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Client-server Approach in the Navigation System for the Blind

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ABSTRACT: The article presents the client-server approach in the navigation system for the blind - "Voice Maps". The authors were among the main creators of the prototype and currently the commercialization phase is being finished. In the implemented prototype only exemplary, limited spatial data were used, therefore they could be stored and analyzed (for pathfinding process) in the mobile device's memory without any difficulties. The resulting increase of spatial data scale and complexity required a modification of the data storage and operation. Consequently, the decision was made to maintain a central spatial database, which is accessed remotely. After that modification, the mobile application fetches the required batch of spatial data (with the pathfinding and search results) from the central server through the mobile internet connection, which has also become necessary for other purposes (e.g. voice recognition). The authors present the advantages and disadvantages of this new approach along with the results of the server operational tests.

1 INTRODUCTION

The main goal of the "Voice Maps" project was to design and implement a fully operational navigation system supporting movement of the blind. The system should work properly in dense urban areas. The development process consisted of two main parts: the creation of the prototype and the product commercialization phase. The second phase included field tests with end users.

There are two main approaches to the vector data (Shekhar et al. 1999) storage mechanisms. First one is the remote database access (Google 2013). Second one is to keep all the necessary map data in a local mobile device memory (Nokia 2013).

All of the known and investigated by the authors applications supporting navigation of the blind use local memory. Processed geographical data is stored on the navigational devices, such as smartphones or tablets (Sendero GPS 2013, Trekker 2013, LoadStone 2013).

In the first phase of the "Voice Maps" project, which consisted of research and preliminary software development, the system prototype was successfully implemented. It consisted of main mobile application and, stored in local device memory, exemplary spatial data gathered by the authors and cooperating project-team members using both existing data sources (e.g. OpenStreetMap) and in-situ data acquisition methods (Kaminski et al. 2011).

The application User Interface (UI) had to be designed for the blind users. Developed solution consists of a touchscreen-based main menu, which is divided into 12 equal square fragments (Fig.1). The options are chosen by moving the finger on the screen.

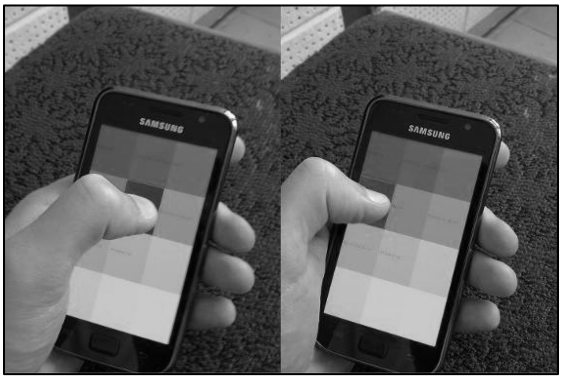

Figure 1. Main menu of the application (Kamiński et al. 2011).

All of the available options are read to the user using the speech synthesis. Input data, e.g. addresses or Point of Interest (POI) names, is entered using dedicated and customized software keyboards (e.g. gesture or voice recognition keyboard) built-in into the application (Fig.2).

In the preliminary design various versions of the mobile application were to be created for different mobile operating systems and they would be linked by shared Java libraries. In the later stages of the development process a decision was made to focus on Google Android operating system and its compatible devices. This change was based on the fact that other planned platforms did not offer sufficient functionality and have lost most of its market share (mainly Symbian and BlackBerry supported by JavaME – Fig.3).

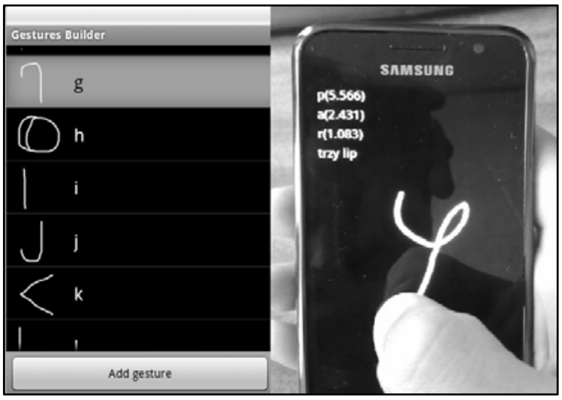

Figure 2. Gesture keyboard for the blind (Kamiński et al. 2011).

Figure 3. "Voice Maps" application on Android, Symbian and JavaME (Kamiński 2012).

