CAMPUSGIS ROUTING
– A WEB-BASED LBS FOR THE UNIVERSITY OF COLOGNE

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ABSTRACT:

The CampusGIS of the University of Cologne (http://www.campusgis.de) is designed, developed and established by the GIS & Remote Sensing research group at the Department of Geography. It is a web-based application to provide and visualize general and spatial campus information, e. g. advanced search functions, orientation, routing, and facility management. Several existing relational database systems of the University of Cologne with spatial data were connected within that online GIS environment. The overall design approach is based on this database linkage with spatial data to provide location-based services (LBS) (Baaser et al. 2008). This paper presents the major recent networking improvements based on a topological validated line-network to provide online routing applications for pedestrians and comparable user groups. Therefore, several objects and attributes of the CampusGIS geodatabase were surveyed, digitized and joint to selected objects of the ATKIS-street dataset (ATKIS = Authoritative topographic cartographic information system of the Federal Republic of Germany).

1   INTRODUCTION

Due to the lack of digital information about buildings, institutions, and persons, the CampusGIS of the University of Cologne (http://www.campusgis.de) was designed, developed and established by the GIS & Remote Sensing research group at the Department of Geography. CampusGIS is a web-based application to provide and visualize general and spatial campus information, e. g. advanced search functions, orientation, routing, and facility management. The overall approach of this project is to link different non-spatial databases to spatial entities within an online GIS environment. To be platform independent the internet was chosen as it comes with a digital, forward-looking and ubiquitous technology. Besides the web, GIS technology is used to provide geodata and attribute information about buildings, staff, and institutions in a spatial context.

The intern communication of CampusGIS is based on AJAX (Asynchronous JavaScript + XML) that allows a fast "Web 2.0"-*look and feel* (O'Reilly 2005). The latest release of the system is an ESRI ArcGIS Server Java-based application.

CampusGIS contains the following applications (status quo: December 2009):

- Web-based search engine for staff, buildings and institutions
- Building visualization in 3D – LoD1
- Embedding of CAD-drawings for facility management
- Pedestrian routing (under construction)
- GUI for mobile devices (under construction)
- Pedestrian sight-seeing tours based on several themes, e. g. history or architecture; each with 7-10 locations showing points of interest with background information (under construction)

2   NETWORK ANALYSIS APPROACH

This paper presents the development of the pedestrian routing application which is embedded into the latest version of CampusGIS. This routing application is based on the network analysis approach (ESRI 2009). According to Bill (1999), network analysis with predominantly curve objects are similar-distinguished GIS applications like intersections of polygons or interpolations of point objects. Networks are designed to simulate the flow of goods or data, e. g. water or electricity through a utility network, oil and gas pipelines on a commodity network or traffic on a road network (Curtin 2008). In the presented context the network analysis provides a routing application for pedestrians and comparable user groups at the Campus of the University of Cologne by using the three components:

- Topology
- Modeling a multimodal network
- Calculating the Shortest Route model

3   THE NETWORK DATASET

The CampusGIS geodatabase consists of different datasets: Besides (i) alphanumerical data, (ii) aerial and satellite images, and (iii) georeferenced CAD-drawings, geospatial geometry data is stored as feature classes in a relational file geodatabase, containing (iv) authoritative topographic geodata, and (v) surveyed data of buildings, building-entrances, footpaths and retail trade and services.

3.1   Topology

The digital base map of the system is derived by selected and grouped objects of the ATKIS-dataset (Authoritative topographic cartographic information system of the Federal

Republic of Germany), combined with footpaths, buildings of the university and building-entrances (Baaser et al. 2008).

For verification whether all the footpaths, buildings and entrances are digitized correctly, several rules are implemented in the geodatabase with regard to its topology. A topology describes the connections and relationships between objects. The topology model is based on the mathematical graph theory and describes points as nodes and lines as edges (Bernhardsen 2002). Topology rules are defined to erase topology errors. Compared to geometry data, topology data does not know the distance between two nodes, but their spatial distribution to each other (Bill 1999a).

