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Mobile Applications Aiding the Visually Impaired in Travelling with Public Transport

Piotr Korbel, Piotr Skulimowski, Piotr Wasilewski and Piotr Wawrzyniak
Institute of Electronics
Lodz University of Technology
ul. Wólczańska 211/215, 90-924 Łódź, Poland
Email: {piotr.korbel, piotr.skulimowski}@p.lodz.pl

***Abstract*—The paper presents a set of mobile applications aiding the visually impaired in using the public transport. A user equipped with a modern smartphone with mobile data transmission and positioning capabilities can access location related context information. Keeping up the connection with dedicated system servers gives the user access to additional services, e.g. enables the use of passenger information system and provides access to services facilitating the navigation in urban areas. The paper describes an overall architecture of the system for guidance and public transport assistance of the visually impaired. Then, the details of the applications developed for Android based smartphones are presented. The applications are mainly focused on aiding in urban navigation and provide various ways of accessing data from public transport passenger information system.**

***Index Terms*—Context-aware services, mobile computing, personal communication networks, pervasive computing, radio navigation**

I. Introduction

ACCORDING to the World Health Organization there were more than 285 million visually impaired living in the world in 2012 [1]. Even moderate vision impairment may strongly affect their everyday activities and often leads to social exclusion. Inability to sense the surrounding environment, poor orientation and navigation capabilities, difficulties in accessing textual information result in a limited mobility of the blind and the visually impaired [2]. Travelling becomes especially challenging in urban areas. Lack of good spatial orientation makes difficult to find a safe path among obstacles, and to locate and identify points of interest (POI) like bus stops or pedestrian crossings. Inability to access textual information like street name, public transport timetables, numbers of vehicles gives rise to additional difficulties. Recently, a number of electronic travel aids (ETA) addressing the needs of the visually impaired have been developed. The devices are used to overcome difficulties associated with everyday activities, i.e. problems with spatial and geographical orientation, navigation, accessing visual information. Electronic systems aid the visually impaired in mobility and in accessing various public services. One of the applications of the electronic aids is to facilitate access to public transport services. Precise information on user location can be used to retrieve position related data from public transport passenger information systems, e.g. bus or tram arrival times, information on routes, temporary changes to the timetables, etc. A number of electronic systems aiding the visually impaired in urban travelling involve various beaconing techniques to identify landmarks like bus or tram stops, entrances to public buildings, etc. [3][4][5][6][7]. Transmitters installed in the landmarks send signals uniquely identifying the place. System information can then be decoded with the use of a dedicated handheld receiver and presented to the user as voice messages. Another approach to guidance of the blind involves the use of dedicated user terminals equipped with GPS receiver, GSM transceiver and inertial sensors [8][9]. With the growth of popularity of advanced mobile phone terminals, more and more smartphone applications aiding the visually impaired in navigation and travelling appear on the market [10][11][12]. Some of them, like OnTheBus project [10], address also the problem of public transport accessibility. Significant number of various ETAs have been developed so far trying to solve different mobility difficulties. However, many of the assistive devices and applications address only selected aspects of the mobility problems, and hence have not gained wider acceptance of their target group of users so far. Therefore, there is still a pursuing need to develop complex solutions aiding the visually impaired in mobility as well as aiding other groups of users in travelling in urban environment.

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II. System for guidance and public transport assistance

The architecture of the proposed system for guidance and public transport assistance of visually impaired is shown in Fig. 1. The system consists of several subsystems: a mobile user terminal, a network of radio beacons, and application servers. The mobile user terminal can either be a dedicated electronic device or an Android based smartphone. Dedicated terminals, equipped with GSM/UMTS transceivers, GPS receivers, inertial sensors and a camera are used to obtain precise user location information, to provide communication channel to remote assistant of the user, and to present voice messages to the user. The Android smartphone based version of the terminal in general plays the same role, however, its functionality can be easily modified by installing additional applications. In the next section of the article we present a

