Multilayer Information Management System for Personalized Urban Pedestrian Routing

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1 ABSTRACT

The present paper aims to describe the work carried out inside the ARGUS project to design and develop a software tool that manages heterogeneous cartographical datasets in order to offer personalized routing services. The project is focused on guiding blind and visually impaired in urban and rural environments with the help of binaural sounds. The navigation algorithm in the ARGUS smartphone application relies on GPX tracks containing the path to follow and informative points of interest along the path. These GPX files, previously recorded or created on demand, are downloaded from the remote service platform where the Multilayer Information Management System is hosted.

This module handles, on one hand, crowdsourced data from OpenStreetMap and ARGUS users and, on the other hand, cartography from individual city providers. Moreover the system defines a set of spatial attributes to categorize the most relevant and signifcant types of urban elements for the target user group, which are represented as geographical point or lines, enabling users to decide which type of objects have a positive effect such as tactile pavements, negative or neutral effect during the trace of a path. This user specified aproach affect the route finding by changing the routing weights. Different levels of visual impairment and skills from one user to another, as well as personal preferences, make this module a decisive configurable abstraction layer for the route calculation module.

2 INTRODUCTION

2.1 The visually impaired and ARGUS project

Navigation systems for cars and road traffic are widely used by millions of people everyday to reach unknown destinations or simply help during driving. In a similar way, navigation solutions for pedestrian also exist, and with a proper interface, they can get even more useful in the case of people with disabilities to help them live more autonomously.

The ARGUS project was born with the aim of developing a solution that provides new means of pedestrian navigation for users with visual impairments. It relies on a satellite based navigation (GNSS/EDAS – EGNOS Data Access System) terminal for people with impaired visual capabilities, guiding them along pre-defined tracks using binaural sounds. It introduces an innovative guidance support system based on the provision of a non-intrusive virtual-lead-line perception. This offers a more natural “track navigation” instead of the classical “waypoint or route navigation” which is used for car navigation or people with all visual capabilities. Appart from the innovative binaural instructions, the project has covered the development of an underlying personalized route generation module, which works upon an heterogeneous spatial data set managed by the Multilayer Information Management System module. This Multilayer Information Management System (MIMS) is what this paper aims to present, which basically consists of a PostgreSQL database with PostGIS pgRouting extension and a set of C++ classes.

2.1.1 <u>System architecture</u>

The general architecture of the whole ARGUS solution is as shown in Figure 1. The Service Platform offers the web services used by the user interfaces to interact with the itinerary creation and management modules. The MIMS module handles all the data that comes from different sources, such as cartography providers or information uploaded by users, and interfaces with the web services and the itinerary creation.

The User Terminal shown in the figure, consists of a smartphone application and a positioning unit for the GNSS reception and processing.

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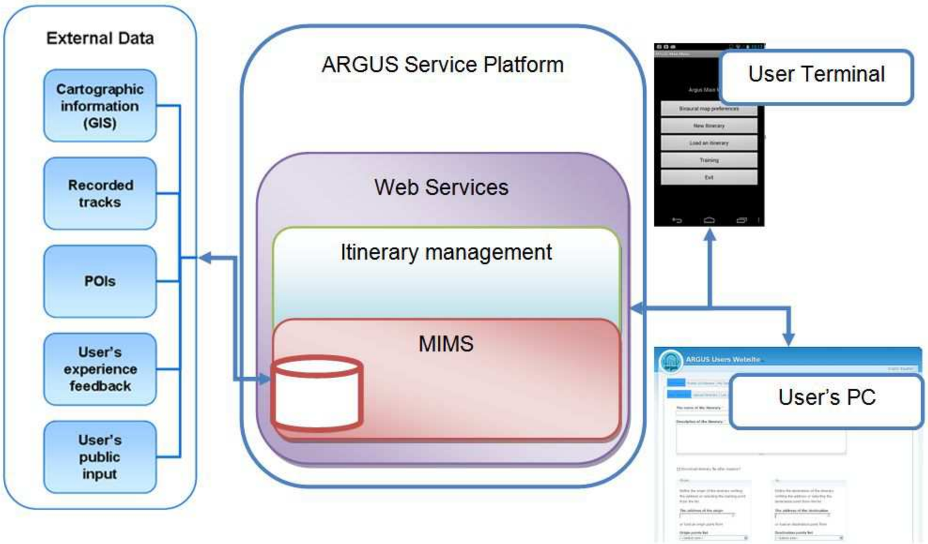

Fig. 1: General architecture of the ARGUS Solution

3 SPATIAL DATASETS

3.1 OSM

The Base Cartography is the geographical data needed to create the base spatial layer upon which the routing network topology is built. Digital mapping providers (both commercial and crowdsourced) digitally recreate the different real-world kinds of roads, ways, areas or buildings geographically referenced. Crowdsourced maps use inputs from community users. This base layer in ARGUS is taken from OpenStreetMap, one of the most known crowdsourced open source map service worldwide, with good coverage in Europe. The prototype consists of cartography in the following cities: Soest (Germany), Vienna (Austria), Madrid (Spain), San Sebastian (Spain) and Portsmouth (UK).

