BlindHelper: A Pedestrian Navigation System for Blinds and Visually Impaired

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ABSTRACT
Notably valuable efforts have focused in helping people with special needs. Daily routine which is trivial for most of us is a real survival problem for groups of people with special needs and abilities, especially in a society with the bad habit to push to the side such people. This paper is focused on the problem of pedestrian navigation of visually impaired people. BlindHelper primarily enhances the ability of a visually impaired person to navigate efficiently to desired destinations without the aid of guides. Moreover it can provide multiple other uses during outdoor navigation such as dialing a call and notifying the current location in case of an emergency situation. The proposed system has been implemented as a smartphone application which interacts with a small embedded system responsible for reading simple user controls, high-accuracy GPS tracking of pedestrian mobility in real time, and identifying traffic light status and near-field obstacles along the route. This information is communicated to the smartphone application which in turn issues voice navigation instructions or undertakes further actions to help the user.

CCS Concepts
• Applied computing → Life and medical sciences → Health informatics • Applied computing → Life and medical sciences → Health care information systems • Computer systems organization → Embedded and cyber-physical systems → Embedded systems.

Keywords
Blind; Visually Impaired; Pedestrian/Outdoor Navigation; GPS Tracker; Atmega328p; Smartphone; Android; Sonar Detection.

1. INTRODUCTION
Computer science can provide technological means to facilitate human life. Its contribution has been notably valuable during the past years and through unabated ongoing efforts in helping people with special needs. Daily routine which is trivial for most of us is a real survival problem for groups of people with special needs and abilities, especially in a society with the bad habit to push to the side such people. A characteristic example of how computer science can help a person with severe disabilities in speech and movement is the case of the famous theoretical astrophysicist Steven Hawking. SH is using a computer-based communication system including a software keyboard and mouse control operated by cheek movement, a speech synthesizer to communicate and give lectures, as well as facial recognition aimed at improving the communication speed.

Numerous scientific efforts in the field of assistive technologies and e-accessibility, such as those addressed in the ICCHP (e.g. [1]) and PETRA international conference series, have provided a unique source for learning and understanding the theoretical, methodological and pragmatic specializations in this area. These works, with a unique user focus, offer a significant body of evidence for the enormous impact on improving the quality of life of people with special needs and enhancing their performance in a wide range of settings. At the same time they address the often neglected usability issues for all users regardless of their abilities.

The present effort in the domain of pervasive technologies for assistive environments is focused on the problem of daily pedestrian navigation of visually impaired people. Our objective is to come up with an innovative, competitive and at the same time cost-effective system which solves efficiently this problem. BlindHelper primarily enhances the ability of a visually impaired person to navigate efficiently to desired destinations without the assistance of guides. Moreover, it provides multiple other uses during pedestrian navigation, such as dialing a call, notifying a location or an emergency situation etc. The proposed system comprises a smartphone application which interacts with a small embedded gadget responsible for reading user controls via a simple keypad, high-accuracy GPS tracking of pedestrian mobility in real time, and identifying traffic light status and near-field obstacles along the route. This information is communicated to the smartphone application which in turn issues voice navigation instructions or undertakes further actions to help the user.

BlindHelper stands competitively between several available systems in the same domain. Since the GPS system was introduced there have been many attempts to integrate it into a navigation-assistance system for blind and visually impaired people. Loadstone GPS is an early effort for satellite navigation for blind and visually impaired users which started in 2004 and is available in open source [2]. It runs on the Symbian OS and on Nokia devices with the S60 platform and utilizes a GPS tracker, a screen reader application and the OpenStreetMap project. A similar project is LoroDux developed in JavaME, also using data imported from the OpenStreetMap project [3]. Relevant products on modern platforms include Mobile Geo running on Windows Mobile smartphones, including a screen reader and integrating technology from former Braille navigation products [4]. The same company has developed also a similar application for the iOS platform, Seeing Eye GPS [5]. Features unique to blind users include a simple menu structure, automatic announcements of intersections and points of interest, and routes with heads-up

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announcements for approaching turns. It uses Foursquare and Google Places for points of interest and Google Maps for street info. Another application on the iOS platform is BlindSquare using crowd sourced data [6]. It uses Foursquare for points of interest and OpenStreetMap for street info. In comparison with BlindHelper, none of these systems integrates near-field object detection and avoidance, and traffic lights status information, as well as the degree of interactivity with the surrounding environment along the navigation route that BlindHelper provides.