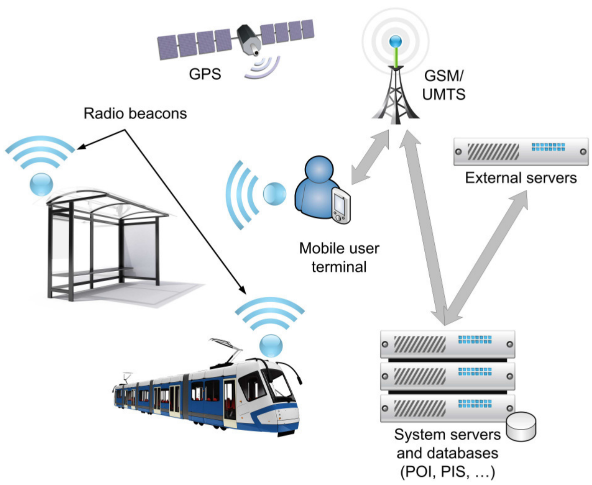

Fig. 1. Architecture of the electronic system for guidance of the visually impaired in urban environment.

set of mobile phone applications aiding in urban navigation and public transport accessibility. The network of low power and low range radio transmitters is used to provide precise information on actual location of the user and to facilitate access to position related data, e.g. a timetable of vehicles arriving at the bus or tram stop [13]. The servers of the system store public transport passenger information data and points of interest databases, as well as expose services enabling communications between all of the system components.

A. Passenger Information System

Currently a lot of cities operate real-time public transport management systems (PTMS). Such systems help transport company to increase the efficiency of running vehicles, reduce travel times and/or improve the punctuality, especially when PTMS is integrated with traffic lights management system. Very often PTMSs include passenger information subsystem (PIS) providing information about estimated arrivals and/or departure times as well as travel times. Usually such data are displayed on dedicated signs located within bus stops. However such approach is very useful for almost all passengers it is completely useless for blind and semi blind people for obvious reasons. Similar system is operated in Lodz, Poland by municipal transportation company MPK. Lodz is mid-size city in central Poland of the area 300 km^2 with more than 700000 inhabitants. MPK operates about 200 trams and 400 buses serving almost 100 routes. Trams and buses fleet is managed by RAPID system delivered by Sigtec, Australia integrated with adaptive traffic system SCATS developed by Road and Maritime Services in Sydney. Currently RAPID controls 14 passenger information signs located on tram stops, in 2013 next 16 signs will be added. Vehicle localization in MPK system is made by on-board GPS receivers. Vehicles send data to the server in 20 seconds intervals. Position messages are also sent when the vehicle enters or exits stops and intersections. This allows the server to estimate travel times and send predicted departure times to stop signs. In case of traffic problems passengers can also see appropriate messages. Unfortunately blind people due to the nature of their disabilities cannot be informed about, vehicles approaching or awaiting at the stops, vehicle delays and temporary changes in route paths introduced in response to serious traffic problems. Visually impaired people may also found problems with stops localization, especially when they do not know city topology or stops were moved to temporary locations due to street construction works. Blind aid system designed in Institute of Electronics is connected with MPK system through VPN tunnel and receives in real time all major information: current timetables, route paths, vehicles allocations, trips cancellations, detours, run-ins and run-outs. The system also incorporates radio tags placed on stops, points of interests as well as vehicles. There are running two services for travel aiding: trip planner and trip assistant. The aim of the trip planner is to find optimal from blind people point of view route from point A to point B. Trip planner optimizes travel time as well as walking distance necessary to reach the destination. Starting and ending trip points may be described as geographic coordinates and/or points of interest including public transport stops. Travel start time interval must also be described. For guided people convenience trip planner allows for maximum one vehicle exchange. Vehicle kind (tram, bus or both) may also be specified. Regardless the form of describing start and end points of the travel trip planner locates up to 10 nearest stops. Even if direct trips were found the system also searches for trips with one exchange. This allows to find several trips serviced with different routes and select the best one for the guided person. In the case where no trips were found system increases default values for the maximum distance between change stops and searches for start and end stops within greater radius. As a result following data for each trip are obtained: trip identifier, route number, direction, vehicle identifier and type (tram or bus), estimated arrive times for first and last stops, distance between starting point and start stop and the distance between ending point and end stop.

