

## DECISION SUPPORT SYSTEMS USING 3D OGC SERVICES AND INDOOR ROUTING – EXAMPLE SCENARIO FROM THE OWS-6 TESTBED

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### ABSTRACT

The OGC OWS testbeds are conducted annually with partners from the industry, research institutes and universities. A Decision Support Scenario (DSS) has been designed for investigating the combination and usage of different OGC standard specification technologies such as a Web Map Service or Web 3D Service inside such a thread. The scenario comprises a emergency situation inside a federal building and a potentially affected airport building nearby. A W3DS was used to process CityGML data and make it accessible for computers and other mobile devices. Thereby the CityGML data is analyzed and converted into X3D. In contrast to outdoor environments, there are no commercial providers of indoor space information, thus a routing network for emergency routing must be created for this project. Furthermore the route service (an OpenLS Route Service) had to be modified in order to create correct indoor graphs. Problems related to addressing indoor locations which will be necessary in order to use OpenLS for this purpose, and visualizing route instructions are discussed

### 1. INTRODUCTION

The OWS-6 testbed was part of the OGC's Interoperability Program, "a global, hands-on and collaborative prototyping program designed for rapid development and delivery of proven candidate specifications into OGC's Specification Program which can then be formalized for public release" (OGC 2008a). The Open Geospatial Consortium (OGC) conducts these testbeds annually with partners from the industry, research institutes and universities. For the academia it's an opportunity to showcase concepts and technologies and test them in a larger framework.

The content of the OWS-6 initiative was organized around five threads, for which distinct scenarios were developed. The scenario describes involved actors, data that must be available or accessible, data formats, data exchange interfaces for accessing data, communication, access constraints and security measures, and the general workflow required for solving the issue.

A 3D component was involved in the Decision Support Systems (DSS) thread which is described in more detail in the following. DSS "...focuses on presenting and interacting with data obtained from the sensor web and geoprocessing workflows in the most effective ways to support analysis and decision making" (OGC 2008b). Portrayal of maps containing context and situation specific information plays a major role in the assessment phase of the scenario. For this purpose OGC technologies, e.g. Web Map Service (WMS), Web Feature Service (WFS) and Styled Layer Descriptor (SLD), were used. A 3D environment was used for visualizing a city model, an airport, as well as for supporting indoor navigation. OGC technologies for setting up the 3D part include a WFS serving CityGML models, a Web 3D Service (W3DS, see [www.w3ds.org](http://www.w3ds.org)), a potential standard for streaming landscape and city models, and a 3D route service. Furthermore, an integrated 3D client was provided which was used by mobile task forces in the scenario. The client is capable to access a range of OGC services and visualize indoor 3D models for indoor routing.

### 2. LITERATURE REVIEW

In the area of emergency response and decision support in indoor environments, there is little research available. In Meijers et al. (2005) a semantic indoor model for emergency evacuation is described. The model is capable for single evacuation and route calculation, but due to missing semantic information not for mass evacuation. Furthermore the work rather concentrates on the model itself, but not on data storage or a proper visualization for the rescue forces.

In Lee, Zlatanova (2008) a data model for emergency management is proposed with an additional algorithm for the identification of feasible and safe routes in buildings. Another approach is a 3D Navigable Data Model (3D NDM) proposed by Lee (2007). It represents a conceptual framework of a building model, which is an important part for real-time evacuation. However, it does not describe how to connect the outdoor with the indoor environment. The work in Pu, Zlatanova (2005) proposes a 3D model-based approach for giving evacuation instructions. The proposed model is stored in a DBMS and the evacuation algorithm takes several circumstances (e.g. accuracy, speed) into account. This approach focuses on instructions for the affected persons inside the building.