Besides these commercial systems, several other research efforts have delivered relevant outcomes. Some works focus on the problem of indoor navigation for blind people, mainly in public buildings. Since our system has another scope focusing on outdoor independent navigation we only reviewed typical efforts with a similar focus. Ref. [7] describes some similar concepts, but relies entirely on an embedded CPU (ARM Cortex-M3) instead of using a hybrid smartphone/embedded system solution. It is using a Braille capacitive touch screen, a GPS receiver, a compass and a GIS database through an SD card. However, this paper includes only a specification of the proposed system and not evidence of an implemented system. Ref. [8] describes a similar microprocessor-based system replacing the Braille keyboard with speech technology and introducing a joystick for direction selection and an ultrasonic sensor for obstacle detection. The reported location accuracy is 5m. Another similar aged approach based on a microprocessor with synthetic speech output featuring an obstacle detection system using ultrasounds is presented in [9]. This system provides information to the user about urban walking routes to point out what decisions to make and nearest obstacles. Another well known aged system is Drishti [10] employing a "wearable" Pentium computer module and wired headset (quite weighty and intrusive nowadays), IBM's ViaVoice vocal communication, and GIS database and Mapserver. It uses DGPS as its outdoors location system and an ultrasound positioning system to provide precise indoor location. Navigation in all these systems ([7-10]) relies on the GIS-based model described in [11], which provides a detailed valuable experiment on guidance.

2. EMBEDDED SYSTEM

2.1 Microcontroller

The proposed application relies on an external microcontroller in a system bonding with a smartphone. A good choice of microcontroller is Atmega328p featuring small size and low power consumption, which are important requirements for a portable device especially in the context of our application. The microcontroller is the cornerstone of the proposed embedded application, as it is running the code responsible for the reception of the geographical coordinates of the moving person, handling of the keypad and user commands, sending of application data to the android application via Bluetooth, as well as measuring object distance in real time along the route of the visually impaired person. The right choice of the microcontroller component is a definitive step towards the implementation of the proposed system. The microcontroller is the central component of the embedded application having an impact to the total cost and future upgrades of the embedded application.

2.2 GPS Tracker

The GPS tracker is the component of the embedded application which provides in real time and with excellent precision the geographical coordinates of the moving person. Our embedded application employs a GPS tracker based on the u-blox NEO-6M chip (besides GPS, it also supports the Russian GLONASS system), interfaced to the microcontroller via UART at 4800bps baudrate. It features a precise positioning exploiting up to 16 geostationary satellites, leading to a precision of 13 decimal places and location accuracy of 0,11m. The maximum refresh rate of the geographical coordinates is 1Hz, i.e. once in a second. The selected tracker also demonstrates an Eco Mode which deactivates the acquisition engine as long as the tracker location can be calculated through an adequate number of satellites.

The use of an external GPS tracker provides a much greater positioning accuracy to the application compared to the integrated smartphone tracker. We measured deviations in the order of 10m between the locations reported by the smartphone GPS tracker and the corresponding real geographical coordinates. Such deviations may not be that important for car navigation, but are crucial for pedestrian mobility. Therefore an external high-precision GPS tracker must be employed in the demanding context of our pedestrian navigation application for visually impaired people. Figure 1 illustrates the significant deviation in location precision between the external and the phone GPS tracker and represents the shortest deviation measured in a number of trials. The external GPS tracker was receiving signal from 11 satellites providing a precision of 13 decimal places and location accuracy of less than 0,4m.

11	85	37.947731018023.6643733978534	01/22/2016	07:29:22	697	13.00	0.00	0.04	N	2391	316.76	NW	35235 140	386
11	85	37.947731018023.6643733978541	01/22/2016	07:29:23	702	13.10	0.00	0.04	N	2391	316.76	NW	35736 142	392
11	79	37.947727203323.6643753051550	01/22/2016	07:29:24	713	13.20	0.00	0.04	N	2391	316.76	NW	36237 144	398
11	79	37.947727203323.6643753051559	01/22/2016	07:29:25	720	13.40	0.00	0.04	N	2391	316.76	NW	36739 146	402
11	79	37.947727203323.6643753051569	01/22/2016	07:29:26	730	13.50	0.00	0.00	N	2391	316.76	NW	37243 148	407

Figure 1. Deviation in location accuracy between external (red marker) and smartphone (blue marker) GPS tracker.

