Reverse Service Area Analysis of Styrian Hospitals Based on OpenStreetMap Data

Gregor Zahrer*, Clemens Strauß*, Gernot Hollinger**, Florian Schöggl*

* Graz University of Technology, Institute of Geoinformation, NAWI Graz, Steyrergasse 30 / I, 8010 Graz, Austria
** Graz University of Technology, Institute of Remote Sensing and Photogrammetry, NAWI Graz Steyrergasse 30 / I, 8010 Graz, Austria

Extended Abstract

This study tests a new approach to analyze the accessibility of Styrian state hospitals based on open data. The entire geoprocessing toolchain is described, from data acquisition to analysis and visualization – all based on free or open-source software. The aim of this project is to find and calculate the best facility for emergency and hospital treatment for each municipal territory in Styria. A four steps strategy is applied: After acquiring necessary (geographical) data from open data stores, creating a topological network capable of routing and performing various routing algorithms, the results are visualized in a proper way eventually. A future goal is to implement a location-based service for mobile and desktop browser applications to show and navigate to the nearest hospital.

Proprietary GIS software, such as ArcGIS (Network Analyst), Intergraph or Smallworld, offers network analysis tools for road or, more general, infrastructure optimizations. Open-source software packages provide an even larger number of tools to model networks and solve related problems. In our research, we use the PostgreSQL database management system (DMBS) with a spatial extension, called PostGIS. This extension enables the DBMS to handle geographic features including spatial reference and projections. Geometric features are stored using the OGC Simple Feature Model, which supports points, lines and polygons with their respective multigeometrical appearances as well as collections of geometries. Another extension for PostgreSQL, pgRouting, provides geospatial routing functionality.

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Study Area

Styria is the second largest state in Austria, comprising an area of some 16,000 km². In the northern half, the terrain is determined by the mountain ranges of the Northern Calcareous Alps and Central Alps. The Eastern Alps in Styria are divided by longitudinal valleys in an east-west direction (Enns, Mur, Palten-Liesing valleys). The southern parts have lower relief energy with a basin opening southwards from the capital, Graz. A relief representation and the Styrian road network are illustrated in *Figure 1*.

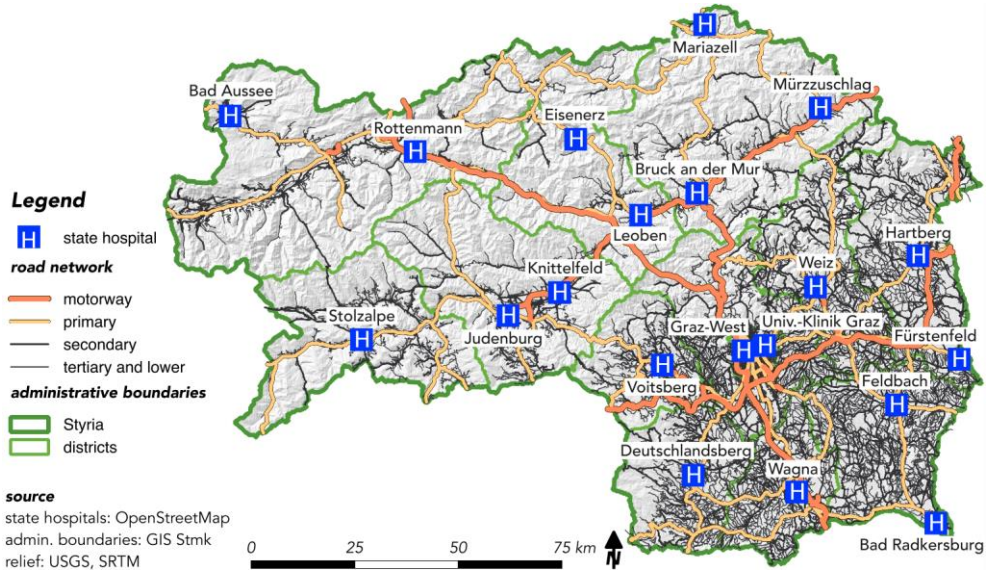

Figure 1. Map of the Styrian road network (highways, primary and secondary roads) including state hospital sites.