### 3. SCENARIO

In the scenario for the DSS thread a potentially hazardous situation is described. An emergency situation evolves in a federal building located nearby an airport. A preceding hostage situation leads to a fire in the affected building. Upon receiving the notification of the fire, the first responders are informed and called into action to respond to the fire. To assist in assessing the overall situation, the dispatch office uses GIS software to create an overall context map view of the affected region. Additional information such as airport features is integrated as layers to enhance the details. A search of an OGC web service catalogue is initiated for finding available resources that are useful such as a WMS, WMTS or W3DS which can be

integrated into a mobile 3D client. Furthermore information about those services, e.g. endpoint URL or filtering parameters (radius, type of buildings etc.), are provided to the on-scene fire fighters. Among others, this search results in the discovery of a secured WFS with details about nearby airport facilities. On-scene, the first responders receive an email from the dispatch office providing information on how to access spatial data from the authorities' servers. That is, the first responders use the integrated client to download and view maps and building models encoded as CityGML. A detailed indoor model of the affected building is downloaded from the W3DS. The client visualizes cross sections of each floor and helps finding routes to the location of the fire. A 3D OpenLS Route Service is utilized for route finding. Since the fire may have an impact on the airport operations and threat nearby fuel storage tanks, the first responders recommend setting up a danger zone around the building within a distance of 1100 meters.

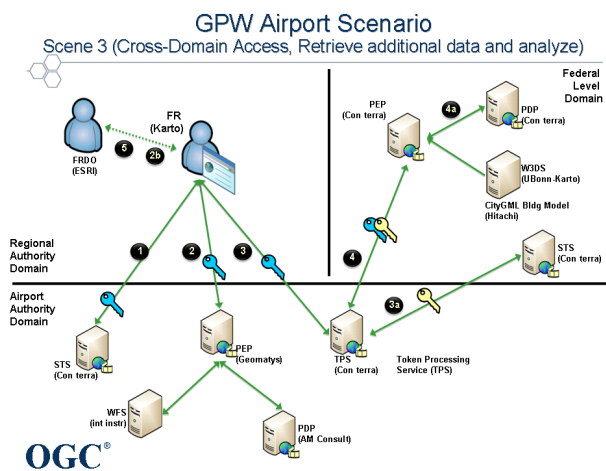


Fig. 1: Information flow within the DSS scenario between 3 involved authorities. The key symbols indicate secured data access using encryption and policy enforcement middleware.

The extent and possible impact of this zone is visualized by the integrated client. Figure 1 shows the information flow within a specific scene of the scenario. Basic information has been already handed over to the first responders (FR) by the dispatch office (FRDO) and data is accessed across 3 different domains through a security middleware.

#### 4. TECHNICAL BACKGROUND

The W3DS was used to process CityGML data and make it accessible as portrayal service. This enables also clients connected to mobile networks, e.g. laptops with 3G access, to download and visualize the data. The benefit of using a 3D portrayal service is that all data can be optimized for the display on modern graphics hardware. The optimization procedure affects the internal model structure, improved material and texture definitions, and conversion into 3D formats, in this case X3D. The data sets that were processed include a terrain model which was triangulated and spatially partitioned to enable an effective streaming, a street network, airport facility and buildings provided as CityGML.

CityGML has a well defined structure and provides elements for describing walls, roofs, windows, doors, and other features. Each of these features can have its own attribute set, geometry and material definition. The conversion process into X3D analyses the model structure and decides how to configure geographic features which will be eventually stored into a 3D

database used by the W3DS (OGC 2009b). Usually, the building elements are extracted from CityGML and stored as features, i.e. database entries. However, the process may be also configured to use another model level, e.g. groups of building, or building parts, if they need to be accessible individually. This database stores tables for each data set containing all available information. Each row in this table represents a GIS feature which is a more traditional way to maintain geographic data sets, compared with the possibly hierarchical nature of XML files. Each row/feature contains a 2D footprint for 2D map representations, the center point for selecting features, a unique ID, the 3D geometry encoded as X3D, and attributes.

