Conception of a 3D Geodata Web Service for the Support of Indoor Navigation with GNSS[1]

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Abstract

This paper addresses the concept of a 3D Geodata Web Service for the support of indoor navigation with satellite-based positioning systems like Galileo or GPS. The presented work is part of a project called INDOOR, which principally aims at the support of satellite positioning and navigation within buildings. The intended web service shall provide 3D building data to mobile clients, where it will be used to calculate the indoor signal dispersion and to provide location based information to the user. After an expose of the detailed requirements on the service CityGML has been selected as best fitting data format. It is shown how the inherent material properties of 3D building elements can be included in CityGML. Further on the possibilities to transfer data, which is enabling for a personalised and a situation aware 3D route calculation, is shortly discussed.

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1 Introduction

After the great hype around LBS (Location Based Services) at the beginning of the century in the meantime numerous solutions have demonstrated their feasibility, for example the services implemented in the EU-funded research projects PARAMOUNT [Sayda et al. 2002, Mundle et al. 2004] and LoVeus [Blechschmied et al. 2004]. The positioning of many of these services relies on GNSS (Global Navigation Satellite System) signals, in particular because of its global availability and precision. For most applications satellite-based positioning with Galileo or GPS is still depending on the direct "visibility" of the satellites. Hence the mentioned location aware services can only be provided for outdoor environments with an adequate GNSS signal availability and not for buildings (indoor) or areas with comparable signal shadowing effects (border areas between indoor and outdoor). To extend the positioning capabilities also to indoor environments (inside buildings) additional localization techniques are required. In recent years a multitude of such indoor positioning technologies has been developed. Most of them are based on the concept of "pseudolites"[2], on wireless communication networks like WLAN [Zehner et al. 2005] or Bluetooth [Genco 2005], make use of installed beacons like RFID [Okuda et al. 2005] or Infrared [Brassart et al. 2000] or apply additional positioning sensor systems [Okuda et al. 2005]. However, when a precise localisation is needed, all of these techniques have the disadvantage that they require an additional infrastructure installed in the buildings.

An expansion of GNSS positioning to indoor environments would do without such local installations and therefore be much more convenient. As shown by Eissfeller et al. (2005) depending on the building materials sensitive outdoor receivers are capable to acquire the damped GNNS signals inside of a building, but the waiting time for such a measurement is by far too long for a practical application. The aim of the INDOOR project is to bridge these deficits through developing new GNSS signal processing methods and new receiver systems. This paper is focused on one part of the research, aiming at the setup of a geodata web service providing 3D building information to mobile clients. It will enable the dedicated simulation software to calculate the GNSS signal dispersion at their current position and to use this information for the improvement of the positioning accuracy.

The remainder of this paper provides a more detailed insight into the objectives of the INDOOR project in the next paragraph. Based on that, the requirements on the demanded 3D geodata web service, which is providing

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[2] http://en.wikipedia.org/wiki/Pseudolite

building information necessary to model the GNSS signal dispersion, will
be defined in chapter 3. In chapter 4 an overview on possible data formats
and standards will be given and an appropriate choice is made for the pro-
ject. The paragraphs 5 and 6 address the particular concepts for the inclu-
sion of material properties in the building model and the 3D routing data.

2 The INDOOR Project

The principal aim of the INDOOR project is to support satellite positioning
and navigation within buildings or in critical border areas between indoor
and outdoor areas. Therefore, the main focus within the project is on the
development of new signal processing methods and new receiver systems,
the connection to modern wireless communication systems as well as ex-
ternal sensors and the transmission and ray-tracing modelling of the signal
dispersion in buildings. Investigations will be focused on how building
parts, like for example walls, influence the GNSS (Global Navigation Sat-
ellite System) signal transmission and which properties, like materials or
age, are necessary to model the signal dispersion. Based on the results of
this research a 3D geodata web service, which is providing the building in-
formation, will be implemented. On a mobile device, equipped with an in-
door-capable GNSS receiver developed in the project, such information
could then be used for the simulation of the GNSS signal strength of the
current position in the building and therewith for the improvement of the
positioning accuracy.
The projects results will be exemplified and demonstrated by application
scenarios within the domains of SAR (Search and Rescue) and logistics.
For security-sensitive applications (e.g. public responsibilities of security
politics, administration and services) and traffic-logistics applications, in-
door navigation is of particular interest. For example the exact localisation
of an emergency call within a building and later on the reliable localisation
and navigation of the SAR teams can be deciding factors for the rescue
mission. The availability of GNSS positioning within buildings offers new
possibilities for LBS and other navigation applications.

3 Requirements on the 3D Geodata Web Service

The main objective of the proposed web service is to provide the informa-
tion, necessary to simulate the GNSS signal strength within a building.
Therefore, all building elements passed through by the available satellite

signals on their direct paths between satellites and the receiver antenna, have to be known. Building elements information must contain their geometries as well as certain material parameters. Generally it should be possible to link a specific material (like concrete or steel) to properties (e.g. physical constants, refractive index) relevant for the signal dispersion calculation. Since it might not always be possible to assign a single material to a building element, alternatively an attribute containing a signal effect factor will be assigned. This factor has to be acquired through test measurements in the field. To simulate the signal dispersion a model, which is only containing the main building elements, like walls, ceiling, roof and basement, will not be sufficient. Every object in the building, which has a measurable influence on the signal, has to be considered in the model. This also includes things like beams, pipes, doors, curtain walls, bigger cables and railings. Summarized for this application a complex model for the appropriate representation of buildings has to be developed.

