# HETEROGENEOUS CARTOGRAPHICAL DATASETS HANDLING FOR PERSONALIZED URBAN PEDESTRIAN ROUTING. THE ARGUS USE CASE FOR BLIND AND VISUALLY IMPAIRED.

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***Abstract***

*Route planning services for visually impaired people need precise information of the paths and obstacles of all kind that can be found while walking. The ARGUS project is presented, whose objective is guiding people with visual impairments by using binaural sounds, and offering personalized routing services. The spatial datasets used are heterogeneous. A base routable network for five European cities was prepared from OpenStreetMap, and in two of them, a more detailed cartography was included. In addition, ARGUS users can upload, categorize and share new points of interest and tracks. Users are encouraged to set their preferences according to which type of street elements they find helpful, hazardous or neutral, for a personalized route calculation. Therefore, this work describes the methodology used for handling all the spatial datasets involved. The paper would also like to put the focus on a growing interest about quality digital cartographical data for pedestrian use.*

## INTRODUCTION

Route planning services for blind and visually impaired people must rely on detailed pedestrian cartography datasources, containing precise information of the path and several obstacles of all kind that can be found while walking. In terms of quality and availability, digital maps for pedestrian use are way too far from those targeted to vehicles or driver oriented.

The ARGUS project is presented in this paper as an example use case. The main objective of this project is to guide people with visual impairments in urban and rural environments with the help of binaural sounds. The developed prototype relies on a Smartphone application running a navigation algorithm to generate non-disturbing 3D sound instructions according to the desired GPX file, previously loaded. Different spatial datasets are used by the ARGUS server to generate and enhance these GPX files which contain route points that describe paths and informative points of interest along the way.

The heterogeneity of the datasets in the project consists in the existence of diverse spatial data sources and their diverse formats. First, a base routable network topology for four testing cities in five European countries has been prepared from OpenStreetMap, extracting and linking walkable street segments. Moreover, in two of the cities, a more detailed cartography has also been made available by individual city providers, with geographic information such as precise sidewalks, road crossings and different types of street furniture elements. In addition to this, through the accessible user interfaces, ARGUS users are able to add, categorize and share new points of interest they know in advance or they have found on route.

A set of spatial attributes have been defined in order to classify the most relevant and significant types of urban elements for the blind and visually impaired pedestrians. These elements are represented in the database as geographical point or lines, and users are encouraged to set their preferences according to which type of objects found in the street have a helpful effect to them (such as tactile pavements), negative (as bollards) or neutral effect during the activity of walking from one point to another. This preference configuration is crucial because of the differences in levels of visual impairment and skills from one user to another.

The ARGUS server hosts the software modules that are in charge of offering web services consumed by the Smartphone application and the user website during the three travel stages: before, during and after navigation. For example, all the spatial layers, and the user preferences are combined by these software modules whenever a user requests a new route creation, to calculate the best path to go from the specified origin to the destination. This calculation is done by a database driven shortest path function over dynamically weighted street segments or edges. Depending on the helpful or negative points that are mapped to an edge, its cost changes (negative points increase it, while helpful points decrease it), thus the suggested route for the same origin/destination pair may be different from one user to another.

Therefore, on the one hand, this paper describes the methodology used in the ARGUS project for handling all the spatial datasets involved, automatically prioritizing the best cartography available in each city and enhancing this by user data, with the aim of offering a personalized routing and navigation solution. On the other hand, this work would also like to put the focus on a growing interest about quality digital cartographical data for pedestrian use, which will allow new applications to help on several aspects of everyday life.

## ROUTING SERVICES FOR PEDESTRIANS WITH DISABILITIES

Different constraints determine the way of generating suitable travel paths for users with difficulties on everyday mobility. Obtaining the shortest route from an origin to a destination, according to distance or time, is the most evident. But the condition of each individual user, thus, their ability is essential to determine if a route is appropriate or not. In the special case of visually impaired and particularly for blind pedestrians, safety is one basic requirement as many try to avoid big, crowded, and noisy cross-ways and would thus accept a longer but safer route [1].