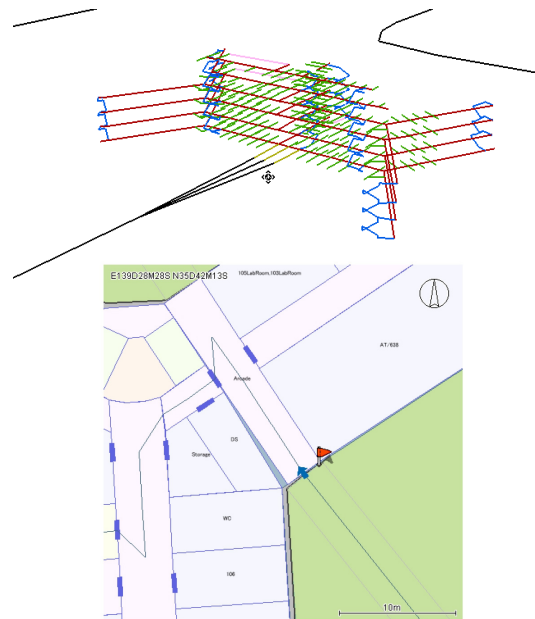


Fig. 2: Preparing indoor routing in OWS-6. Top: route network. Bottom: route displayed within a WMS map (from OGC 2009a).

The airport data including runways, facilities, and ground infrastructure was provided in a special military CityGML profile derived from UTDS. Despite the additional complexity this data set could be loaded into the integrated 3D client without any modifications. This demonstrated the versatility and extensibility of CityGML.

#### 5. ENABLING 3D INDOOR ROUTING

The most common approach for doing outdoor routing is to create a topological graph from the street and way network and to run route finding algorithms on this network graph. This graph consists of edges representing way segments and nodes connecting them. It may also contain constraints such as one way streets, speed limits, and additional costs at traffic lights and traffic jams. The simplest algorithms include Dijkstra and A\* (Neis et al. 2007) which have been implemented for previous projects.

Base data for the street network can be easily purchased from various providers, but there is currently no market for indoor networks. They must be derived from existing 3D building models, either automatically using semantic building information (e.g. Becker et al. 2009) or manually from the building geometry. Indoor networks are usually more complex and require different methodologies not only for the creation but also for the interpretation.

In case that the network is stored and provided in common exchange formats, for instance shape files or GML, the topology must be reconstructed. The usual approach for creating the graph structure is to detect vertices with same coordinates and optionally crossing line segments, and create nodes at these positions connecting the network edges. However, indoor networks may contain vertical elements (elevators) and horizontally overlapping parts at different levels. Built-in tools in COTS GIS software will produce incorrect results since they consider only the horizontal identity of vertices. Therefore the graph generator which is currently used for [openrouteservice.org](http://openrouteservice.org) had to be modified slightly in order to create correct indoor graphs.

The indoor network was connected to the street network at the entrance points resulting in a single network comprising streets, pedestrian paths, and building hallways, stairways, rooms of multiple buildings (Fig. 2). Indoor segment names (e.g. "Room 203", "Stairway A") were manually applied using 3D GIS software. Since the route finding algorithm is based on the topology only, it is possible to route from any address or point in the network into a specific room inside a building.

If a fire breaks out in a building, elevators are usually disabled so that the route service must be capable of restricting the access routes to stairways. This can be done by blocking segments with a specific attribute.

## 6. IMPLEMENTATION ISSUES

The route service was set up as OpenLS Route Service. On request, the integrated 3D client sends GetRoute requests containing start and end addresses (or alternatively coordinates), navigation mode (pedestrian, car, bicycle), and other options. The response to the GetRoute request contains route geometries with 3D coordinates which exactly match the building model already downloaded from the W3DS. This is a minor modification, but which is still OpenLS conformant. Since the 3D route geometry cannot be derived otherwise, it must be provided by the service.

Unfortunately, the address schema used by the OpenLS specification is not sufficient to describe floors and rooms. It can be only used to specify country, ZIP code, city, street name, house number, all information that is usually stored in an address database. For our use cases, it would be very useful to have an address schema enabling us to describe a building address together with a specific location within the building in a single entry. Additional information could include room number, floor number, name of person, gate or counter (e.g. at airports), and identifier of hallways, elevators and staircases.

