METHODS OF NAVIGATION IN THE MOBILE APPLICATION SUPPORTING MOVEMENT OF THE BLIND

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This paper presents conclusions from the last development phase of the "Voice Maps" project. Authors specify newly found available options for navigation in affordable system for the blind with all their related aspects. System uses dedicated geographical data, built-in smartphone GPS receivers and DGPS external device in order to assist blind users in their everyday travelling. Authors also discuss new methods to improve positioning accuracy and navigation reliability (map matching and remote pathfinding) along with interface modules for the blind.

INTRODUCTION

"Voice Maps" system prototype was discussed in last year's article presented during XXIX Symposium on Hydroacoustics (SHA 2012) [1]. In this paper authors discuss conclusions from the last phase of this project, during which final version of the system was developed.

Implemented solution is significantly cheaper than other competitive products. It also offers a richer set of functionalities than existing solutions, especially in a field of positioning. The simplest method is based on built-in GPS (Global Positioning System) smartphone receiver, but its accuracy in certain conditions, e.g. bad weather, high buildings in close proximity, is not sufficient for pedestrian navigation. This flaw is compensated by methods discussed in the third chapter of this paper. Reliability can be further improved by wireless (Bluetooth) communication with the DGPS (Differential Global Positioning System) receiver, which was also implemented and operationally verified. External GNSS (Global Navigation Satellite System) receiver that allows carrier-phased measurements along with real-time kinematic algorithms could be also integrated into the application. Moreover "Voice Maps" mobile application is not using dedicated mobile hardware, which is a frequent disadvantage of similar projects. It is developed for Android operating system, which is available on a wide range of mobile devices, i.e. smartphones and tablets (Fig.1).

Fig.1. Voice Maps mobile application on the Android smartphone [photo by NCBiR].

Geographical data (from urban areas) in “Voice Maps” were specifically acquired for the blind and include POI (Points of Interest) and POA (Points of Attention) information, which are used to warn users of nearby obstacles and potential hazards located on their path. Methods of data acquisition devised for this project are universal and not localization-dependent, it is possible to use them worldwide in order to extend “Voice Maps” operational coverage.

1. SYSTEM ARCHITECTURE

“Voice Maps” system architecture was originally local. Mobile application (main system client) along with all the data (prepared in the dedicated editor and stored in the external database) were copied onto the smartphone and no internet connection during the navigation process was needed. It was a requirement specified in the initial phase of the project [2]. When authors found methods to implement new UI (user interface) elements to assist the blind in entering data into the application (chapter 4), which required internet access, it was decided to reject this requirement. Consequently, new UI mechanisms could be implemented and it was possible to modify the system architecture to become remote based (Fig.2). All the data and pathfinding service were moved to the external server accessible through the internet. It significantly decreased the size of the application and its hardware requirements in the context of memory size and computational power, which are limited on the mobile devices.

There is also a possibility, by using OSM data importer on the server - where system main geographical database is located, to use spatial data from the open source project OpenStreetMap. It was founded in 2004 and was inspired by the success of the Wikipedia. Every user can add and edit existing data and its coverage is still expanding.