Assistive solutions for pedestrian navigation have been studied intensively since the 1980s. The MOBIC system [2] for example, offered a pre-journey system for route planning and exploration. Commercially available navigation systems specifically developed for visually impaired user such as Humanware's Trekker [3] or Sendero GPS [4] use map data previously optimized for car navigation. U-Access [5] provides a web-based system for the routing and prescriptive analysis of pedestrians with different physical abilities within built environments.It provides pedestrians with the shortest feasible route with respect to one of three differing ability levels, namely, peripatetic (unaided mobility), aided mobility (mobility with the help of a cane, walker or crutches) and wheelchair users.  RouteCheckr [6] is a client/server system for collaborative multimodal annotation of geographical data and personalized multicriteria routing of mobility impaired pedestrians. Another example is Mobility Support GIS, which can support a variety of pedestrians including elderly, disabled, pregnant, and infant users. It provides area and route accessibility information for all pedestrians with the newly developed universal-designed accessibility database of terrains and facilities on roads [7].

### The ARGUS Project

The ARGUS project [8] 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) mobile application 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. ARGUS, thus, is more than a route planning service, but its cartographical and routing aspects are described in the present paper.

The ARGUS server (or Service Platform) offers Web Services to access the different remote functionalities available in the system, such as route creation or personal points uploading and editing. The Service Platform uses a PostgreSQL [9] database to store all the spatial and non-spatial information (with postGIS and pgRouting). In the following sections, the different layers involved in the route generation process are described and the methodology to handle them is shown.

## CARTOGRAPHY LAYERS

Four kinds of spatial layers are used in the project (see Figure 1).

L0: The Base Network is the geographical data needed to create the base spatial layer upon which the routing network topology is built. 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).

L1: City Data is an optional dataset available is some cities providing extra accurate geospatial information. In this prototype, data for Vienna (Austria) and Soest (Germany) is available.

L2: A Track is an ordered sequence of points that describe a path. This can be generated using the route calculation module, or uploaded to the system after recording it using a GNSS receiver. It can be a GPX file, and can also be 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.

L3: Points 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).

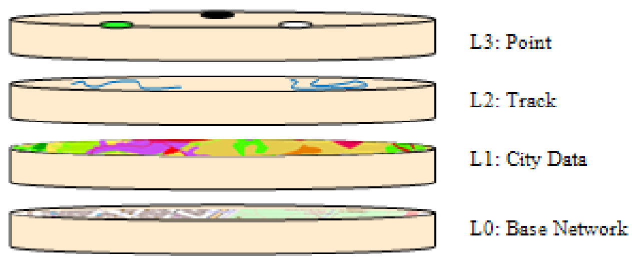


*Figure 1. Type of layers in the ARGUS system*

## CREATION OF A ROUTABLE NETWORK

As mentioned, in the previous section, OpenStreetMap data has been used as the Base Network. The data structure is based on nodes, ways, relations and tags. To make the network routable, it is important that every way element is fragmented at every crossing of the streets. The converter and routing engine tool osm2po [10] has been used to create the routing network from the downloaded sources. A routing topology table is created by this tool with the connection information from one edge to the next. Based on the length of the edges and the average speed configured for each road category (this settings can be configured through a XML file), it calculates the default costs. These default costs of the tool could be used for pedestrian routing. However, in ARGUS, a personalized service solution is aimed to reflect different behaviours and preferences of people with visual impairments Therefore the ARGUS system implements its own dynamic weight model that will be covered later in this paper. The Dijkstra algorithm implemented in the PostGIS shortest_path function is used to get the optimal path based on the lowest weights.

Apart from the road categories, additional information regarding OSM point data is very helpful (for example the existence of letterboxes). The goal of a routing topology engine (like osm2po) 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, so this attribute information of the edges and nodes has to be imported into the database. In the project ARGUS, the import tool osm2pgsql [11] 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 inserts the data into the database, but it has no routing functionalities, so the dataset ignores 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.

### Assignment of POIs to the ARGUS street network graph

For a good dynamic weighted routing network graph, which is used by the routing algorithm, points of interests must be linked to their belonging network edges. Streets are represented virtually by digitized lines, which represent a centreline of the street or a borderline in the digital representation of the street. In the real world, the street is not limited to this line, but to the width of the street. Most of the time, this type of attribute is rarely available within street attributes. The classification of the streets is more common, which is based on the different street types within the traffic or building regulations. The ARGUS system defines a set of default buffers which are used to map the POIs to their associated edges. This set of buffers varies in buffer size and is based on the OSM street classification (primary, secondary, etc.). For the city network data, the different types of street categories are mapped to the OSM schema.