The Android operating system definitely dominates current smartphone market (Gartner 2012) and offers key features for the navigational systems for the blind.

The preparations for the commercialization are currently being finished. During the last project phase it was necessary to assess the prototype version of the system, especially the mobile application, in terms of using the system on the large scale. This evaluation could not be performed only in the limited testing environment. It quickly became apparent that the data locally stored on the device were not the optimal option. Spatial data scale and complexity changed significantly and the system had to be redesigned in order to modify the data storage and access.

After the modification, the mobile application downloads through the internet necessary parts of spatial data on-the-fly, as it is needed, remotely from the central server. This approach is new in the navigational systems for the blind and its advantages and drawbacks, along with the data transition, are being analyzed in this paper.

2 COMPARISON OF THE OLD AND NEW SOLUTIONS

2.1 *The previous solution – data stored on the client*

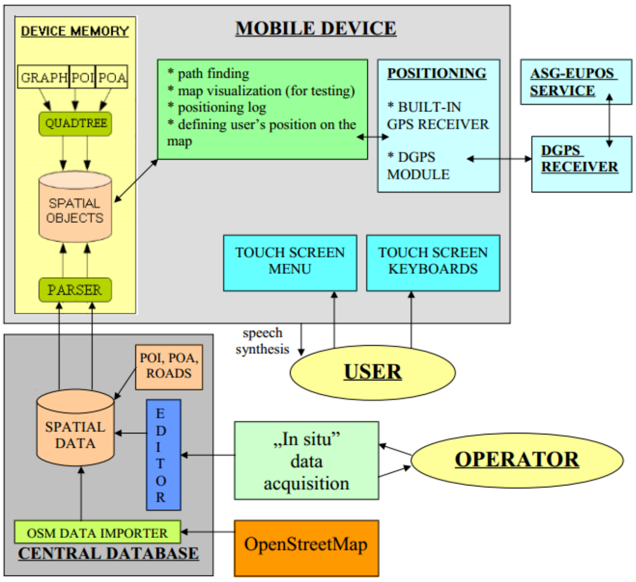

Figure 4. The first version of the "Voice Maps" system.

The simplified diagram of the "Voice Maps" system prototype is presented in the Figure 4. The system modules used for the spatial data acquisition, storage and access are visualized at the bottom. The first version of the system stored all the spatial data in the central database. The data was then converted into "Voice Maps" native format (quadtree structure) and copied, as a whole, onto the mobile device memory. The pathfinding between the current position and the chosen destination (i.e. POI or address) was performed on mobile device. This was done locally, without need to establish connection to the central database (Stepnowski et al. 2011).

Precision of built-in Global Positioning System (GPS) receiver is sufficient in the most cases (Zandbergen & Barbeau 2011) and therefore it was used for positioning. There is also an option to replace it with external Differential Global Positioning System (DGPS) module in order to further increase the accuracy.

While performing the operational analysis of the system prototype the project team have identified a few important issues. Those problems concerned the system design, authors recognized the modules that needed to be redesigned and required to be reimplemented. During the prototype phase of the system development the spatial data was limited and not very complex. Therefore the solution in which the spatial data were stored and processed locally performed very well. With the acquisition of consecutive data from other parts of Gdansk and other cities it became apparent, that the aforementioned solution was increasingly inconvenient in the terms of "Voice Maps" navigation system.

The spatial data updates in the previous system version had to be done manually on each of the devices. The update process consisted of copying all the data from the central database onto the smartphone. Despite providing the notification mechanism implemented in the application, user action was required during each update. Additionally, storage of the considerable amount of data on the mobile device, in terms of the software and hardware limitations, imposed the implementation of the complex algorithms, that were optimizing the spatial data access time (i.e. quadtree structure). Also the optimal pathfinding between two points was done on the mobile device, which became great issue due to limited computational power compared to the desktop computer.

In order to solve these problems the authors decided to change the model of data storage, access and processing. It was decided to move a part of the functionality from the mobile device to the remote server. All the required changes are described in the next chapters of this paper.

2.2 *The new solution – data storage, searching and pathfinding on the server*

During the preparation phase it was decided that the best solution is to move all the gathered data into the central database, from which only necessary pieces of information will be downloaded via wireless connection by the mobile application. All the main advantages and disadvantages of that decision are presented in the next two paragraphs of this article.