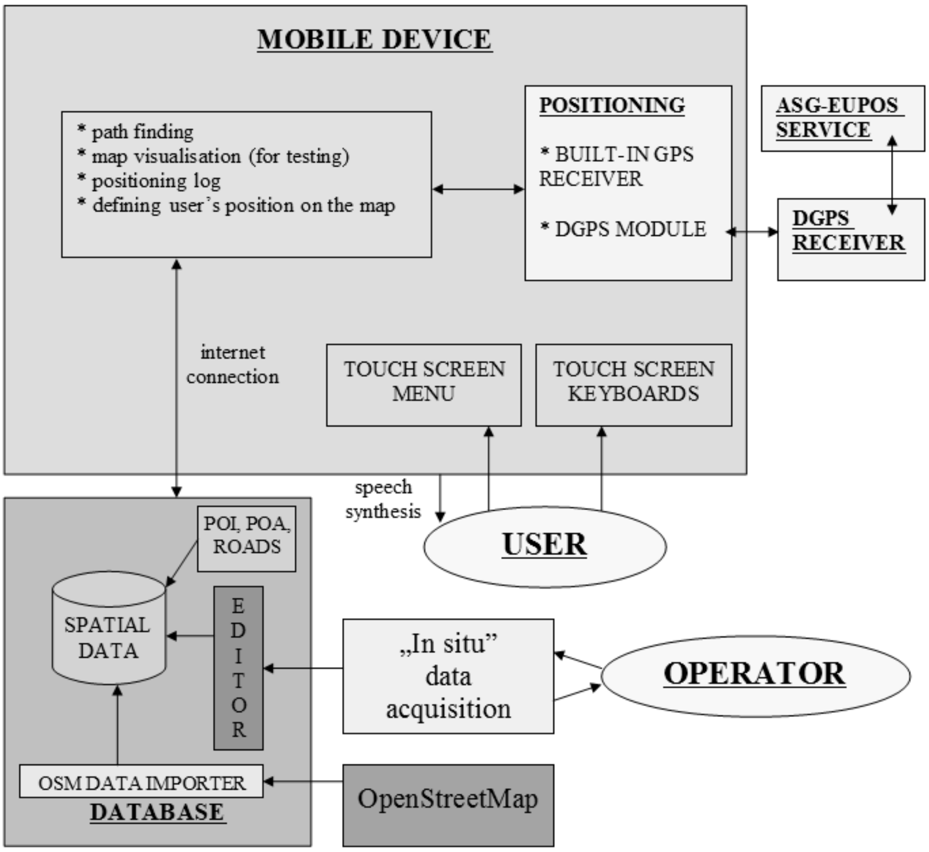

Fig.2. The final version of the "Voice Maps" system architecture.

2. POSITIONING

Accurate positioning is one the most important aspects of pedestrian navigation, especially when it comes to assisting visually impaired people. Various methods are used (GNSS, DGPS, RTK - Real Time Kinematic, etc) in order to obtain position - two of them are used in "Voice Maps".

First method is to obtain position via built-in or external GPS/GNSS module connected in Android using Bluetooth. This method uses standard GNSS positioning techniques based on NMEA (National Marine Electronics Association) protocol sentences.

More sophisticated receivers like u-blox LEA-6T module [10] allow to obtain carrier-phase measurements. LEA-6T allow to measure GPS system L1 signal, more expensive receivers allow to receive L2 signal as well. Research [6] was made to perform evaluation of this module using RTKLib [11] software and corrections from ASG-EUPOS DGPS service [8]. Obtained results were satisfactory and there is a possibility to use discussed methods in "Voice Maps" after further research.

Tab.1. Advantages and disadvantages of GNSS positioning.

Advantages	Disadvantages
- cheap (most devices have built-in GPS) - easy in use and configuration - quick positioning	- not very accurate - more accurate methods require long initialization time

Second way of positioning is to use external Differential GPS (DGPS) receiver [9]. The device can be connected via Bluetooth by dedicated software module in "Voice Maps" application. DGPS uses specialized base stations as a reference to perform positioning corrections. Although this solution is not perfect (it has bigger requirements and is more expensive), the main advantage is that it provides better accuracy than standard GPS. During testing phase device from eTrex was used (Fig.3).

Fig.3. eTrex DGPS used in "Voice Maps" tests [9].

Tab.2. Advantages and disadvantages of DGPS positioning.

Advantages	Disadvantages
- more accurate than standard GPS	- expensive device - require additional time to plug-in and configure - require signals from reference stations

As a source of reference and corrections ASG-EUPOS [8] service can be used (polish system of reference stations). It can also provide ionosphere corrections in real time. This data can be integrated with raw measurements to provide better accuracy of positioning [6].

Methods described in previous paragraphs provide solutions to obtain more accurate measurements of the geographical position provided by satellite positioning systems. Even if the acquired position is more reliable, errors connected with time measurement, atmospheric effects and especially multipath issues may still occur. Navigational systems in applications for the blind must be extremely dependable and the need of additional solution for maximizing positioning quality has emerged.

Map matching is a technique used to determine user geographical position based on location information and electronic map. In general this problem is difficult because both location and digital geospatial data are typically not accurate.

First of all terminology must be defined - since in “Voice Maps” the representation of the geographical features is kept in a form of the graph, the graph theory definitions will be used. The edge or section in the graph represents linear objects, e.g. streets or sidewalks. The vertices in graph represent crossroads, points of attention (POA), e.g. stairs, road signs or other obstacles and points of interest (POI), e.g. bus stations or hotels.