The road widths are based on the maximum building regulation of the different street types. The difficulty to estimate a buffer of the street depends on its representation in the database. Most of the time, within the OSM dataset, only one line is representing the entire street which can consist of multiple lanes in both directions. The representation of one virtual line for both directions in higher class roads is used as a basis for the estimation of the buffers, based on the building regulation of Austria/Germany. The building regulations for streets of Austria and Germany were compared and there were no major differences between these countries. Two of the five pilot locations are located in this area, so this assumption was accepted for all.

The estimation takes the maximum width of a street category and divides it for both street sides to get a rough estimated buffer. For catching also POIs beside the street (like toilets, shop, benches), which should be used for information purpose or routing purpose, an extra distance of 10 metres is added to take tram ways between the roads or inaccurate positioned POIs into account. On pedestrian-only street categories (steps, footway), only the half of the extra distance (5 metres) is added. The footway or step categories can be used directly for the pedestrian and for that reason the buffer does not include other lanes like parking vehicles or tram way lanes.

A good example for the complexity of the estimation of street width is the Ringstreet in Vienna. This street is categorized as a secondary street, but the width around 50 metres in total (including tram lanes, medial strip and parking areas, which are situated between the walking area and the street) is a special exception of the routing network of Vienna.

The combination of the different street-based categorization and the catching size of near objects leads to the ARGUS buffers, which are used for the mapping.

### *Example of San Sebastian (OSM)*

In order to show how the dataset obtained from OSM looks like, San Sebastian is used here as the main example. According to the aim of providing routing services for pedestrian use, ways forbidden like motorways are not part of the network graph, so both road classifications and access allowance information are taken into account. Therefore, data is filtered before its inclusion in the ARGUS database, and the classification is stored accordingly.

*Figure 2*, on the left, describes how some steps are defined in the original OSM source. On the right, the same steps already included in the ARGUS database are visualized using the QuantumGIS 1.8.0 tool [12]. Its classification metadata is included. The figure contains orthophotos of the areas obtained from the Gipuzkoa Web Map Service [13]. The red lines describe the segments (***edges***) that are used later by the route calculation to create the paths, all the segments create the ***network.*** At the same, time, segments are connected among them by ***nodes.***

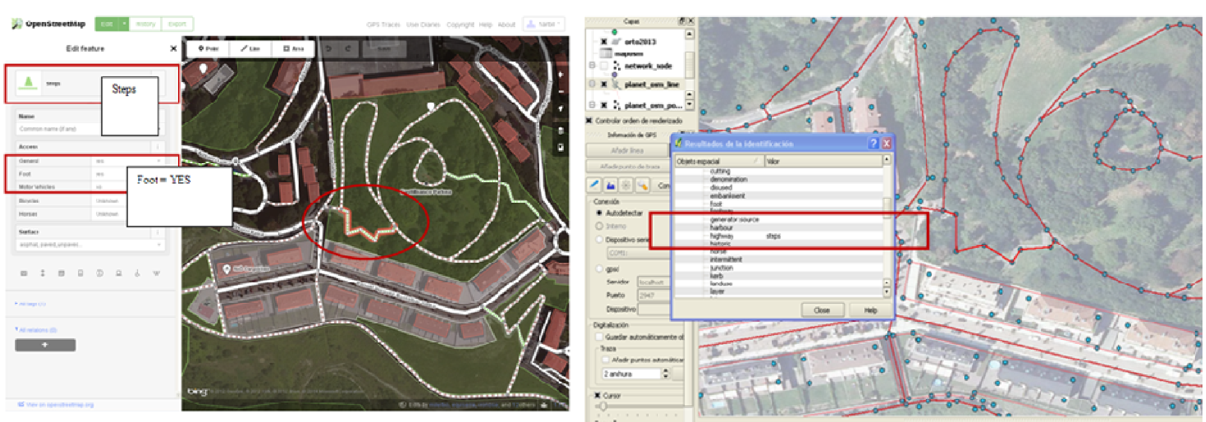


*Figure 2.(LEFT) The original source (detail of a set of stairs near a park), displayed directly in the online OSM ID editor. (RIGHT) The ARGUS database holds info about the "steps" type line element.*

The whole San Sebastian area covers more or less 3 x 8 square kilometres. Apart from San Sebastian, the network of the other four cities has been included: Soest (Germany), Vienna (Austria), Portsmouth(UK) and Madrid (Spain).