The mobile application has become a client, used mainly to send requests to the database, provide the user interface, positioning, navigation and to store user's configuration preferences. The server has become more extensive as three new modules were added to its architecture (Fig.5).

Those modules are:

- Data sharing module, which allows mobile application to download selected data from the database,
- POIFetcher, that allows to search for the requested Points of Interest,
- Routino (Routino 2013), a specialized module which finds a path between two given points.

The new solution is to provide the mobile application with fragments of data that describe area in the closest surroundings of their current location. Provided data dynamically change when users move to a different location, so application always contains only information that is needed to guide user toward his current destination.

In addition, the announcement module, which used the voice synthesis, was also extended in the mobile application. It became apparent that messages should sound more human-like, therefore specialized module was implemented to process the description data of the nearest surroundings and prepare a natural language message.

All the data are not stored on the device in this new solution, so the mobile application cannot provide full search of the path whenever the requested destination point is outside the temporary graph, because of this fact part of the new solution was to transfer path searching algorithms onto the server. The mechanism of path searching is provided by the specialized server module – Routino.

To keep up the most accurate Point of Interest data, POIs also were moved to the server-side central database. The new solution is to keep POIs data on the server and provide users with categories and search mechanisms.

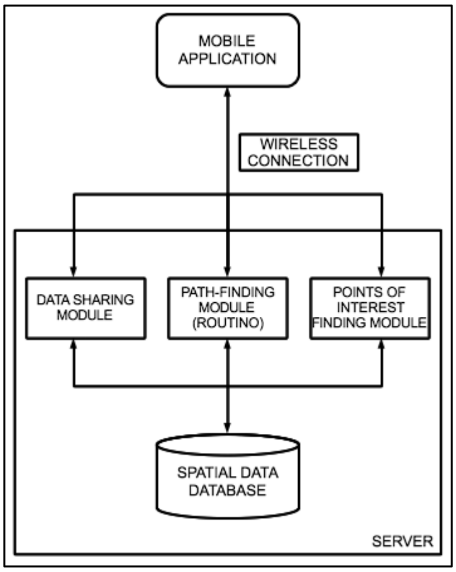

Figure 5. Changes in the system architecture forced by the adoption of remote database access.

Application is always supplied with the most current data and users can select categories (e.g. "shops", "restaurants") and server will find a shortest path from the user's current position to the nearest POI from that category. The graph used in the application is temporary and the given route is static. There is a need to synchronize these two sources of data every time a graph of the nearest area changes, this functionality is performed by the mobile application. The effect of this synchronization is described on Fig.6.

The most important part of the data stored in the server is the graph representation of geographical features. Data format is standardized for Geographic Information System (GIS). Open Street Map (OSM) is incorporated as the base layer of the spatial data. OSM is an open source project aiming to create an editable world map (Hazzard 2011). Data is available under a Creative Commons open content license. OSM contributors perform regular surveys with GPS devices, government and commercial data sources are also used.

OSM spatial data set consists of three types of data structures:

- points,
- lines (multilines),
- polygons.

Points represent discrete places with defined geographical position such as address points, Points of Interests (POI) or Points of Attention (POA). Lines consist of a set of points and segments which represent linear objects (e.g. roads, sidewalks, rivers or crossroads). Polygons include a set of lines which create bounded areas which represent buildings, country borders, etc.

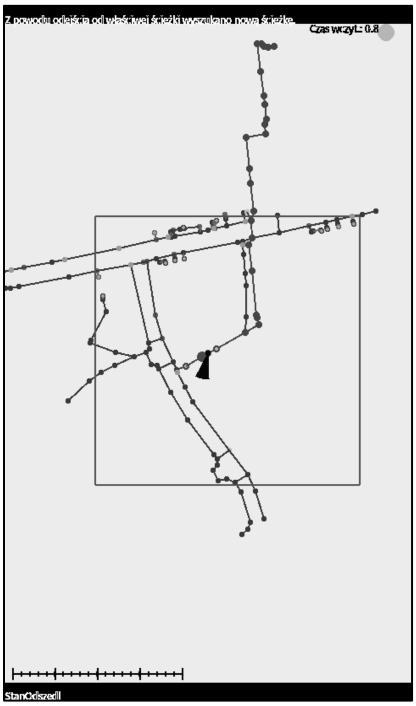

Figure 6. Graph of nearest surrounding synchronized with found path.