Furthermore the data shall be visualised on mobile devices of users (e.g. PDAs or rugged tablet PCs for the SAR teams), provide location based information and enable 3D routing calculations, in particular within buildings. The visualisation should contain detailed information about the indoor environment. It should comprise main landmarks, like furniture (e.g. the information desk in the entrance hall of an airport) or main way posts and textures for surfaces like walls or floors.

Within the INDOOR Project the routing calculations will be made on client side, which means, that the data for the routing calculation, has to be made available through the service. The final route description or verbal route instructions will be calculated by the client application. Nevertheless the available data has to be adequate for the following requirements on the route calculation. It should be personalised and adjustable to specific situations, like for example an emergency rescue or logistic transports of heavyweight material. In complex public buildings, like for example an airport, the accessibility of a path depends not only on the direction and the means of transport (e.g. on foot or using a wheelchair). Many of the paths are only accessible for employees of the airport or the security staff. Other paths should only be used under certain circumstances, like for example an emergency exit window should only be smashed in emergency cases. At the same time these circumstances will probably prohibit the use of an elevator. These examples demonstrate the importance of a consideration of personalisation and the current situations as affordances [Raubal and Worboys 1999] of the paths for the route calculation.

Emphasis is also put on the consideration of the weights of graph edges and the path optimisation strategy, like for example shortest path or optimised regarding to certain parameters. In emergency cases main exit routes

should be preferentially chosen to allow for a safe and controlled exit. Thus a simple graph weighting according the length of the edges will not satisfy.

In general, for the service interfaces and transfer data formats international standards are preferentially chosen. But, as it will be shown in the next paragraph, the different areas of application with their varying requirements on the building model and the service interfaces are not yet fully supported by any existing system or standard.

4 Overview on possible Data Formats and Service Interface Standards

As mentioned in the previous chapter, for the service interfaces and the transfer data formats international standards are preferred. But the manifold requirements like the

1. detailed 3D visualisation including textures,
2. semantic information about building elements,
3. material properties of the building elements,
4. and personalised and situation aware routing possibilities

are not yet fully supported by any available standard.

Existing 3D graphics standards, like VRML or its successor X3D [ISO/IEC 19775:2004], accomplish all requirements in terms of 3D visualisation independently of the required level of detail (LoD). But they do not provide semantic information or additional thematic attributes for the graphical objects. With those standards it is not possible to define building elements or indoor installations as object classes (e.g. roof or door) and to attach the corresponding material properties.

The IFC (Industry Foundation Classes, [IFC 2.x.2]) defines an exchange format for building models. It has been specified by the IAI (International Alliance for Interoperability) and became publicly available international standard. IFC provides a very detailed semantic model for building elements and building installations. Its known lack of defined concepts of outdoor object types (e.g. streets or vegetation), as pointed out by [Kolbe et al. 2005], is not crucial for indoor applications. IFC is supported by most CAD software products, in particular by those specialised on architectural design.

CityGML [OGC 06-057], which is probably the latest data format for city and building models. It is a GML profile (Geography Markup Language),

which is defining building object types based on the IFC model. CityGML provides a geometric, topological and semantic data model. It is less detailed than IFC, but since it is extensible, missing object types can be added for specific applications. The required material properties can also be added to each object type. Compared to IFC, CityGML additionally provides the possibility to define different LoDs for each object and it contains more defined outdoor object types, in particular necessary for city models. For indoor applications only the most comprehensive LoD4 is useful, since this is the only one which considers interior structures like rooms, stairs and furniture. Anyway, for border areas between indoor and outdoor, which are also part of the INDOOR application frame, less detailed LoDs are a nice feature. For example, they can be used for the visualisation of the buildings in the direct neighbourhood of the target building. Another advantage of CityGML is the definition of terrain intersection curves for each building, which allow for a better integration of buildings and the surrounding terrain [Kolbe et al. 2005].

