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OGC® OWS-6 Outdoor and Indoor 3D Routing Services Engineering Report

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Preface

Suggested additions, changes, and comments on this draft report are welcome and encouraged. Such suggestions may be submitted by email message or by making suggested changes in an edited copy of this document.

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OWS-6 Testbed

OWS testbeds are part of OGC's Interoperability Program, a global, hands-on and collaborative prototyping program designed to rapidly develop, test and deliver Engineering Reports and Change Requests into the OGC Specification Program, where they are formalized for public release. In OGC's Interoperability Initiatives, international teams of technology providers work together to solve specific geoprocessing interoperability problems posed by the Initiative's sponsoring organizations. OGC Interoperability Initiatives include test beds, pilot projects, interoperability experiments and interoperability support services - all designed to encourage rapid development, testing, validation and adoption of OGC standards.

In April 2008, the OGC issued a call for sponsors for an OGC Web Services, Phase 6 (OWS-6) Testbed activity. The activity completed in June 2009. There is a series of on-line demonstrations available here: http://www.opengeospatial.org/pub/www/ows6/index.html The OWS-6 sponsors are organizations seeking open standards for their interoperability requirements. After analyzing their requirements, the OGC Interoperability Team recommended to the sponsors that the content of the OWS-6 initiative be organized around the following threads:

1. Sensor Web Enablement (SWE)
2. Geo Processing Workflow (GPW)
3. Aeronautical Information Management (AIM)
4. Decision Support Services (DSS)
5. Compliance Testing (CITE)

The OWS-6 sponsoring organizations were:

- U.S. National Geospatial-Intelligence Agency (NGA)
- Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD)
- GeoConnections - Natural Resources Canada
- U.S. Federal Aviation Agency (FAA)
- EUROCONTROL
- EADS Defence and Communications Systems
- US Geological Survey
- Lockheed Martin

- BAE Systems
- ERDAS, Inc.

The OWS-6 participating organizations were:
52North, AM Consult, Carbon Project, Charles Roswell, Compusult, con terra, CubeWerx, ESRI, FedEx, Galdos, Geomatys, GIS.FCU, Taiwan, GMU CSISS, Hitachi Ltd., Hitachi Advanced Systems Corp, Hitachi Software Engineering Co., Ltd., iGSI, GmbH, interactive instruments, lat/lon, GmbH, LISAsoft, Luciad, Lufthansa, NOAA MDL, Northrop Grumman TASC, OSS Nokalva, PCAvionics, Snowflake, Spot Image/ESA/Spacebel, STFC, UK, UAB CREAF, Univ Bonn Karto, Univ Bonn IGG, Univ Bunderswehr, Univ Muenster IfGI, Vightel, Yumetech.

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OGC® OWS-6 Outdoor and Indoor 3D Routing Services Engineering Report

1 Introduction

1.1 Scope

This document described the Outdoor and Indoor 3D Routing Services which are used in the OGC OWS-6 Decision Support Services (DSS) thread. The objective is to enhance a network topology for the current CityGML specification based on the knowledge acquired through the development and experimental evaluation of this project.

This OGC™ document is applicable to the OWS-6 DSS thread in order to retrieve the datasets used in the navigation scenario and display the map information which can make users know the way.

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1.3 Revision history

Date	Release	Editor	Primary clauses modified	Description
2009-03-31	0.1	Akiko Sato	All	First Version
2009-03-31	0.3	Akiko Sato	All	Minor changes such as spell checking
2009-04-17	1.0	Akiko Sato	All	Final Version
2009-05-28	1.1	Akiko Sato	All	7. Technical issues and suggestions added
2009-08-27	1.2	Akiko Sato, Nobuhiro Ishimaru	All	Revised for public version
2009-10-07	0.3	Carl Reed	Various	Prepare for publication

1.4 Future work

This is the final version.

2 References

The following documents are referenced in this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OGC 06-121r3, *OpenGIS® Web Services Common Specification*

NOTE This OWS Common Specification contains a list of normative references that are also applicable to this Implementation Specification.