Voice Maps is a system created for the navigational assistance of the blind or visually impaired. It requires a different data set than the typical navigation systems (i.e. purposed for cars) (May et al. 2003). Accurate spatial information about sidewalks and pedestrian crossings are especially important and are not typically included in OSM and other popular databases as shown on Fig.7.

It was decided that additional data is required. Survey was performed by the project cooperator, OPEGIEKA LLC, for the test area of the city of Elbląg in Poland. Acquired data contains information about crossings, addresses, surroundings description (i.e. POI / POA) and corrections to the OSM data.

Client application is a front end of the "Voice Maps" system. The mobile application, a client, is a proxy between the user and server-side modules (e.g. geospatial database, algorithms). Touch screen interface allows blind user to utilize all functions of the project. "Voice Maps" can also be controlled with the voice commands. Voice recognition is implemented using Google API. When user selects this option the voice sample is recorded on the device and then sent through the internet to Google servers, where it is analyzed in a matter of seconds. After that the set of the most probable text strings, which represent the content of the user's speech, are sent back to the mobile application. These strings are mainly used to choose options in the main menu or to input data (i.e. addresses, POI). This method is proved to be the most comfortable for the blind users, whereas the visually impaired preferred dedicated software keyboards.

Figure 7. OSM data without sidewalks and zebra crossings.

Using touch screen the application can be configured with several options, which are available in the "Settings" menu. It allows to change the application-user communication. User can decide to be additionally informed about the azimuth or distance to the current path destination or the next path node. Application can also inform the user about the details of the surrounding area (i.e. surface type, obstacles) and the closest POI, POA, addresses.

"Voice Maps" system is mainly targeted for users in the urban areas. It requires not only aforementioned spatial data but also high accuracy positioning. Depending on available hardware, application can receive current geographical position from built-in GPS device or external DGPS receiver which typically provides higher accuracy (Monteiro et al. 2005).

3 FEATURES OF THE NEW SOLUTION

3.1 *The advantages of the new solution*

Applications purposed for the blind should be maximally easy to use. All the activities taken by its users have to be repetitious and also should take minimum effort to be learnt and remembered (Farrel 1956). Number of actions performed by the blind to achieve their goal must be minimal. All of the user actions require simplicity, for example in the remote data access the latest version of the software is acquired in the easiest manner possible, simply by running the application and sending queries to the server. Since the most of the data, which is the graph representation of geographical features along with its description, is kept on the server side, no action from the user is required to receive updated data. Moreover, some enhancements and improvements, like pathfinding or POI search, can be added without changing the client.

Navigation system for the blind is different from typical car navigation systems (Millonig & Schechtner 2005, Aslan et al. 2006). Providing direction for sightless pedestrian requires much more precise and accurate data including user's current position, directions and information about the nearest surroundings. The target users of “Voice Maps” have the limited ability to orientate and identify obstacles in their nearest surroundings – given information must be as exact as possible. One of the elements is the high density graph representation of metropolitan areas' geographical features, which may contain a large amount of vertices and edges.

Significant computational power is required to perform processing of that amount of data. It is also required to assure considerable memory capacity. Since “Voice Maps” system is targeted for the Android-based smartphones the issue of the mobile device capabilities becomes important. Moving most of the geospatial data from client to server not only reduces the size of the software, but also lowers the system requirements. It is especially important for the older devices.

What is also worth mentioning, the spatial database and elements of the server-side software can be used in other Geographic Information Systems (GIS). The existing high-density data and advanced graph algorithms can be easily adapted to become elements of different (e.g. car or pedestrian) navigation applications.

The new solution makes application development less difficult. Thorough and wide testing of software is easier to perform thanks to the availability of the server logs. Moreover, it enables the possibility to add several enhancements to the system, for example the functionality to remotely monitor the behaviour of the blind.

3.2 *The disadvantages of the remote server access*

Remote spatial database access in “Voice Maps” requires stable wireless internet connection. Since the navigation system for the blind must be very reliable, various problems with network (including lost connection, transfer speed or limits and lost signal) may become very important. However, nowadays, coverage of the cellular network in the metropolitan areas is usually high and should be sufficient. When user receives information about geographical features located in a fixed distance from his position, additional data are sent only if he leaves the aforementioned area. This kind of approach not only limits the needed transfer to minimum but also, if the connection is temporarily lost, ensures data availability. It is also worth mentioning that module for spatial database access is not the only software component that needs stable internet connection. Since the voice recognition software is incorporated in “Voice Maps”, wireless internet connection is necessary.