## Limitations of OSM and City Data

One of the limitations of the OSM data included in the previous cities is that the routable network segments are mostly part of road segments, and thus, not very safe in some cases. Although the streets used are marked as walkable (even though if they are not pedestrian ways, they could be expected to have a sidewalk), the geometrical line segment describes the centre of the road, thus, probably a little bit separated from the sidewalk longitudinal axis.

In the majority of the cases, the exact geometry of a pedestrian walking axis is not recorded in OSM. In this case, the sidewalk will be added as an attribute on the street geometry, which only indicates the existence of a sidewalk (e.g. sidewalk=left).

In order to analyse the benefit of including other more detailed urban cartography data, the cities of Vienna and Soest were also used inside the project. The city of Vienna provided routable pedestrian data from the GIP (Graphenintegrationsplattform) [14] 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 [15] dataset of Germany.

### *Example of Soest*

Soest is one of the cities were both network layers (OSM and City Data) are available. The following Figure 3 shows a detail of the two cartography layers for comparison purposes. The OSM data is limited to describe road centre axis which is by no means safe for pedestrians. The detailed cartography contains correct geometries of the sidewalk axis and pedestrian crossings.


*Figure 3. Comparison of OSM and Soest City Data: sidewalks and pedestrian crossings*

## PARENT-CHILD CONCEPT FOR THE DATASOURCE ABSTRACTION

The city data of Soest and Vienna were integrated in the ARGUS database making use of the inheritance within PostgreSQL. The use of inheritance in the database layout offers a flexible and extensible way to import different city GIS data, and gives the possibility to integrate them in the future. In general, city data layers are heterogeneous datasets which provide different attributes and no common structure among different sources (like GIP vs. ALKIS).

The concept of inheritance allows joining common attributes of several datasets in the same table and provides unique IDs for all datasets. This is based on the parent-child table concept. For that reason, a common set of minimal attributes for the creation of a routing network graph was defined. Every dataset willing to be integrated in ARGUS must comply with this set of attributes: 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 heterogeneous 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).

### Removing duplicate POIs

Within the city data network graph, the use of both OSM points and city points may lead to duplicities and incorrect route calculations. The complexity of the filtering process of this data comes from the different accuracy level (the same point can be located within a few meters distance in different sources) and the non-standardized structure of the OSM data.

To filter out the duplicate entries, the following system was used: Within the city_network table, an indicator attribute was defined. The comparison of the POIs is based on the distance between POIs and the category compliance of ARGUS, because the name is not usable for unique identification of duplicate entries (due to non-standardization in OSM). All POIs of the city network graph will be marked if they are within a special defined distance and have the same POI category. The buffer distance for the removal of the duplicates is based on the type of object. Only the non-marked city POIs will be used to calculate the dynamic weighted network graph, which is the input for the routing calculation of ARGUS.

## USER POINTS AND CATEGORY PREFERENCES

ARGUS users have the possibility to add, edit and share personal points that can affect the routing weights. Moreover, they 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. A set of categories was defined based on requirements collected from user surveys and completing it with OSM categorizations. 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.

## ROUTE PLANNING

The CreateItinerary Web Service is the responsible of starting the route calculation process. This web service needs an origin and destination pair of coordinates (green points can also be used) as input parameters.

The Route Calculation module is contained inside the RouteCalculation C++ file. The constructor of the RouteCalculation class creates a pointer to the MIMS module with the correct database connection parameters in order to link the route calculation with the tables where cartography and user data are stored.