Data Acquisitions from OpenStreetMap

As a first step, locations of all state hospitals in Styria are queried from the OpenStreetMap (OSM) database. OSM is a free map of the world, collaboratively maintained by more than 1.8 million users as of October 2014 around the world (OSM Statistics, 2014). More than that, it is a queryable (geographic and semantic) data store, describing the mapped information and visualizing it in various ways. Querying OSM can be done via the Overpass Application Programming Interface (API): To acquire geocoded information, data is filtered by attributes using key-value pairs (e.g. “amenity” = “hospital”) or by location, defining spatial / topological restrictions (e.g. bounding boxes, maximum distance). For the sake of simplicity and comprehensibility, the reachability analysis will only cover public state hospitals.

For network analysis, street data has to be obtained from OSM. Osm2po is a java-based toolkit to download and parse both geometric entities and its street information for a specific country in a topologically correct format (Osm2po, 2014). Results are written to a SQL file and then loaded into the PostgreSQL/PostGIS database. pgRouting is an extension of the PostreSQL/PostGIS database management system and provides geospatial routing functionality. Various routing algorithms are implemented, such as functions for Dijkstra's, A*, Travelling Salesman or Driving Distance. In a first processing step, a routable topology has to be created from the topologically correct input data. After that, routing functions may be applied and results are given as cost-path-datasets including identifiers for nodes and edges of the corresponding line segments.

Reverse Service Area Analysis

The strategy is a combination of two typical network analysis scenarios: closest facility and service areas. The first one tries to find the nearest facility (in our case hospitals) to a specific point location (accidents, emergencies) where support / assistance of the mentioned facility is needed. "Closest" can also be seen as "best", not only in a minimization of distance, but also in terms of traveling costs or other factors (road surface and slope), limiting the accessibility of road vehicles. The second analysis tool estimates the area, for which a certain point location can provide its service within a specified timeframe. A classic example could be the area consisting of all network nodes within a distance from a hospital that can be covered in 5-, 10-, 15-minutes and therefore can be serviced by this medical facility.

After data retrieval from OSM, the discussed combined strategy is applied to the dataset: First, a stored procedure written in pl/pgSQL-Code iterates over all (n) hospitals in the database, implementing a Dijkstra-algorithm. For this operation, a hospital is set as the start location for routing. Considering that hospitals, as well as other larger scale facilities are stored as polygons, a further refinement has to be implemented: by calculating a representative point location for the respective areas. This location is matched to the closest topological network node.

An infinite (or very high) maximum cost value allows us to calculate cost factors for all other nodes in the network. In particular, reverse costs of edges are used, describing the travel time from each node to the given hospital. In the resulting dataset, a node has n (virtual) layers, containing traversing costs to the hospitals respectively. Up next is the aggregation on a 1x1 km raster grid or by municipal area: Nodes are selected by location and the average cost per raster cell or municipality respectively is calculated for each hospital. The best (closest) hospital for each administrative boundary is represented by the layer with the least estimated costs.

A subsequent application is a public location based service on mobile devices, helping citizens to find the nearest physician (on duty) for a medical specialty. Considering this application not only state hospitals, but all facilities for medical treatment should be included in a future analysis.

References

GIS Stmk (2014) GIS-Steiermark GeoDaten. Administrative boundaries.
http://www.gis.steiermark.at/cms/beitrag/10481712/14292094/
Accessed 29 July 2014

OSM Statistics (2014) OpenStreetMap stats report.
http://www.openstreetmap.org/stats/data_stats.html
Accessed 10 October 2014

Osm2po (2014) osm2po - openstreetmap converter and routing engine for java.
http://osm2po.de/
Accessed 8 October 2014

USGS, SRTM (2014) Shuttle Radar Topography Mission. Elevation Data.
http://eros.usgs.gov/elevation-products
Accessed 15 June 2014