In the previous solution, the most time-consuming operations, like pathfinding and search for requested vertex in a graph, were performed on the client side. In the new solution all of those operations are executed on the server. This approach requires a sophisticated server infrastructure. Moreover, considering the characteristics of blind users, the quality of that service must maintain a very high level of reliability. Therefore, the new solution enforces keeping considerably expensive data center.

Communication with remote spatial database created non-trivial problems in the software development. The issues of synchronization with database processes (such as response time, network delay) and client-side threads are only a part of them. On the other hand, new version of “Voice Maps” does not require advanced methods for optimizing the size of the files containing information about the geographical features (e.g. quadtree).

4 SERVER OPERATIONAL TESTS

After the system prototype completion a set of software simulators were implemented in order to check server operation in various conditions, regarding the performance of commands executions and data transfer effectiveness. The main goal was to measure the average response time of the server when 1000 queries are being sent at the same time from the simulated mobile applications.

The first test evaluated the time needed for the creation of the graph based on the OSM geospatial data. Queries were sent to the server and the average time of the graph creation was 297 milliseconds (Figure 8). This delay is not noticeable for the user. The maximum value was about 2.6 seconds, but it was concluded to be caused by the mobile connection problems, not the mobile application or server itself.

During the next test the effectiveness of the POI generation for the nearest area of the user current geographical position was measured. The average response time was about 60 milliseconds, so taking into the consideration that typical user will not move faster than 1 m/s, the process is almost instantaneous and it is sufficient for pedestrian movement.

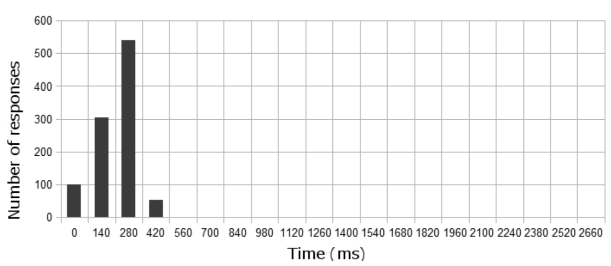

Figure 8. Distribution graph of the measured system response time to a request for graph creation.

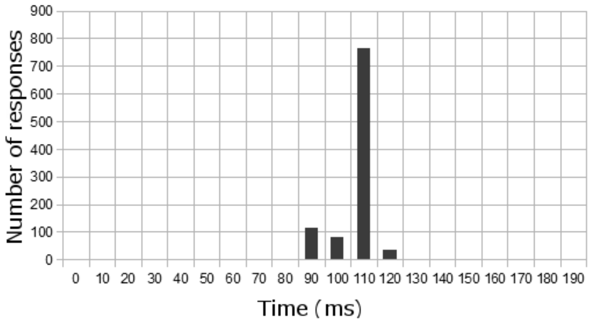

Figure 9. Distribution graph of the measured system response time to a request for generation of a new route.

The third and the last test was checking the performance of the Routino pathfinding module on the server. Queries for various paths were sent from the mobile applications and the average time of the shortest path generation for the selected destination (within one city) was 110 milliseconds and the maximum time was 190 milliseconds (Figure 9). From these values it can assumed that the pathfinding server module response time is sufficient for navigational assistance during the typical pedestrian movement in the urban areas.

The results of the server tests along with successful field tests of the mobile application show that the "Voice Maps" server is operational and the system as a whole is ready for the commercial deployment.

5 SUMMARY

Test results of the new solution are very promising. Instead of performing difficult and time-consuming calculations, the application now focuses on a user and navigation interaction. There is still room for some improvements in the future, but for the time being the solution is well rated by the end users. Most of functionality trials, along with a part of reliability and server tests, were performed by the end users.

The main advantage of the new solution is an increase of time efficiency for both the users and developers of the system. Updates are no longer an issue, as they are now performed on the server. This assures that user always gets the most current data. The application is lighter and, which is important, needs less computational power – that also means less battery consumption. Main calculations are performed on the server and downloading data became the most time-consuming task. However, remote data access causes the main disadvantage, i.e. a need for the server and a reliable network connection. The first one is an important architectural problem, while the second is not very significant in the era of fast and omnipresent internet.

A significant advantage of the presented solution's strengths over its drawbacks, as well as encouraging test results, confirm our belief that the system division into client and server side (along with the remote database access) is the best solution in the navigation systems for the blind.

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