Arrive times are calculated by averaging travel times between consecutive stops for given route, type of the day and time of the day. As the type of the day working days, Saturdays and holidays are distinguished. The whole day is divided for 2 hours intervals, so separate calculations are performed for peak and off-peak hours. Trip assistant starts working when the passenger begins journey approaching starting stop. Awaiting passenger may be informed about estimated arrive time of the desired vehicle. Next, when passenger entered the vehicle, he/she may be informed about remaining stops to the destination or the exchange stop as well as about remaining time of the travel.

III. Mobile Applications for the Visually Impaired

To present the information from the public transport Passenger Information System to the users, a set of mobile phone applications was developed. POI Explorer and Public

Transport Explorer applications dedicated for Android based smartphones are used to aid the visually impaired users in urban navigation and travelling. Two other applications use NFC and USSD technologies to access the data. The NFC application can be used with any NFC enabled device. Taking into account low market penetration of NFC capable phones, also USSD messaging was implemented as an option available to almost all the range of mobile phones.

A. Smartphone Based Urban Navigation ij POI Explorer and Public Transport Explorer

Blind users usually use iOS or Android based mobile phones. The reason for that is that both the systems have built-in text to speech modules: Voice Over [14] and TalkBack for iOS and Android respectively. Availability of such system modules allows developers to create their own applications using standard GUI elements which can be easily presented to the visually impaired users. Most of smartphones are equipped with touch screens and have gesture-based screen readers, for example a single tap causes a button's description to be read, requiring a double tap to activate the button's original function. Such an interaction with a smartphone requires the use of both hands and may be especially uncomfortable for blind users who are at the same time using a white cane. That is why we proposed a dedicated electronic device, equipped with Bluetooth module and keyboard which can be used to control selected functions of mobile applications [15]. Moreover, it can be used to read data from a network of radio beacons indicating various point of interest [13], and to pass this information to the phone. Depending on the beacon type, application can present the user information on entering some area, on vehicles approaching a stop, etc. We developed two applications POI Explorer [16] and Public Transport Explorer aiding the visually impaired in travelling with public transport. They are dedicated for the most popular mobile platform: Android. First one uses points of interests to the navigation purposes. They are stored on remote MySQL/PHP server, which allows to keep the database update. Moreover, such a solution allows to provide a universal API for other platforms. To exchange the data between the server and mobile phones XML language was used. Users can also add additional personalized information to the points (text notes, voice records) to enrich the database. POIs are organized into categories and subcategories, which allows to find necessary information easily. After logging in it is possible to add user's private data (paths or points of interests).

Users are navigated along the predefined paths or to the selected point (e.g. selected bus stop) using distance and direction information. Because the electronic device is equipped with an electronic compass, mobile phone can be kept in a pocket and the user can use the device for the orientation purposes. Keyboard allows to select application functions. Text to speech module is used to read messages. Additional feedback is provided by the vibration engine. POI Explorer can be also used without the device, in this case TalkBack screen reader is used for sonification of messages. The POI

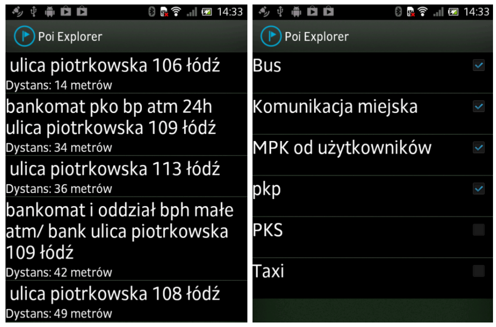

Fig. 2. Screenshots from the POI Explorer application captured by Sony Xperia S Android Phone. The list of the points of interests in the front of the user (direction is calculated based on compass values) are presented in a standard list box. On the right: list of subcategories of the category "Transport".

database can be managed using web application. Such solution is dedicated for sighted persons (for example someone from visually impaired person family) and allows to plan path or to manage private POIs.