A parameter we had to fine tune was the refresh rate of the longitude and latitude coordinates of the walking person. As refreshing the coordinates every second at the maximum tracker rate will increase the power consumption while not differentiating significantly the new coordinates from the last ones, we specified a 5 sec refresh rate. A slower rate might obstruct a blind person from navigating efficiently in real time.

2.3 Keypad

The use of a keypad was required since visually impaired persons cannot use the smartphone touch screen for system configuration and operation. The operation principle of a hex keypad is very simple consisting of 4 rows and 4 columns and uniquely mapping keys according to their positions in the 4x4 matrix. A dual button operation was implemented in order to double the available offerings. Through the keypad, the user is able to select a destination among up to 32 predefined destination locations.

2.4 Bluetooth

A Bluetooth module undertakes to send the application data from the microcontroller to the smartphone application. The proposed system integrates a EGBT-046S Bluetooth module which is based on the CSR BC417 radio chip. The module is interfaced to the microcontroller via UART at 9600 baudrate and is administered via AT commands. Serial communication over UART was implemented using the SoftwareSerial basic library of the Arduino IDE. Data can be received via a 64-byte buffer even when another task is occupying the microcontroller.

2.5 Sonar Distance Meter

Goal of this function is to inform the blind or visually impaired about obstacles in the near field along the route and the best way to bypass them, in parallel to the ongoing vocal navigation using the GPS information. We implemented this functionality interfacing a small-sized sonar (sound navigation and ranging) device mounted on a servomechanism able to quickly direct the sonar beam across a large viewing angle so as to detect the width of obstacles and help the application issue proper avoidance instructions (see Figure 2). Its operation principle relies on the Doppler phenomenon. The particular sensor integrates an ultrasound generator and a receiver. Obstacles reflect the transmitted ultra sound back to the receiver. Taking into account the speed of sound in air, the elapsed time serves to calculate the distance to the remote object. The proposed embedded system integrates an HC-SR04 ultrasonic ranging module featuring up to 4m measurement function and 15 degree measuring angle. Measuring angle can be reliably extended via the integrated servo-mechanism implementing a semi-circle radar view function, as depicted in Fig. 2. The distance of the remote object is calculated from the width of the positive level of the received echo pulse using the formula (high level time * 340m/s)/2.

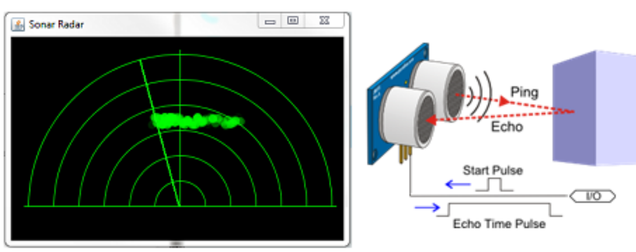


Figure 2. Ultrasonic ranging module and radar view operation

By properly operating the servomechanism to implement a visual identification of obstacles similar to a radar view function, the object positions and distance in the near field of the navigating person can be accurately calculated. Moreover the application can take advantage of increasing the spatial range of the ultrasound wave. The objects in the near field can be depicted on a plane with linear, and even area, calculations revealing the best way to avoid them and triggering the corresponding voice instructions.

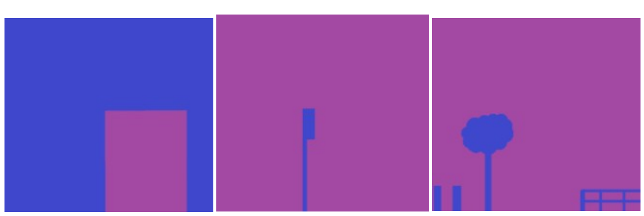


Figure 3. (i) Wall avoidance through door. (ii) A post or traffic light. (iii) Multiple obstacles.