3.2 City Data

OSM provides the possibility to map pedestrian sidewalks as a separate geometry, but in general, the exact geometry of the pedestrian walking axis is not recorded. In that case, the sidewalk is usually added as an attribute on the street geometry, which only indicates the existence of a sidewalk (e.g. sidewalk=left).
Therefore, the ARGUS project partners tried to get more detailed geometry data within the different pilot areas to improve the cartography of the ARGUS network and inherently, the route calculation. Detailed pedestrian data was acquired from the test region of the city of Soest and the test region of the city of Vienna. The city of Vienna provided routable pedestrian data from the GIP (Graphenintegrationsplattform) dataset of a small test area near the Vienna town hall with additional relevant Points of Interests for blind pedestrians. Furthermore,the city of Soest provided detailed routable pedestrian data for the whole region of Soest from the ALKIS dataset of Germany.

3.2.1 Comparison

For the sake of a comparison, an example of a small extent in Vienna is shown in Figure2, where OSM network and specific Vienna city network are overlapped. The main contribution of the City Data is that sidewalks and zebra crossings geometries are perfectly defined and aligned along the axis of the streets where pedestrians can walk safely.

3.3 Points of Interest

The Points of interest in ARGUS are both Generic POIs obtained from the cartography providers, and personal points that users can upload to the system. They can be classified according to different categories. Also, user points are classified into three possible natures: GREEN (private personal points), BLACK (shareable negative points) and WHITE (shareable positive points). The negative or positive nature of a point influences the calculated route. Some categories of Generic Points of Interest can also have a default nature of WHITE or BLACK, if they should be treated as points to avoid or as helpful points (like acoustic zebra crossings).

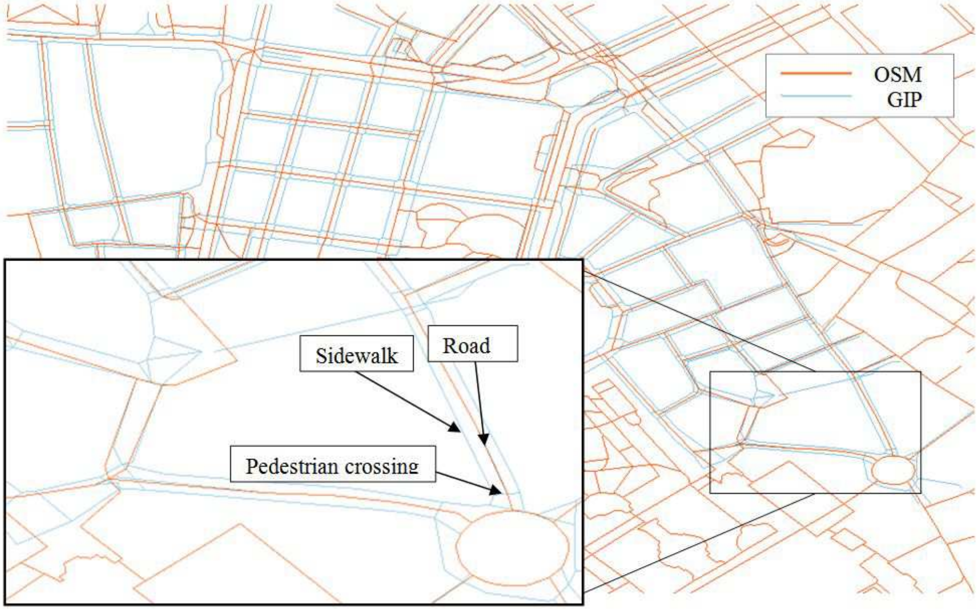

Fig. 2: Comparison of the two OSM and City networks in Vienna

3.4 Tracks/Routes

Tracks and routes are ordered sets of geographic points that describe a path, stored in a GPX file, and also represented as a linestring in the ARGUS database. On one hand, the route calculation module generates a GPX file for an origin - destination pair on each request (called route) based on the cartography and the Points of Interest; on the other hand, the User Terminal can record a real path (called track) performed by the user and upload it to the system for later use (instead of creating a new route) or sharing it with the community.

4 DATA PRE-PROCESSING

4.1 Preparation of the OSM data

The data structure is based on nodes, ways, relations and tags. For a routable network it is important that every way element has to be fragmented at every crossing of the streets. In ARGUS, the converter and routing engine tool osm2po is used to create a routing network. This tool creates a routing topology table with the connection information from one edge to the next. Additionally, it calculates default costs which are based on the length of the edges and the average configured speed of the different road categories. These default costs of the tool cannot be used for the pedestrian routing in ARGUS, because the speed is not relevant for the route calculation due to the different user behaviours of people with visual impairments. Therefore the ARGUS system implements their own dynamic weight model based on the different users.