The CampusGIS routing algorithms use the following implemented topology rules (ESRI 2004):
- Buildings must not overlap
- Entrance-points must be covered by an endpoint of a footpath
- Entrance-points must be covered by the boundary of buildings
- Room-entrance-points must be covered by the boundary of rooms
- Room-entrance-points must be covered by endpoint of a indoor-footpath
- Footpaths must be single part
- Footpaths must not overlap
- Footpaths must not self-overlap
- Footpath must not overlap with streets
- Indoor-footpaths must be single part
- Indoor-footpaths must not overlap
- Indoor-footpaths must not self-overlap
- Indoor-footpaths must not overlap with footpaths
- Indoor-footpaths must not overlap with streets
- Rooms must be covered by building-polygons
- Streets and Footpaths must not have dangles

3.2 Graph theory

A mathematical graph is the basic principle to describe the topology of a network. A graph is connected, if there is a connection from any node to any other node. If two arbitrary nodes are connected through particularly one path, that graph is known as a tree. A graph is planar, if all the paths are at the same level (Fig. 1).
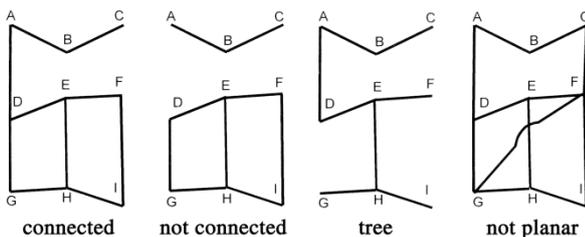

Figure 1. Types of graphs (de Lange 2005, p. 94, modified).

If one point is marked as the starting- and another as the endpoint, the graph is directed. A directed graph is marked with arrows. The edges can be weighted, e. g. according to travel distance or time (Elias 2007).

3.3 The multimodal network CologneMultiNet

Joint modeling of different networks results in a multimodal network (Bartelme 2005). With a multimodal network, it is possible to union numerous topologies, e. g. streets, footpaths, railroads, etc. into one single complex network. This provides the possibility of working with different topologies from different entities. Within this multimodal network the connectivity is defined by connectivity groups.

To meet these requirements with the routing extension of CampusGIS, streets and footpaths are stored in the first connectivity group CG1, tram tracks in CG2, and the tram stations are connection points and therefore stored in both CGs.

Based on this theory, a multimodal network named CologneMultiNet was developed for CampusGIS, containing seven object classes. Every edge is associated into one of the two above mentioned connectivity groups:
CG1: street network
CG2: tram network

Tram stations are point objects connecting the two connectivity groups to a multimodal network. The tram stations allow changing from one network to the other.

Within feature classes the connectivity policy defines how to model line segments as edges: If "end point"-policy is set, line features are split into multiple edges only at their endpoints. With "any vertex"-policy line features become edges at coincident vertices (ESRI 2009). The tram lines become edges only at coincident endpoints, because there is no way to get in and off or change one's direction except at tram stops. The "any vertex"-connectivity is set to footpaths and streets. At point features the default is to honor the edge source's connectivity policy. As tram stops may be placed at an intermediate vertex, the tram stop-point feature policy will "override" the default behavior of connecting a junction to a given edge.