Near ground obstacles and abnormalities (e.g. curbs, potholes etc.) cannot be easily handled through the sonar. The blind can instead efficiently handle such ground obstacles through his/her cane.

The application provides information on the existence of stairs in the near front field. The dead-end sonar indication when ascending stairs can be disregarded using the relevant map information. The descending stairs case is jointly signaled through the map information and the clear sonar view.

To minimize the annoying frequent issuing of unnecessary sonar information, the implemented radar view functionality continuously calculates successive measurements and reports only those objects in collision trajectory which are stepwise approached by the blind or visually impaired. Walking persons can be recognized among fixed obstacles via relevant velocity calculations. In case of a fixed obstacle identified by the radar in collision trajectory towards the blind person, the system issues avoidance commands taking into account the width of the obstacle (e.g. "Obstacle at 2m. Move 1.5m to the right to avoid it").

The sonar/radar function is able to reliably guide the user to walk in safe distance parallel to building walls along his/her route as well as in safe distance from parked cars along the pavements.

3. ANDROID APPLICATION

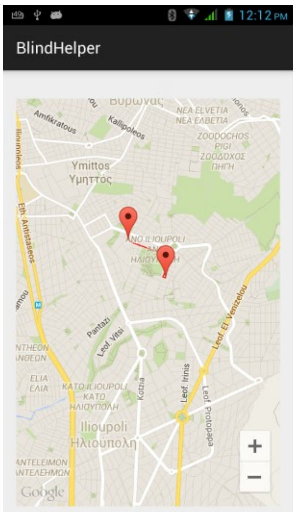
The smartphone application was developed on the Android platform, which according to IDC dominates the worldwide smartphone OS market. The Android market share in Q2 2015 reached 82.8% with iOS far behind at 13.9% and Windows Phone at 2.6%. These figures reveal not only that the vast majority of people are using Android devices but also a fierce competition between Android smartphones manufacturers which has squeezed Android smartphone prices against the other competitors. The key reason behind adopting Android is therefore the fact that it drives the product price, including the smartphone cost, lower than any other development platform. The BlindHelper application runs on all devices running Android version 5.0 or newer and supporting Bluetooth connectivity and Internet access over a mobile radio access network.

3.1 Libraries

Finding and using appropriate libraries is a cornerstone of an efficient software implementation. The use of libraries can help avoid needless code writing and shorten time to market. Their effective use assumes an essential understanding of the functions implemented in the library. Sometimes minor or several changes in a library function code may be required for the correct operation of the system under development. In our reference development we have used the following libraries: (1) android.bluetooth: Handling of Bluetooth connectivity and socket communication for data transmission and reception. (2) com.google.android.gms.map: Handling of Google Maps. (3) java.net.HttpURLConnection: Used to receive the routing path in JSON format, including streets in code format. (4) android.os.AsyncTask: Used to translate Google places data in JSON format.

3.2 Main Class

A handler, basically a message loop, is created whenever the application is reading data via Bluetooth. The BluetoothAdapter class represents the local Bluetooth device and is used to instantiate a connection with the embedded Bluetooth module with the proper connection parameters, as well as to create a Bluetooth socket to read the Bluetooth packet with the start and destination location coordinates in message format. A map method places two markers at these locations on the map. Next the navigation instructions are downloaded (via downloadUrl) in JSON format and an AsyncTask parser method undertakes to decode the streets and call voicenav with the HTML instructions that speaks the navigation. Voicenav exploits the Texttospeech class calling its speak method to convert the string type instruction to a voice command (e.g. "At 32m head east on Mavrommateon toward Mezonos. At 56m slight right onto Thrasivoulou. At 200m turn left onto Evridikis. At 100m turn right toward Mavili. At 44m turn right. Take the stairs. Destination will be on the left").

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   },
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},
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Figure 4. Android application.

3.3 System Configuration

The Android application includes a configuration activity which allows an assistant person to easily configure and store destination locations of interest in the application for navigation purposes and assign destinations and other useful functionality to the keypad buttons. Our goal is to provide a personalized system which can be adapted to the particular needs of the individual users.

4. ADDITIONAL FUNCTIONALITY

ATMega328p is an expandable microcontroller which provides a lot more interfacing capabilities than those reserved by our system. Therefore, several system upgrades are feasible which are highlighted below.