Edge weights must be calculated in order to find suitable routes for people with visual impairments, as the whole route cost will be tried to minimize by the route calculation. Additionally, the ARGUS user has the possibility to classify special categories as helpful objects or objects that should be avoided during the route. These different user preferences influence the weight of the routing graph. The Dijkstra algorithm implemented in the PostGIS shortest_path function is used to get the optimal path based on the lowest weights.

For the computation of the weights of each edge, additional data have to be added. The goal of a routing topology engine is to process only the OSM data relevant for the routing calculations. Therefore, it does not provide information about the complete attributes of the OSM data. The user defined attribute information of the OSM dataset will also rely on OSM attribute information (like for example letterboxes, etc.) and therefore attribute information of the OSM dataset of the edges and nodes has to be imported into the database. In the project ARGUS, the import tool osm2pgsql is used. Osm2pgsql is a tool, which converts and imports the OSM data format to a PostgreSQL database. This tool adds features that use certain tags, which are defined by a configuration file and transforms the nodes and ways to linestrings and polygons. It is only used to import the data into the database, but has no routing functionality in it, so the dataset can't tell which linestring is connected to each other.

The imported OSM attribute data is connected with the routing table by the use of the unique OSM ID. This enables the routing table to get more information about the used attributes of edges or nodes.

4.2 Preparation of the City data

The cartography used in Vienna and Soest is very heterogeneous. First, they do not have a common structure (ALKIS dataset of Germany, GIP dataset attributes of Austria). And, second, they use different attributes. The database inheritance concept within PostgreSQL has been taken as a basis to abstract the underlying original data source from the above common layer used by ARGUS web services. Therefore, tables are classified as "Parent" – "Child" tables. The concept of inheritance allows joining common attributes in one table like geometry, name, etc. of various datasets and provide a unique ID for all datasets. For that reason, a common set of attributes was defined which every dataset has to fulfil. These attributes are the minimal necessary attributes for the creation of a routing network graph: source, target, geometry, length of the edge, name and the classification of the street based on OSM classification value which is used for the buffer and the assignment of POIs to the network edges. The parent table holds the common information of all child tables and is connected to each child table. The child tables provide further information about the inhomogeneous attributes of the datasets. The same concept is also used for the city POIs; therefore, two parent tables were created (city_network and city_POI).

Among the advantages of this approach, on one hand, a common structure is obtained, with additional diverse attributes in the child tables. On the other hand, simple extendibility and the use of same attributes of all available city data is achieved. The use of inheritance in the database layout offers a flexible and extensible way for the import of the city GIS data and gives the possibility to easily integrate them in the future.

5 PERSONALIZED ROUTE CALCULATION

5.1 Category and Preference configurations

A set of categories was defined based on requirements collected from user surveys and completing it with OSM categorizations. Street segments can be categorized according to OSM attributes (both coming on line or point elements) or the existence of generic or user defined points of interest nearby. Table "category" collects all the possible categories and their default behaviour on route calculation (as seen on Table1). Two tables ("category_preference" and "category_preference_extension") handle specific user preferences to modify this behaviour.

Id	categoryname	defaultnature	typeuser	class	value	osm	typeroute
50	Pavement Furniture	3	TRUE	Others	0		TRUE
51	Stairs and steps	3	TRUE	Others	-1	"highway=steps"	TRUE
53	River	3	FALSE	Others	-1	"waterway=river"	FALSE
56	Specially adapted walkway	1	TRUE	Users	1		TRUE
57	Dropped Kerb	0	TRUE	Users	2		TRUE

Table 1: Sample values in table "category" where categories are classified and tagged

The calculation of weights in the routing algorithm is done for each edge within the graph. Basically, the different points and line information are categorized in general information and relevant information for routing. Some categories are able to influence the cost value of the edges (typeroute=TRUE) and furthermore also the route from a start to an end point, as the cost increases where difficulties for visually impaired appear (black nature), and reducing it wherever helpful points are found (white nature). Other categories are registered with the aim of providing information about things or services found near the route but they cannot influence the route.

5.2 Route Calculation results

Every time a user wants to create a new route, the request comes from the CreateItinerary web service. This request contains an origin and destination pair of coordinates (green points can also be used). The best cartography available is chosen automatically if both exist (OSM and City). In the Figure3 below, the two cartographies were tested manually to see the different results obtained in Soest.

Fig. 3: Comparison of the routes obtained for different cartographies (OSM and City network in Soest).

6 CONCLUSION

This paper has presented the Multilayer Information Management System of ARGUS, which offers the management module to handle heterogeneous datasets to offer personalized pedestrian routing services. It is oriented to assist blind and visually impaired users on more autonomous everyday situations.

7 ACKNOWLEDGMENTS

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