4 CALCULATION OF THE SHORTEST ROUTE

The CampusGIS-Routing application allows the calculation of user-aware routes: The system provides the user the choice of either pedestrian routes or special routes for handicapped and disabled people. To solve a route, CampusGIS differentiates between algorithms without stairs or without stairs and ramps with an inclination of more than 6%. Based on the network dataset CologneMutiNet "calculate shortest route"-models are generated with ESRI ArcGIS Model Builder. The model for the calculation of routes without stairs and ramps is exemplarily displayed in figure 2: CologneMultiNet comes with the network attributes distance and time of travel for pedestrians as resistance to any line segment. It is the input dataset to the "Make route layer"-tool that creates a new data layer. With the "Add locations"-tool the user is prompted to specify the starting point and the destination. "Add locations"-tool is also used to load the barriers point objects avoiding stairs and steep ramps depending on user's selection. The tool "solve" generates a network analysis layer by using ESRI's Network Analyst's common algorithm of Edsger W. Dijkstra to find routes on a connected, positive weighted and directed graph (Dijkstra 1959, ESRI 2009). Due to the fact that ArcGIS Server does not accept the data type "network analysis layer" as an output parameter, the routes sublayer is selected using the "Select data"-tool. This sublayer is shown as the generated route. Simultaneously a python script is accessed to convert the text directions in HTML (ESRI 2009).
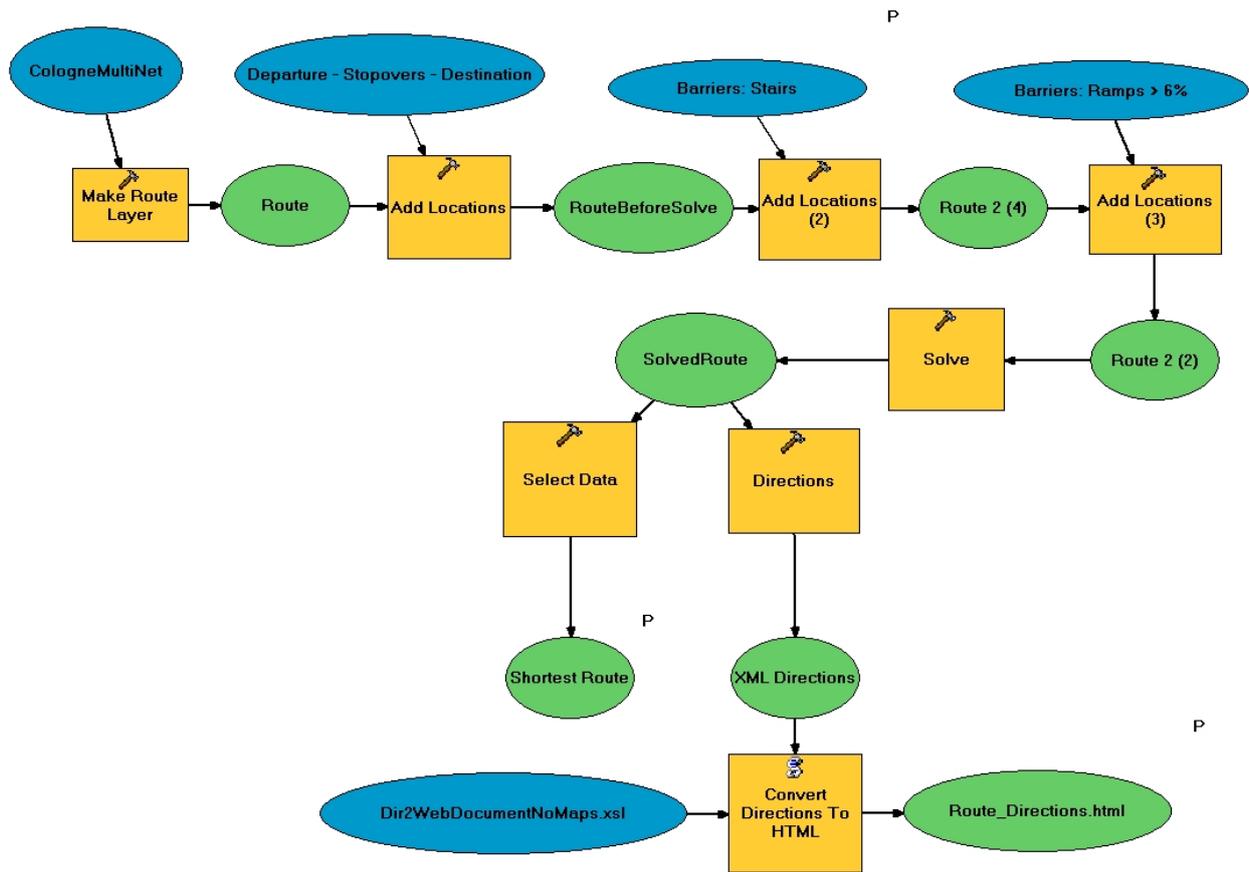
Figure 2. "Calculate Shortest Route for handicapped"-Model