Map matching procedure begins with finding the edges in the area of received geographical location. Search should start from fixed distance value and if appropriate number of edges was not found, search should be repeated with higher distance value. Initial value estimation should be based on graph density. Founded edges are being referred to as candidate polylines [4] or edges.

In the literature several map matching methods were proposed [3][4][5]. The easiest one is based on finding the edge that is closest to the received position. For each of the candidate edges an orthogonal projection of current user position onto the edge is calculated. Distances, which are equal to the length of the segments between determined points and user location, are being compared and the edge with the smallest value is chosen. This solution may produce unpredictable errors as presented in figure (Fig.4). Let’s assume that user is moving along the A edge. When he is close to A and B segments’ intersection his determined position is wrongfully placed on the B edge.

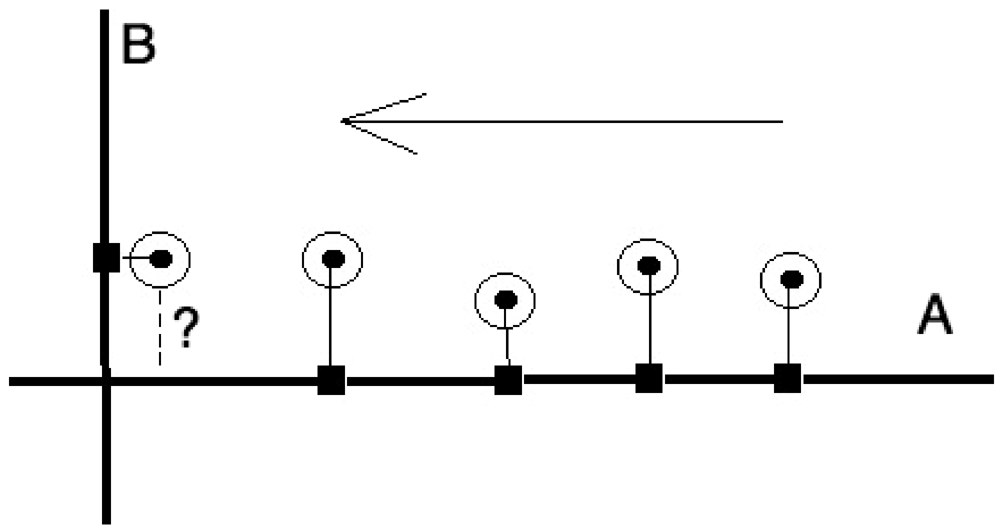

Fig.4. Incorrect map matching to the closest edge.

It is clear that another set of parameters must be taken under consideration. Since the information about topological relations in graph and past travel path is available, there is a possibility to use them for error detection. Previously chosen edge can be compared with the new location data to obtain better accuracy. It can be assumed that user may stay on the last found edge or can move to the next edge when there is a connection between them. Segments that do not have topological relation with previous edge should be removed from the candidate edges set. Figure 5 presents situation in which user would be falsely placed on the B edge instead of A edge if only the closest segment method would be used.

If the time rate of a location data acquisition is high, then the distance travelled between calculated positions is sufficiently short. Therefore other map matching parameter can be established as the length of the path between previous edge and candidate segments. It can be assumed that the edge with the smallest path should be chosen. As shown in Figure 5, the path containing A, B and C edges is longer than the one containing only the A segment.

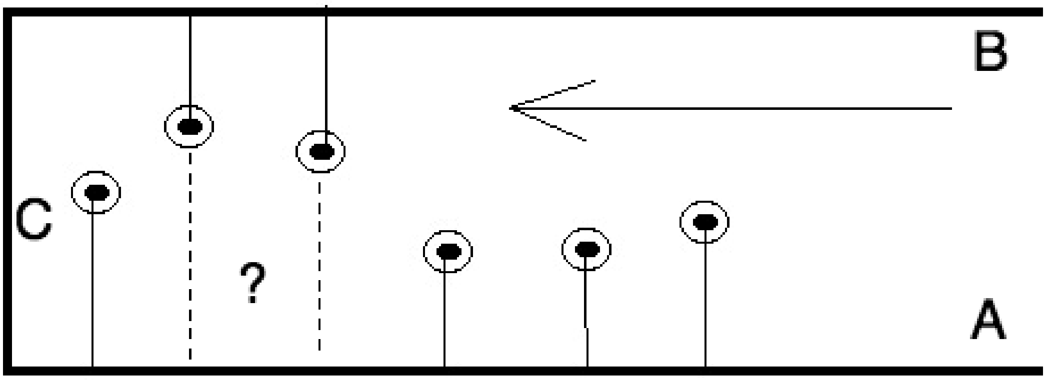

Fig.5. Incorrect map matching to the edge without topological relation with previously selected edge.