The C++ implementation of the routing algorithm is composed as follow:

### Query preparation and automatic layer selection

The route calculation queries are called from the C++ RouteCalculation.cpp class. When the "Itinerary Creation" web service is called, a Route Calculation instance is created. The best cartography available is chosen automatically if both exist (OSM and City). The Figure 4 below describes a general overview of the algorithm used by the CreateItinerary Web Service to decide which network layer must be used by the shortest path query.

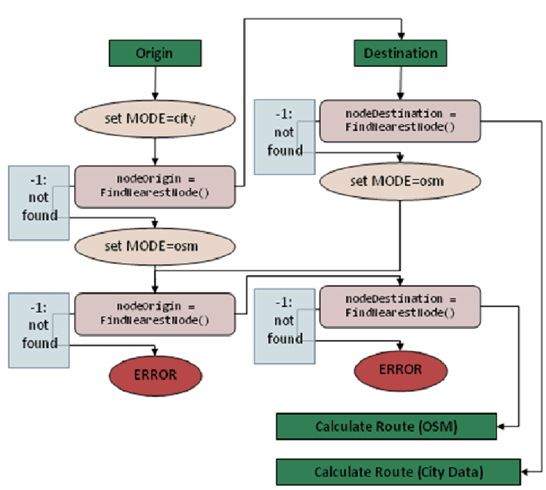


*Figure 4. Network layer selection algorithm*

First, the nearest network node of the origin – given in coordinates or as a green User Point – is searched in the detailed cartography (mode = "city"). If it is not found, the algorithm searches in the OSM cartography (mode = "osm").

Then, the nearest network node of the destination – given in coordinates or as a green User Point – is searched in the same cartography mode as used for the origin**.** If it was mode = “city” and no node is found for the destination, the algorithm tries with mode = “osm”. If the node is found, the origin is recalculated using mode = “osm”. Both origin and destination node must be obtained from the same base cartography. If origin or destination not available in any of the cartographies, the route calculation is not possible. The SQL shortest path query is called according to the “mode” selected.

### Routing Query

The ARGUS routing query is based on the shortest path algorithm included in the pgRouting plugin. It calculates the best path for the ARGUS user with minimal length from a start location to an end location. The algorithm relies on a user defined dynamic weighted network graph, which is based on the different types of spatial data described in above sections. The calculation of the dynamic network graph is done according the user specified classification preferences of Black Point categories (which are obstructive) and White Point categories (which are helpful objects) for the current user.

The calculation of the weights within the dynamic network graph is based on the following simplified formula:

$$W_e = L_e + \sum_{i=1}^{n} B_p - \sum_{i=1}^{n} W_p \rightarrow W_e \geq 0$$

*Equation 1. ARGUS weight calculation equation*

Within the above shown Equation 1, the Parameter $W_e$ is described as the weight for a network edge. The basis for the weights of the routing network graph is the length of the different network edges ($L_e$). For the ARGUS project, the speed of the visual impaired people was not taken into account, because the speed of the users is inhomogeneous and cannot be defined for all user groups. Furthermore, it also depends on the additional means that will be used (e.g. cane, dog or no aid). All Black Points along the edge will be multiplied with the user specified category factor (amount of metres that the user is willing to make a detour) which results in Black Point parameters ($B_p$) for each of them along the route. After that, the sum of the Black Point parameter amount will extend the total length of the routing edge. The same procedure is done with White Points, but this value will shorten the length of the routing edge.

The result consists of a new weighted edge which is virtually prolonged or shortened within the routing network graph. The shortest path algorithm is influenced by the new weighted routing network graph according to the ARGUS user’s preference. The specific characteristic of the shortest path function is that the edges within the network graph should not have negative values. For that reason, the routing algorithm formula will get zero, if the weight of the network edge becomes negative. For affected edges by black or white categorized points, the above described algorithm calculates a new weight, for the rest of unaffected edges the real length of the edge will be assigned as routing weight.

The ARGUS routing algorithm takes the following point/line information into account to calculate the weight of the edges:

-Influenced edges by black or white points (user defined)

-Influenced edges by black or white OSM (or City) POIs

-Influenced edges by black or white OSM line information (e.g. bridge, steps, ...)