5 RESULTS

The CampusGIS serves several GIS functionalities (Fig. 3). In detail, the following tools are implemented: There are buttons to zoom into a larger scale, into a smaller scale, to full extent, and to Campus extent. With the activated 'hand'-button it is possible to pan the map in every direction. The arrows switches to the last displayed views. Mouse-click on the identify-button 'i' opens a pull down menu. Within that menu, the user is able to select a layer to receive specific information about university buildings, entrances, footpaths, and retail trade and services. A further mouse-click into the map shows alphanumerical information about buildings, footways, entrances, and shops. The 'field-glass'-buttons open complex search forms for searching for staff, buildings, institutions, or catchwords. The results are shown at the top of the right hand of the map (Baaser et al. 2006a). Additionally there are buttons to call the routing applications for pedestrians (Fig. 3: 1) or disabled persons (Fig. 3: 2, 3). The shortest route-application comes with a form the user is called to specify departure and destination as well as optional stopovers by mouse-clicking into the map (Fig. 3: 4). With the 'Run'-button the user starts the calculation of the route. The results are displayed: the calculated shortest route is drawn into the map (Fig. 4) and the directions are listed. The database connections and the routing functionalities are implemented in a Java-based web application using Enterprise Java Beans (EJBs). According to Brabec and Samet (2007) the

Java environment has emerged as "the platform of choice" for cross-platform internet applications. Hence this application follows that actual approach. With handheld devices like mobile phones or personal digital assistants (PDA), routing and navigation by means of location-based services (LBS) will be commonly used applications in the near future (Hennig et al. 2009).

6 CONCLUSIONS AND OUTLOOK

The integration of routing applications results in a great benefit for the CampusGIS user. More detailed input data and data from different sources could enhance the scope of the described system. For better visualization a 3D-LoD1 model has been generated (Hennig 2008), its implementation is under construction. Routing and navigation in combination with 3D-data is much more user-friendly as it comes closer to the perception of the real world.