The available interfaces of the OGC (Open Geospatial Consortium) and their different areas of application are schematised in *Figure 1*. For the INDOOR project prototype system only such mobile client devices will be selected, that have a sufficient processing power. This means that the balancing between the client and the server is not a main issue.
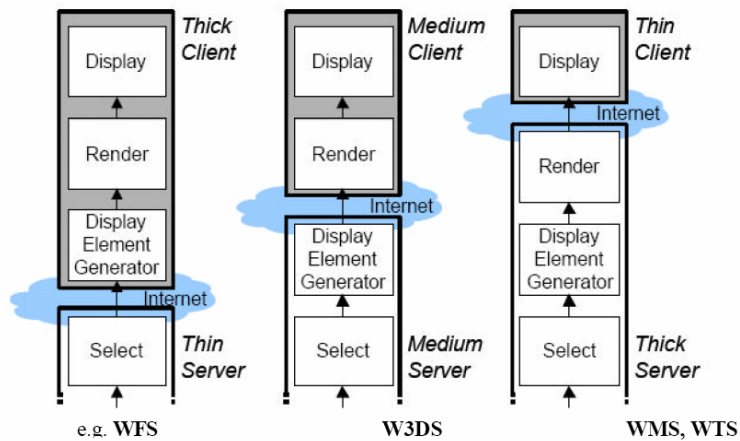

Fig. 1. Different balancing schemes between client and server, (taken from [OGC 05-019])

The WMS (Web Map Service) and the WTS (Web Terrain Service), shown on the right side of *fig.1*, are not appropriate for this application,

since with these interfaces the whole rendering is done on the server and only bitmaps are available for the client. The necessary 3 dimensional geometries and all semantic information of the object types are not transferable with these interfaces. The only "real" candidates are the W3DS (Web 3D Service) and the WFS (Web Feature Service). The W3DS merges different object types into a single scene graph, representing a visual representation of the basic 3D geodata. Server requests are defined through the viewing parameters, like angle of view, distance etc.. The resulting scene graph is rendered on client side. This allows for interaction possibilities for the user, but they are limited by the scene graph. The semantic characteristics and relations are not contained in a scene graph [OGC 05-019]. Thus the W3DS could be an appropriate solution for the 3D visualisation, but the other three main requirements, mentioned at the beginning of the chapter, are not fulfilled. The only interface which is also providing the semantic information of the objects is the WFS. This standard allows for server requests using an ID, bounding box or specific spatial and other operators.

The selection of an appropriate interface for the service is not fully independent of the chosen transfer format. While the W3DS is supporting numerous formats (VRML, X3D) the WFS is mainly supporting GML as transfer format; thus only CityGML can be chosen since the other formats are not supporting GML.

Recapitulating, CityGML is the best fitting format for the requirements on visualisation and availability of semantic information about building elements and building installations. Since CityGML is extensible, required material and routing information can be added to the object type definitions or included through additional object types. Further on CityGML can conveniently be published through the WFS interface, which is widely accepted and implemented in available software products.

5 Inclusion of Material Properties

The example code in the appendix of the paper is illustrating how inherent material properties of 3D building elements can be included in CityGML. Therefore we introduce the *InherentMaterialInfo* element, which is treated like the *genericAttribute* defined in CityGML. It differs from the *Material* attribute defined in CityGML, since this one is defining appearance information of objects and not the physical properties of their inherent materials. The example is schematically demonstrating how different material layers can be defined for, in this case, a door. Correspondingly the material properties of every layered object can be described.

6 Concepts for 3D Routing

To apply existing shortest path calculation algorithms (like e.g. the Dijkstra-algorithm) for indoor routing the network of rooms has to be converted into a graph network representing the walking paths. But since the paths, people are using within a building, are not as well defined as for example the streets are for cars, it is difficult to do this conversion automatically. In particular in huge rooms, like e.g. the entrance hall of an airport, an infinite number of possible walking paths are existing. Every object which is a potential routing target must be represented through a node in the graph network. Further on, the information, necessary for a consideration of personalisation and the current situations in a route calculation, can not be directly attached to the existing building elements. For example rooms are not representing the boundaries of the accessible area, if dividing walls or other barriers are used to restrict the entry for certain persons. CityGML does not provide the possibility to define such areas of uniform accessibility. Because of these reasons we decided to model the graph network independently from the building elements and not to rely on an automatic conversion of the network of rooms. The defined graph network is represented by conventional nodes and directed edges. The nodes refer to the building elements or installations they are representing in the graph network. The edges contain additional attributes about their accessibility and weighting information for each situation, which has to be considered. If an edge is passing a particular landmark, a corresponding link will be stored. Possible restrictions along an edge, like for example the width of doors for logistic applications or the slope and the number of stairs for wheelchairs, are also included. Encoded in GML the resulting graph network can also be published through the WFS interface and enable the client to calculate the routes and verbal route instructions.

Conclusion

The paper introduces the support of satellite positioning and navigation within buildings as a new area of application for 3D geodata formats and the corresponding web service interfaces. CityGML is currently the best fitting transfer format for the introduced server requirements on visualisation and availability of semantic information about building elements and building installations. Since CityGML is extensible, required material and routing information can be added to the object type definitions or included through additional object types. For 3D route calculations a graph network

defined independently from the building data has been preferred, since a personalised and a situation aware routing, which is only based on 3D building data, can hardly be realised.

In our future work we will prove the concepts introduced in this paper by practical tests. This will also include investigations on the efforts necessary to provide such complex 3D models of buildings for Indoor navigation applications.

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Appendix

```xml
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                    ...
            </gml:surfaceMember>
        </gml:MultiSurface>
    </lod4MultiSurface>
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            </materialLayer>
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        </materialLayerSet>
    </InherentMaterialInfo>
</Door>
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