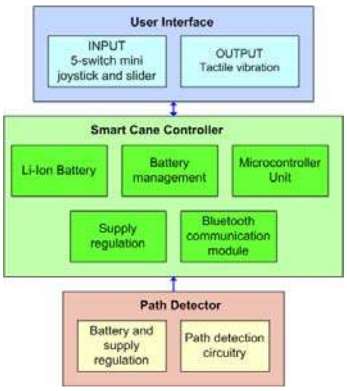

Figure 4. Smart Cane architecture.

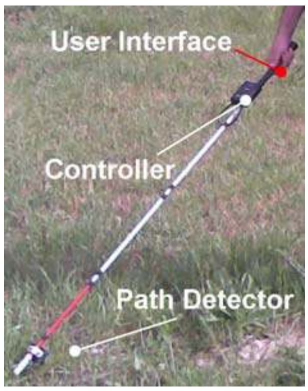

Figure 5. The Smart Cane prototype.

In Figure 6, details of the cane handle and of the cane user input interface are shown. The input interface was designed together with final users. The joystick has five switches, Up, Down, Left, Right, Central (press), and the slider has threes switches, Forward, Backward, Central (press). The input user interface is used to control most navigation and information functions of the smartphone, which is connected to the Smart Cane Controller through a Bluetooth link, avoiding the need to use the smarphone controls and therefore also not keeping busy both user's hands.

Electronics on the Smart Cane was designed to allow a battery life of some hours; a low battery condition is notified to the user by means of a buzzer.

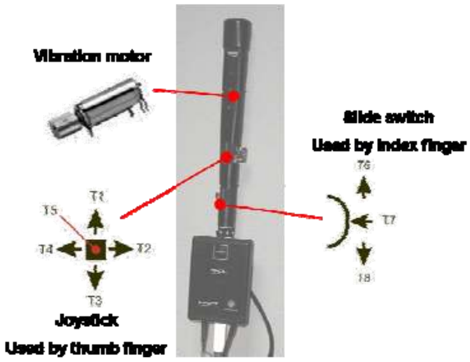

Figure 6. The Smart Cane user interface.

3.3. The Mobile Device

The mobile device used in the system is a Nokia N95 smartphone equipped with a GPS receiver. In a previous version of the system, the internal GPS receiver was used, however it suffered from signal shielding caused by user's body (and therefore the mobile phone could not be kept leaning to the body or in a pocket), but also from a poor receiver performance, not suitable to a typical application scenario. To face both issues, in the newest version of the system, an external GPS receiver was used, connected to the smartphone through a Bluetooth link. Both devices are shown in Figure 7. With the new solution, the mobile device can be easily kept by the user leaning to the body or in a pocket, and the small (82.9 mm x 37 mm x 7.8 mm) and light (31 g) GPS receiver may be mounted on the Smart Cane.

Figure 7. Portable unit (smartphone) and external GPS receiver.

The mobility support application on the mobile device (Symbian operating system) was implemented in Java Micro Edition. The application provides the user with suitable vocal feedback through pre-recorded audio messages which are conveyed to the user thanks to a Bluetooth earpiece; no screen reader for Symbian operating system is therefore needed. More specifically, when the user interrogates the system by means of the joystick, the system analyses i) the position provided by the GPS receiver, ii) the path detection status transmitted by the Smart Cane Controller, iii) the known position of branch and interest points on the path with respect to the user position.

Depending on such information, and the specific button the user selects on the cane user interface, appropriate vocal feedback is provided to the user:

- name and distance of the closest point of interest (Joystick – Left button);
- name and distance of the closest branch point (Joystick – Right button);
- detailed information on recently approached/nearby branch and interest points (Joystick – Down button); in particular, if the path is not detected and the user is on a branch point or within its surrounding area, the system provides information about joining branches, where they take to and about the direction to be taken (e.g. left/right) with respect to the last walked track segment;
- information about the current position of the user (Joystick – Up button). If the user is on the path, the name of the closest interest/branch point is provided. If the path is not detected, if the user is within a branch point area, the name of the branch point is provided, otherwise an "out of path" condition is signalled.

By using the mini-joystick on the Smart Cane, users can therefore control the system that will assist them by providing proper information while following the path.

Moreover, the software application was developed in order to allow an easy reconfiguration of the mobile device for different application sites by simply uploading pre-generated configuration and data files through a Bluetooth or USB link.

4. Prototype Development and Testing

The development and preliminary testing of the system were carried out also using an experimental, reduced path installed on a green area and buried about 30 cm deep. Tests on the use of the internal GPS receiver have shown the poor accuracy and repeatability of the positioning information, leading to the choice of using an external Bluetooth GPS antenna which resulted in an improvement of positioning performance. As further improvement, filtering of unreliable GPS data was added in the application.

During development, some pilot tests on a route were carried out directly by a blind user, who provided feedback about the application functionality, the Smart Cane, the tactile vibration signal and the input/output user interfaces.

The user observed some issues related to the duration of the tactile vibration feedback at high walking speed. This allowed us to tune up the characteristics of path detection feedback. Some considerations on the four joystick positions associated to user commands let us reconsider a new matching. The user considered the voice messages too long, especially when using continuously the system. Voice messages were shortened, especially alerts and indications about nearby points, current position and so on, and a new functionality was developed providing the user, at branch points, with information on branches based on the direction of the last walked track.

5. The Demonstration Phase

5.1. Installation on the Walls of Lucca City and Preliminary Demonstration

The site chosen for the on-field testing and for a further Demonstration with final users was "Bastione San Donato" on the Walls of Lucca city. Preliminarily, some GPS logs were taken in order to estimate the GPS positioning accuracy, which showed some problems under some trees in the green area. Figure 8 shows the relevant GPS logs. Branch points, interest points and their descriptions were also defined and configuration files and vocal files for the application were then generated.

A first demonstration test was carried out by blind users recruited in collaboration with the Italian Association for the Blind. The test was carried out along the pre-installed pedestrian paths inside Bastions on the Walls of Lucca city, see Fig. 9.

Figure 8. GPS logs of the route on Bastione San Donato, Walls of Lucca city.

Figure 9. An internal lane on Bastione San Donato.

In Figure 10 the demonstration path implemented is shown, which included some branch points and some points of interest, i.e. benches along the path, a panorama point on the Walls, some historical buildings and the nearby bus station. Path wires were placed on the ground. In Figure 11 a photo taken during a test session is reported.

The demonstration aimed at showing the system to the potential end-users as well as to collect further impressions and feedbacks on an operative usage. Some users' hints allowed us to tune up the system. We are currently planning a second run of trials with other users in late Spring and Summer 2011, followed by a final Demonstration.

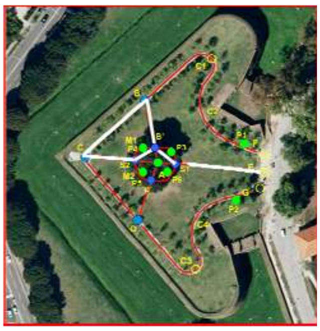

Figure 10. The demonstration path on the Walls.

Figure 11. Test session on the Walls of Lucca city.

6. Conclusion

In this paper we presented the design and prototyping of a mobility aid system for visually impaired people, particularly targeted to urban outdoor scenarios, but also adaptable to indoor ones. The work is now approaching the final Demonstration phase, which will allow users to test and validate the system and to collect hints and feedbacks for a possible engineered future version, in which the path detector and the Smart Cane Controller will be optimized and further integrated in the white cane.

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