Additionally, a graphical user interface for mobile devices will be implemented in the future version. User's position will be grabbed from a W-LAN-router, a cell-ID of mobile telecommunication network or –this would give the highest accuracy– from an internal GPS receiver. With this accurate input location data CampusGIS will provide navigation in real time.
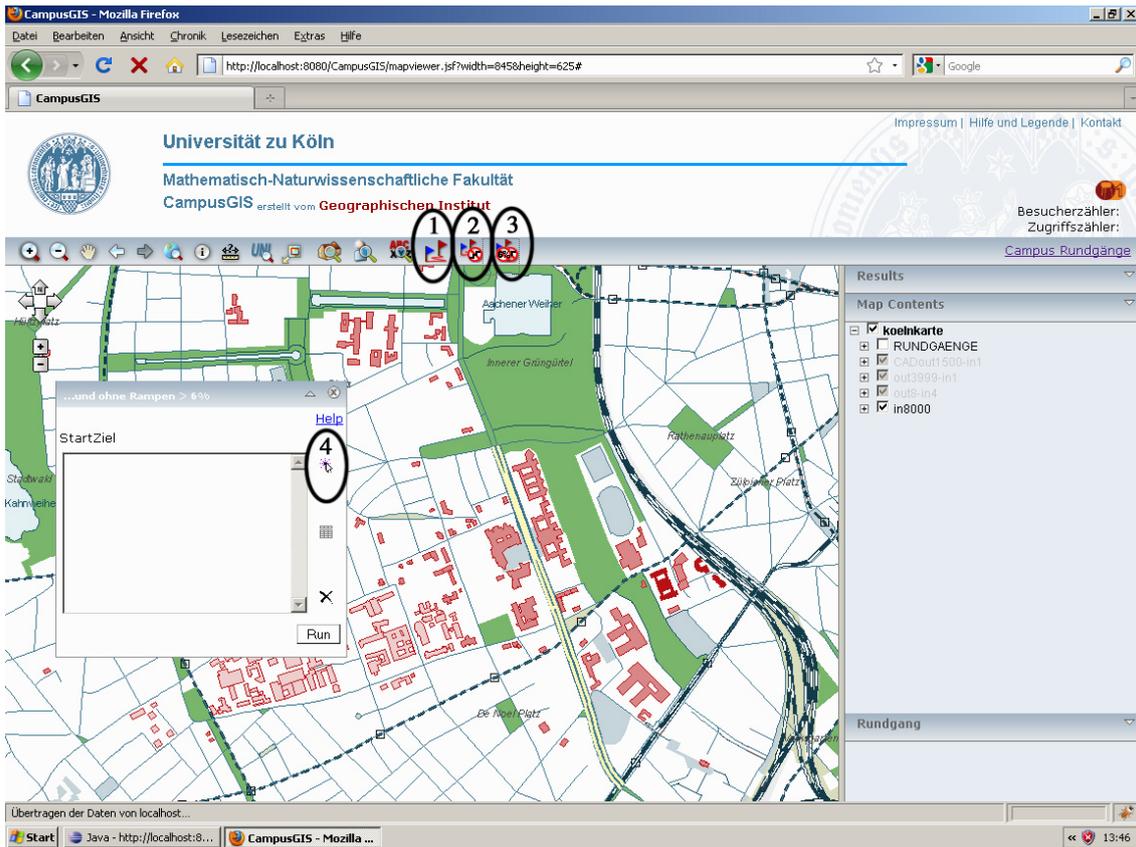
Figure 3. Screenshot CampusGIS-Routing application
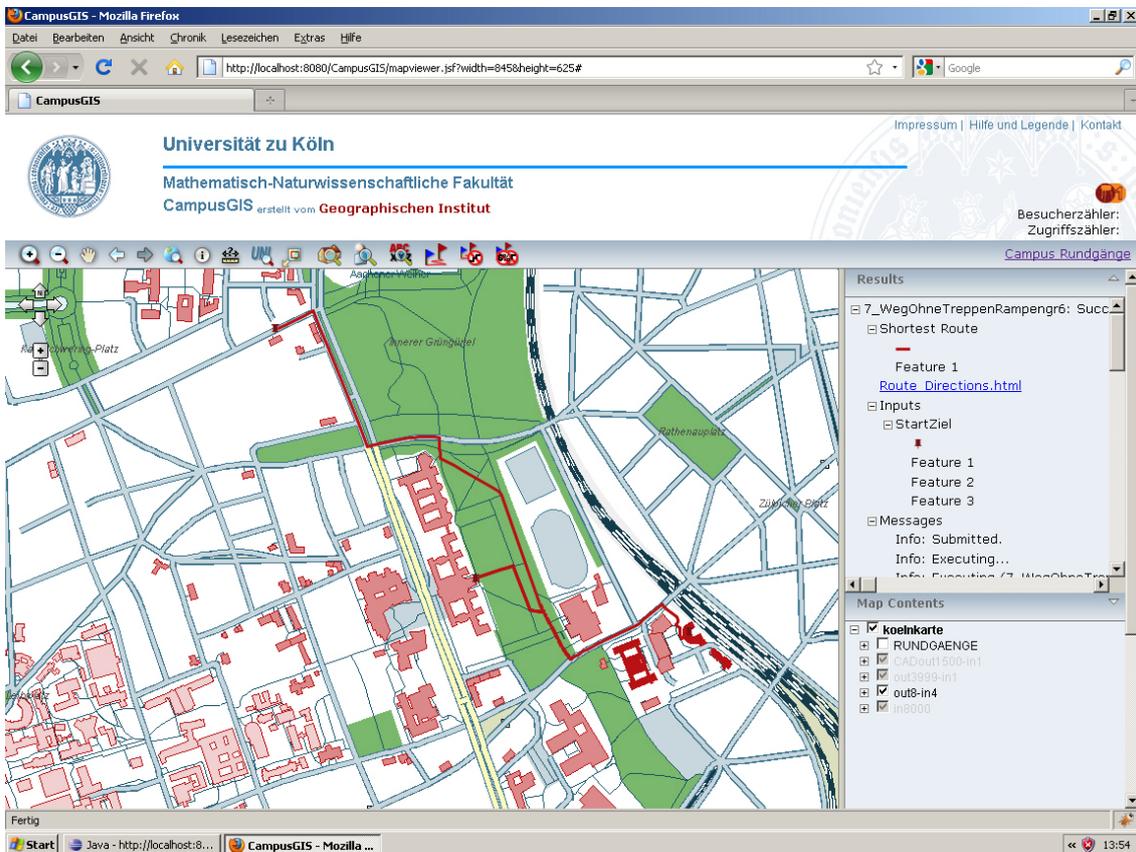
Figure 4. Screenshot CampusGIS - calculated route

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