OGC 08-007r1, *OpenGIS® City Geography Markup Language (CityGML) Encoding Standard*

OGC 06-042, *OpenGIS® Web Map Server Implementation Specification*

OGC 07-074, *OpenGIS® Location Services (OpenLS): Core Services*

3 Conventions

3.1 Abbreviated terms

CityGML City Geography Markup Language

DSS Decision Support Services

GML Geography Markup Language

OGC Open Geospatial Consortium

WMS	Web Map Server
XML	eXtended Markup Language

4 Overview

The Outdoor and Indoor 3D Routing Service proposed in the OWS-6 DSS thread is a service based on data encoded as CityGML and provided by an OGC WMS interface.

There are three featured functions.

1) Network topology for CityGML

Outdoor and Indoor 3D Routing Service is designed to provide navigation information that lets users easily find out how to get to their chosen destination. CityGML is the accepted standard for describing 3D data sets for city environments, including buildings. But CityGML does not currently include a data model for routing information. By adding the network topology, path routing can be performed seamlessly and efficiently between the outdoor and indoor environments. So in this DSS thread, we have developed the route calculation as well as the indoor network topology.

2) WMS interface

To obtain information for Outdoor and Indoor 3D Routing service, the WMS interface can be used. We think these services will be applicable to a lot of devices. Specifically, cellular phones are our main target as well as PCs. Because 3D viewing is too heavy for cellular phones, we decided to provide the information with 2D images. To display some additional navigation symbols, we add some parameters to the WMS/GetMap operation.

3) CityGML dataset for demo scenario

We have developed and evaluated the test-bed program and its experimental environment at the Hitachi Central Research Laboratory (CRL) in Tokyo Japan. So we have made the CityGML datasets of the Hitachi CRL building, which we share in the demo scenario. This data has the walls and the opening doors so that anyone can walk through our building.

Figure 1 gives an overview.

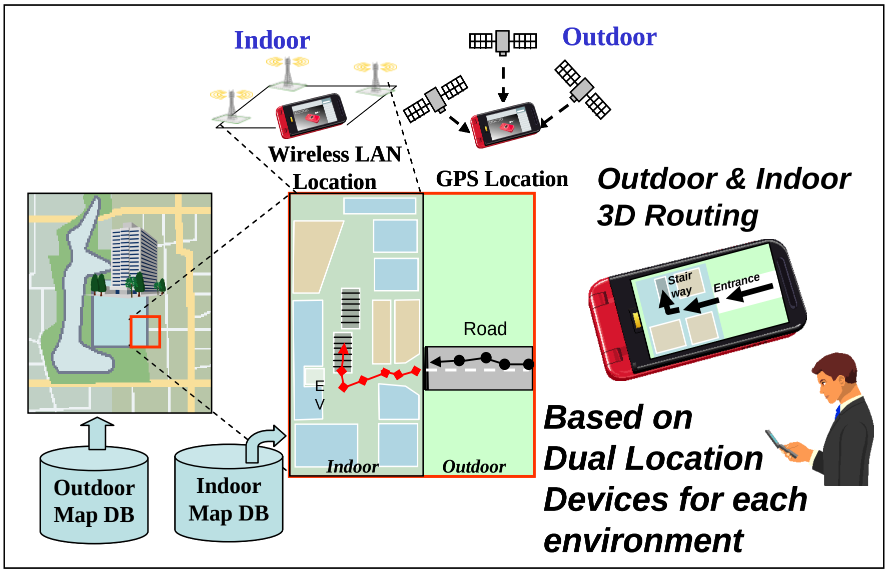

Figure 1: Overview image.

5 Outdoor and Indoor 3D Routing Services

5.1 Introduction

Outdoor and Indoor 3D Routing Service is designed to provide navigation information that lets users easily find out how to get to wherever they want to go. For Outdoor and Indoor 3D Routing Services, the Indoor Spatial Data Modeling is the most important component. Any lines, polygons, and their relation should be stated for expressing locations and areas inside a building and/or underground.

CityGML is the accepted standard for describing 3D data sets for city environments, including buildings. But CityGML does not currently include a data model for routing information. By adding the network topology, efficient path routing between the outdoor and indoor environments can be seamlessly performed. So in this DSS thread, the concept of the network topology is embraced for CityGML.