-Influenced edges by black or white subscribed user points (points from users marked as reliable)

Furthermore, only POIs stored in the ARGUS database within defined relevant categories for routing will influence the weights of the ARGUS network graph. Line information will influence the point as it would be point information.

### Query result processing

The shortest_path query result must be ordered to obtain the route points. The goal is to get the coordinates in combination with the edge IDs in a pleasant way (array) to compare them to each other. Then the algorithm iterates through all Linestring elements (edge IDs) and compares the last coordinate of the current edge ID with the first coordinate of the next edge ID. If they are the same, everything is okay. If they differ, the order of the coordinate array has to be reversed.

## GPX generation

The GPS Exchange Format (GPX) [16] is a light-weight XML data format for the interchange of GPS data (waypoints, routes, and tracks). The GPX file format is used to transmit the generated route to the Web Services and finally to the User Terminal.

Each of the points (defined as coordinate pairs) that describe the path to follow is included in the GPX file as a "routepoint". In addition to this, any informative point near the route is included as a "waypoint". They are not used for navigation by the User Terminal, but for giving information when passing close to them.

### *Safety corridor*

The ExtensionsType in the GPX schema is the element that makes GPX flexible. Using this element, specific schemas can be used that, by default, are not included in the GPX format. That means, within this tag, the safety corridor, annotations and extra information about point categories can be sent along with the GPX file.

Within the first prototype, the safety corridor has a fixed width. It is a parameter to control the navigation instructions when a user gets too far from the original path during the navigation and is included as extra information in the GPX file. In future steps, dynamic corridors could be included, with variable widths along a path, reflecting different safety zones. The safety corridor information is coupled with the route by including the information in the GPX file that is prepared for the use within the User Terminal. That means the safety corridor is a GPX extension and added to the GPX structure.

## TRACK UPLOADING IN URBAN/RURAL AREAS

The availability of cartography in urban areas is acceptable in general but as mentioned in previous sections, in some areas, and depending on the conditions, the quality needs to be improved for safe pedestrian route planning solutions.

The objective of the recorded track uploading option offered by ARGUS is double. It allows downloading tracks without the need of the route calculation based on the cartography. Therefore, users can download previously uploaded GPX files (uploaded by other users or by themselves), after performing the path once in both urban scenarios where the cartography is not good enough, or rural/land areas where cartography is inexistent.

A request of finding an existing itinerary from the public repository needs a pair of origin and a destination (similar to the route creation request, but both points can be the same here). The system returns all the public tracks that pass through a 20 meter radius area from each point.

In this case, the user preferences do not modify the path of the recorded track. However, they do affect the list of informative points of interest that are added to the GPX file on download.

## RESULTS

A short summary of some route calculation results handling different datasources is shown. Figure 5 (LEFT) represents visually the result route after inserting a fourth black point along the edge at the Town Hall front court in Vienna. The different black points should represent, for example dangerous manholes, waste baskets, advertising columns or other user defined obstructive objects (both user defined or given by the cartography provider). The edges near the new inserted edges differ in street classification. The OSM path is based on a pedestrian road classification and the city network edge is classified as a footway. Within the projects, different buffer levels of the street classifications were declared to map black points or white points. For the mapping of pedestrian areas, a buffer of 20.5 meters and for a footway a buffer of 6.5 meters was declared. The first three black points were only mapped to the city network (black triangle) and the last one was also mapped on the OSM network. Figure 5 (RIGHT) shows the change of both routes after the insertion of more different black points. The "costs" of the direct routes were higher than the alternative routes.

The differences between the ARGUS city network route (orange) and the ARGUS OSM route (green) can be seen. The OSM network of this area does not cover the footway between the two parks. Therefore, it switched to the other side of the park to get to the end point and also takes a complete different route. In contrast, in the city network route, the affected edges are avoided and the route goes straight through the square of the town hall. The weight of the OSM network and the city network differs significantly from the start to the end point.

*Figure 5. Different route results after adding black points in Vienna (comparison of OSM and City Data)*


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## REFERENCES


[1] Völkel, T., Kühn, R., and Weber, G. (2008) Mobility Impaired Pedestrians are not Cars: Requirements for the Annotation of Geographical Data. *Proceedings of the 11th International Conference on Computers Helping People with Special Needs (ICCHP'08)*, Springer, Heidelberg, 1085-1092.