Public Transport Explorer application uses data served by passenger information system. Users can get timetables, current position of the selected vehicle, they can also plan their travel. As the passenger information system relies on actual GPS based positions of the public transport vehicles, the data presented to the user are up-to-date. It especially important if the user is inside the vehicle, where GPS signal can be very weak. This feature is also of a great value when the stops are moved to new, temporary locations, or when the routes or timetables of public transport vehicles temporarily change. As can be noticed, the graphical user interfaces of POI Explorer and Public Transport Explorer use large, high contrast characters aiding users with moderate visual impairment. System requirements of our applications allow to run them on low cost devices. Both applications have been consulted with the blind users from the Polish Association of the Blind.

B. NFC Enabled Passenger Information System Access

Near Field Communication (NFC) is designed to allow short-distance data exchange. It supports data exchange in two modes: passive mode, where only one device generates electromagnetic field (carrier) while the other device only modulates it. Moreover, modulating device might use power from electromagnetic field generated by another one, thus making one of the devices a transponder. The other mode is an active mode, where both devices generate EM fields alternately. Developed NFC enabled Passenger Information System makes use of the passive NFC tags. The tags are placed close to timetable boards at the bus or tram stops. Every tag stores a code that uniquely identifies a stop and redirects the user to a dynamically generated web page presenting the most up-to-date information on the bus or tram arrival times. The advantage of the electronic timetable is the use of real time data from passenger information system, therefore the web

Fig. 3. Screenshot of an application for NFC enabled passenger information system access.

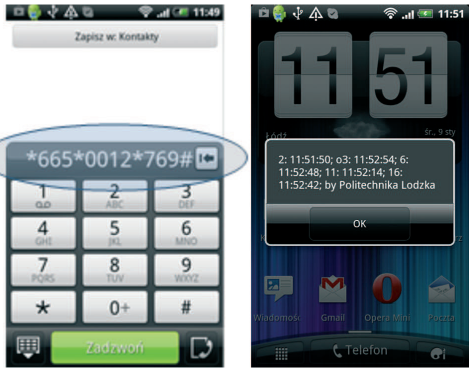

Fig. 4. USSD enabled passenger information system access.

page always displays actual bus or tram departure time as shown in Fig. 3. For this stateless service a dedicated proxy service has been developed. It uses Windows Communication Foundation (WCF) to provide RESTful API for passenger information system.

C. USSD Enabled Passenger Information System Access

Unstructured Supplementary Service Data (USSD) is a protocol used in GSM network for data exchange between mobile phone and Public Land Mobile Network (PLMN) infrastructure. With the use of API exposed in Telco 2.0 model it is possible to use USSD messages for communication between any GSM-enabled device to any Internet service. Proposed access method requires user-initiated USSD session. In the initial message (that is provided in the same manner as number user want call to) user has to provide unique USSD service prefix (assigned by PLMN operator) and a bus or tram stop number. When a user initiates the dialogue, a message is passed through internal PLMN components to Telco 2.0 WebGateway (exposing PLMN features to the Internet) and then to Passenger Information System application server. Information on next bus/tram departure time is then retrieved from the system via aforementioned proxy service and sent back to the user as shown in Fig. 4.

IV. Summary

Although many electronic travel aids have been developed so far, urban spaces and public transport services still remain hardly accessible to the visually impaired. Poor spatial orientation and inability to access textual information makes difficult to locate and identify bus or tram stops and to read public transport timetables or numbers of vehicles arriving at the stops. The system described in the paper is a part of a solution aiming at assisting the visually impaired in travelling with public transport. The passenger information system provides actual data on routes and timetables of the vehicles while proposed mobile applications makes that information accessible to the users equipped only with ordinary mobile phones.

Acknowledgment

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