Location information contains azimuth of the movement, which can also become a parameter for map matching procedure. The angle of the candidate edge can be compared with the azimuth to estimate the approach degree. It can be assumed that the edge with the smallest angle difference is the one to be chosen during the map matching process. Figure 6 presents situation in which previously described methods would produce incorrect results. Comparing the angle approach can provide data that will allow determining the correct solution.

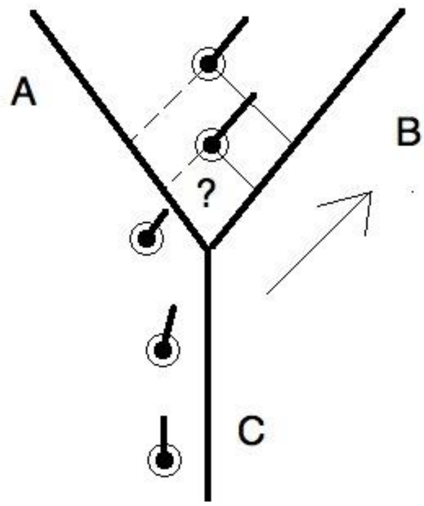

Fig.6. Map matching using approach degree estimation.

The map matching process in “Voice Maps” uses all of the aforementioned methods. The presented algorithm calculates distance d between received location and the point of the orthogonal projections onto all of the elements of the candidate segments set. Thereafter, the path distance p as well as the approach degree a is estimated for all edges.

In the last step, results are normalized and the weight function is created. Formula is as follows:

$$L = w_d \cdot d + w_p \cdot p + w_a \cdot a$$

where:
w_d- distance weight,
w_p- path distance weight,
w_a- approach degree weight,

Edge with the smallest L value is selected in the implemented map matching process.

3. METHODS OF NAVIGATION

Every navigation system require a module which will provide a path to a selected destination. To perform this task, the aforementioned module should provide path-searching process on the graph used for navigation. In “Voice Maps” the Routino [7] module was used.

Routino is used to find routes from the current location to the to the specified destination. This software is published on GNU Affero General Public License. In general it is used to perform vehicle navigation - the process of route-finding uses the spatial data, which includes speed limits and toll information. In the presented solution Routino was configured for pedestrian navigation and data with sidewalks and pedestrian paths were loaded into it.

In order to perform path-searching three sources of data are needed. First one is the current location. As mentioned in the previous chapter this is provided by positioning process. Secondly, there is a need for the navigational graph. In “Voice Maps” graph can be obtained from OpenStreetMap [12] or from dedicated server, which holds previously gathered data. The last source of data is the destination point - in this case it is often represented by the Point of Interest.

Points of Interest (POIs) are a standard element of navigation solutions. Single point consists of typical address data along with geographic position. POIs database can contain information about banks, public services, shops, restaurants, government buildings, etc. In “Voice Maps” POIs are grouped in categories and can be chosen using the dedicated menu. It can be either searched by name or by the closest distance.

Second type of navigational points are Points of Attention (POAs). POA is a specialized point that contain information about places which require special attention (like obstacles, street lamps, construction sites, etc). POAs are divided into several categories. Single point is described in dedicated attribute, which can also contain additional description. When POA point is nearby, application warns the user and reads additional description (if it is available). As these points describe potentially dangerous obstacles, they have significant priority in the voice messages queue.

4. USER INTERFACE SOLUTIONS FOR THE BLIND

During the “Voice Maps” development the design and correct implementation of the UI (user interface) elements for the blind were one of the project’s most important goals and a key factor of success. Those mechanisms were required to enable the visually impaired users to receive information (e.g. directions during navigation process) and input data to the application (e.g. travel destination). Various methods of two-way interaction were successfully integrated.

Voice communication is the obvious choice in interfaces for the blind. In “Voice Maps” system it became the primary method of user interface in both aspects of data direction: input and output. Messages in the application are generated and read using speech synthesis during nearly every interaction with the device, i.e. in the main menu they inform about available options and currently selected item, whereas during the navigation process user is given directions for the next control point of the path and is warned about nearby obstacles and POIs.