4.1 Sync with Traffic Lights

The interaction of the embedded application with the traffic lights can help the blind or visually impaired walk safely. It requires a simple patch to the traffic light including a microcontroller and 3 normally closed relay switches inspecting the traffic light states (red, green, and yellow). The status of the traffic light is broadcasted to the BlindHelper embedded system via an RF transceiver and the user is informed in real time via voice about the status of the traffic light s/he is approaching.

4.2 Weather Information

Weather information is important in our daily routine. Learning about the weather will help the blind or visually impaired person dress properly for walking outdoors. The user can ask the BlindHelper application to report local weather information through the keypad. The Android application is then retrieving weather information through a web service and informs accordingly the user via voice.

4.3 Multiple Uses

An ultimate goal of the BlindHelper application is to easily allow the blind or visually impaired use his/her mobile phone to serve basic needs, such as dialing/answering a call, notifying about an emergency situation, informing about his/her exact location coordinates etc.

5. SYSTEM PACKAGING

The requirement for easy device portability guided our efforts to develop a small wearable device. The BlindHelper embedded device is a small wearable device which can be attached to a hat. This ensures a clearer view of the sky to obtain a GPS signal as well as a clearer sonar view of the near field which allows a more precise depiction of the obstacles in the immediate area and corresponding avoidance guidelines. Currently, a few BlindHelper prototypes have been given to the Lighthouse for the Blinds of Greece in order to evaluate the system with real users and receive valuable feedback for system functionality improvement.

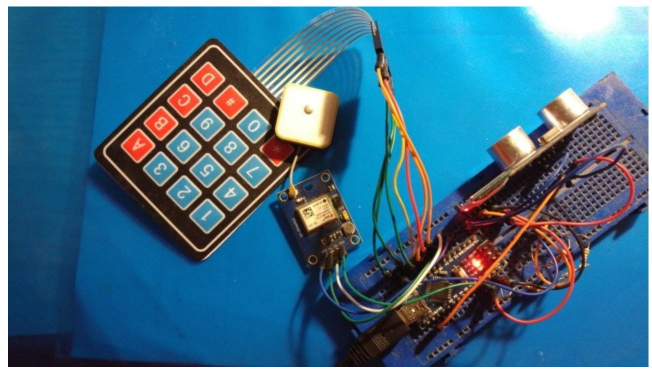

Figure 5. Prototype embedded system hardware.

6. REFERENCES

[1] Miesenberger, K., Fels, D., Archambault, D., Peňáz, P., Zagler, W. 2014. Computers Helping People with Special Needs. *Int. Conf. ICCHP 2014,* Paris, France, July 9-11, 2014. Springer LNCS, Vol. 8547-8.

[2] Loadstone GPS, http://www.loadstone-gps.com

[3] LoroDux, http://wiki.openstreetmap.org/wiki/LoroDux

[4] MobileGeo, http://senderogroup.com/products/shopmgeo.htm

[5] Seeing Eye GPS, http://www.senderogroup.com/products/shopseeingeyegps.htm

[6] BlindSquare, http://blindsquare.com

[7] Ramarethinam, K., Thenkumari, K., Kalaiselvan, P. 2014. Navigation System for Blind People Using GPS & GSM Techniques, *Int. J. of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, April 2014.

[8] Koley, S., Mishra, R. 2012. Voice Operated Outdoor Navigation System for Visually Impaired Persons, *Int. J. of Engineering Trends and Technology*, Vol.3, Issue 2, 2012.

[9] Bousbia-Salah, M., Fezari , M. 2007. A Navigation Tool for Blind People, *Innovations and Advanced Techniques in Computer and Information Sciences and Engineering*, 2007, Springer, pp. 333-337.

[10] Ran, L., Helal, S., Moore, S. 2004. Drishti: An Integrated Indoor/Outdoor Blind Navigation System and Service, *IEEE Int. Conf. on Pervasive Computing and Communications (PerCom'04)*, Orlando-Florida, 14-17 March 2004, pp 23-30.

[11] Loomis, J., Colledge, R., Klatzky, R. 1998. Navigation System for the Blind: Auditory Display Modes and Guidance, *Presence*, Vol. 7, No. 2, April 1998, pp. 193-203.