[2] Strothotte, T., Fritz, S., Michel, R., Raab, A., Petrie, H., Johnson, V., Reichert, L., and Schalt, A. (1996). Development of dialogue systems for a mobility aid for blind people: initial design and usability testing. In *Proceedings of the Second Annual ACM Conference on Assistive Technologies (Assets '96)*. ACM, New York, NY, 139-144.

[3] Humanware Trekker 3.0 GPS orientation system. http://www.humanware.ca/web/en/Trekker3.asp

[4] Sendero Sendero GPS Product Information, http://www.senderogroup.com

[5] Adam D. Sobek, Harvey J. Miller (2006). U-Access: a web-based system for routing pedestrians of differing abilities. *Journal of Geographical Systems* 8. Springer-Verlag, 269–287

[6] Thorsten Völkel , Gerhard Weber, RouteCheckr: personalized multicriteria routing for mobility impaired pedestrians, *Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility*, October 13-15, 2008, Halifax, Nova Scotia, Canada

[7] Yairi I. E., Igi S., "Mobility Support GIS with Universal-designed Data of Barrier/Barrier-free Terrains and Facilities for All Pedestrians Including the Elderly and the Disabled" IEEE Int. Conf. on Systems, Man and Cybernetics, 2006.

[8] ARGUS FP7 project: http://www.projectargus.eu.

[9] PostgreSQL: http://www.postgresql.org. PostGIS: http://postgis.net. pgRouting: http://pgrouting.org/

[10] Osm2po: http://osm2po.de/

[11] Osm2pgsql: http://wiki.openstreetmap.org/wiki/Osm2pgsql

[12] QGIS Development Team, 2014. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

[13] Gipuzkoa WMS: http://b5m.gipuzkoa.net/web5000/es/utilidades/servicios-ogc/wms/

[14] Open Government Wien, https://open.wien.at/site/datenkatalog/

[15] ALKIS, http://www.adv-online.de/AdV-Produkte/Liegenschaftskataster/ALKIS/

[16] GPX the GPS Exchange Format, http://www.topografix.com/gpx.asp

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Patrick Krejci is researcher at the Central European Institute of Technology at the city of Schwechat, which deals with national and EU-funded research projects in the scope of urban development, spatial development, information technology and spatial information technology. He has been working for the institute since 2011.
He finished his study geoinformatics and obtained his master degree on “Entwicklung eines WebGIS mit integrierter wissensbasierter Plausibilitätskontrolle der Wassercheckdatenbank” at the University of Applied Sciences in Wiener Neustadt. His master thesis got the third place in the AGEO Award competition. His research interests concentrate on spatial information technologies based on open source software and data.
Within the range of geoinformatics he already worked on spatial database design and analysis, spatial web services, SDI, GI, user adapted routing algorithms, OSM data management, geometric algorithms, OGC standards like WMS, WFS, CSW and management, analysis and visualisation of geospatial data.

**Estibaliz Loyo, Ph.D.**

Estibaliz Loyo studied Telecommunications in ESIDE (Deusto University School of Engineering, 2003), where she began her research work in Advanced Signal Processing group and worked as an Assistant Professor in the 2004-2005 academic year. Subsequently, she started working in CEIT (Spain) where she developed her Doctoral Thesis (2008). Currently, she is a project researcher at Vicomtech since 2009. At the same time, she is an Associate Professor in Tecnun (University of Navarre).

**Oihana Otaegui, Ph.D.**

Oihana Otaegui is the Head of Intelligent Transport Systems and Engineering Department. She received her MEng degree in Electronic Engineering and her PhD on Acquisition and Tracking for Satellite Navigation from the University of Navarra, Spain. She has a large experience in satellite navigation and transport fields. Before joining Vicomtech-IK4 in 2007, she worked as a Researcher at CEIT (Spain) and at Fraunhofer IIS (Germany) on, among others, fast acquisition algorithms for Galileo/GPS/EGNOS. In her current role she oversees and is responsible of the department projects related to positioning, transport, user information services and security. She has participated in several FP6 and FP7 projects during her activity in Fraunhofer and Vicomtech-IK4.