Data input is more problematic. Initially, only methods based on the mobile device touch screen and dedicated software keyboards were created (Fig.8). First keyboard has the whole alphabet arranged in a form of a table displayed on the whole screen. Letters and digits are placed in columns and rows contain successive groups, i.e. from “1” to “6“ or “w” to “y”. Symbol’s placement is configurable and can be arranged according to the preferences of the user. During system tests with visually impaired users alphabetical order was determined to be sufficiently comfortable. Symbol selection is achieved by sliding the finger on the screen (each selected letter is read to the user) and lifting the finger adds current letter to the string, which, for example, can be used for determining travel destination.

Second software keyboard is based on the gesture recognition algorithm. User is drawing the consecutive characters of the desired phrase, e.g. the name of the restaurant he wants to visit. “Backspace”, “space” and “end” actions also have assigned symbols. All the gestures are predefined using dedicated external editor (Fig. 7) and the whole set is preloaded into the application.

The last method of data input is the speech recognition. It uses a built-in Android feature and requires internet connection. After user’s speech is recorded by the “Voice Maps” application it is sent to the Google API service which analyzes the recording and sends back the set of the most probable results. When the whole process is completed user can select the right string. If the desired phrase is not present, there is an option to retry the speech recognition or input the data using the preferred software keyboard [2][9].

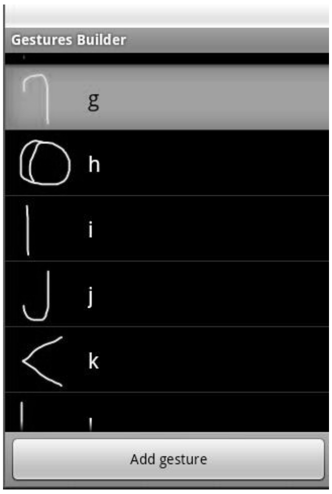

Fig.7. Gesture editor.

Fig.8. Dedicated software (gesture and table-based) keyboards [photo on the left by NCBiR].

5. CONCLUSIONS

This paper summarizes the most important conclusions from the last phase of the “Voice Maps” project. During the development two architecture models were evaluated and the second model, which requires internet access and uses server services remotely, turned out to be more universal (in terms of the mobile device hardware requirements) and provided more possibilities for the UI functionality, e.g. speech recognition.

Various methods of positioning were also researched. Built-in smartphone GPS receivers proved to be the cheapest method, but their use is limited by their reduced accuracy. Better dependability was achieved by the external DGPS receiver. Implemented map matching algorithms substantially reduced the amount of errors occurring in the previously stated methods of positioning and improved the navigation of the blind in the urban areas.

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REFERENCES

[1] Ł. Kamiński, A. Stepnowski, Ł. Markiewicz, Voice Maps – System supporting navigation of the blind, XXIX Symposium on Hydroacoustics, 2012.

[2] Ł. Kamiński, Mobilny system informacji przestrzennej wspomagający nawigację osób niewidomych w terenie miejskim (in Polish), PhD thesis, Gdańsk, 2012.

[3] L. Xi, Q. Liu, M. Li, Z. Li, Map Matching Algorithm and Its Application, Advances in Intelligent Systems Research, 2007.

[4] N. Tradisauskas, D. Tiesyte, C.S. Jensen, A Study of Map Matching for GPS Positioned Mobile Objects, 7th WIM Meeting, 2004.
[5] S. Taghipour, M.R. Meybodi, A. Taghipour, An Algorithm for Map Matching For Car Navigation System, Information and Communication Technologies: From Theory to Applications, 1-5, 2008.
[6] B. Wiśniewski, K. Bruniecki, M. Moszyński, Evaluation of RTKLIB's Positioning Accuracy Using low-cost GNSS Receiver and ASG-EUPOS. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, Vol. 7(1), 79-85, 2013.
[7] http://www.routino.org/
[8] J. Bosy, W. Graszka, M. Leończyk, ASG-EUPOS, a multifinctional precise satellite positioning system in Poland, European Journal of Navigation, Vol. 5(4), 2-6, 2007.
[9] Ł. Kamiński, K. Bruniecki, Mobile Navigation System For Visually Impaired Users In The Urban Environment, Metrology and Measurement Systems, Vol. XIX, 245-256, 2012.
[10] http://www.u-blox.com/de/lea-6t.html
[11] http://www.rtklib.com/
[12] http://www.openstreetmap.org/