Due to the lack of indoor address information we were forced to use 3D coordinates for describing start and end points which could be handled by the OpenLS service. Route instructions are generated from the segment names, travelling distances, and the angle between segments. A Route instruction has the form "go right|left|straight on SegmentName after n km|m|yd|mi", with SegmentName taken from a name column in the network dataset. Indoor instructions could be easily created by filling the name column with recognizable values, e.g. "Entrance Hall", "East Hallway". Creating meaningful route instructions is a research field on its own. However, it will be relatively easy to extend this bare technical approach in order to create instructions that make more sense in indoor navigation by analyzing vertical angles ("go up on Staircase A after n m."). Also, compacting networks will be useful, since indoor networks often contain very small segments which are important to model the correct route course, but dispensable in route instructions.

## 7. DISPLAY OF INDOOR ROUTES

Displaying indoor routes has different requirements compared to outdoor routing. The building structure is usually occluding indoor route segments. Experiments were carried out using transparency and removing parts such as walls from the model. Three alternatives were tested:

1. Horizontal cross sections clipping away the upper part of the building structure in order to see inside the floor at the current route section (Fig. 3). The near clip plane was extended to the distance between viewpoint and the current floor. Pro: familiar view comparable to 2D floor maps. Con: difficult to control view settings (altitude, near clip plane distance), only part of route visible.
2. Making the building structure semi-transparent so that one can see the route also from outside the building. Pro: complete route visible. Con: extremely difficult to apprehend the building structure since information on occluding and occluded parts gets lost, visual clutter.
3. Removing walls from the visualization (Fig. 4). Since the model was derived from CityGML it was possible to filter out elements according to the semantics. Only the ceilings and stairways were shown. Pro: easy to follow the route, no obstacles, complete route visible from flat view angles. Con: information on rooms gets lost, must be added by applying textures of floor maps.

Horizontal cross sections cutting off complete floors as shown in Fig. 2 were finally regarded as the most useful alternative by the DSS group. Although not the complete route will be visible, cross sections make the layout of each floor visible.

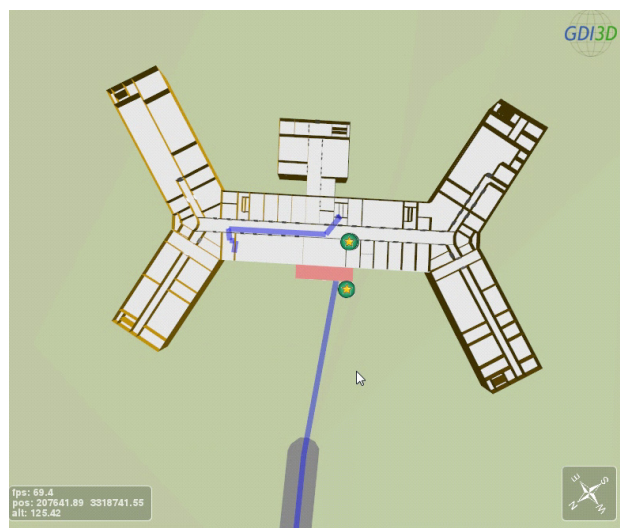


Fig. 3: 3D cross section of building with embedded route provided by 3D route service.

The tests above show that displaying and presenting indoor route instructions require different strategies. Walls, ceilings, and other structures may occlude the view to the actual route. Outdoor route visualization and animation can be achieved by following the route either from the driver's or walker's point of view or from an elevated position. This is hardly applicable to indoor route visualization. The animation style must switch to another mode as soon as the route enters a building.



Fig. 4: 3D indoor route visualization with filtered building structure. Walls were removed.

## 8. CONCLUSION

In the OWS-6 test bed it could be demonstrated how 3D building information can be integrated into the decision making process of dispatch offices and task forces during a response to an emergency situation. Using standards is crucial for quickly accessing data from entities that have not been contacted before and can be life saving. W3DS can be used to get a quick overview of the affected area. Detailed indoor models can be either retrieved from a WFS serving CityGML, a W3DS, or receiving a single CityGML file. Indoor route finding can be achieved using existing network based algorithms. However, some crucial parts in the workflow for creating and distributing 3D networks for indoor routing are still missing. Displaying and creating a meaningful presentation of the computed route requires more empirical tests, since complex indoor environments are usually distracting from the actual information.

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