5.2 Network topology model for Outdoor and Indoor 3D Routing Services

Some types of network topology model are thought to enhance CityGML. The following four types of network topology model were considered for use in Outdoor and Indoor 3D Routing Services.

5.2.1 Model 1: Network topology identical to the outdoor road network

This model is almost identical to that of the outdoor road network. The points on the crossing are defined as nodes, and the lines between nodes as links. This model is applied to the indoor map in Figure 2.

The issue is how to figure out where should be defined as nodes. For example, in Figure 2, the three nodes were defined in the center corridor, because it is adjoined to the room to the right by two doors and also adjoined to elevators by one door. But this process is difficult to execute automatically. Furthermore, this network topology uses a polyline to show the route, but people will often move freely around a room instead of walking along the polyline as shown. This model's best feature is that it can be developed in the same way as the outdoor road network model, so the cost reduction can be estimated in practical use.

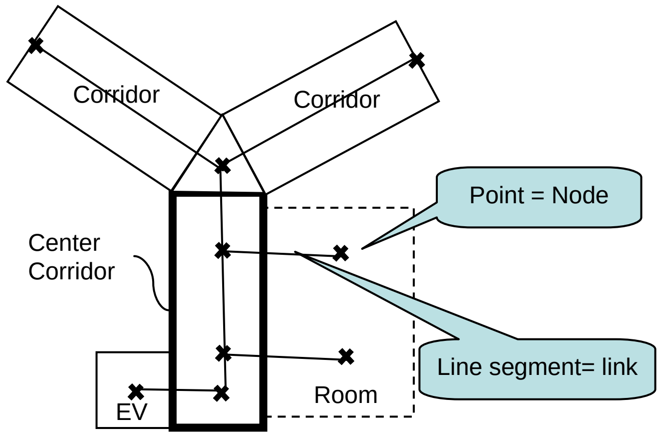

Figure 2: Network model 1.

5.2.2 Model 2: Network topology focused on the center points of each room

This model is focused on the center point of each room. The center points of all rooms and the points where the rooms are adjoined are defined as nodes. The lines between nodes are defined as links. This model is applied to the indoor map in Figure 3.

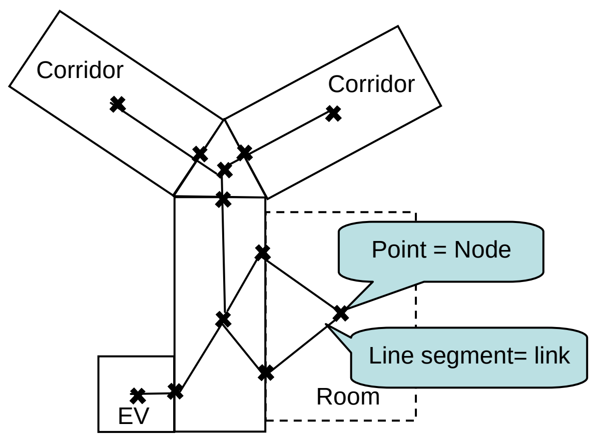

Figure 3: Network model 2.

The best feature is that if the geometries of the building are already stored in the GIS middlewares, almost all nodes and links can be defined automatically. But in the case of a big room, such as an exhibition hall, the issue is that a route that charts a path through the center of the room looks unnatural to users. Additionally, all the center points of each room and all the points where the rooms are adjoined must be managed, so there is a problem from the point of view of scalability.

5.2.3 Model 3: Network topology expanded from Model 2

This model is expanded from model 2. The room is divided into areas called “cells”. The center points of each cell and the points where the cells are adjoined are defined as nodes. The lines between nodes are defined as links. This model is applied to the indoor map in Figure 4.

This model of course has the same merits as model 2. In addition, the route line looks better than that of model 2, because in the case of a big room, it is divided into some smaller cells and the provided route polylines look similar to the user’s real walking path route. The issue is that the numbers of nodes and links to be managed will increase much more than those of model 2. This is also a serious problem from the point of view of scalability.

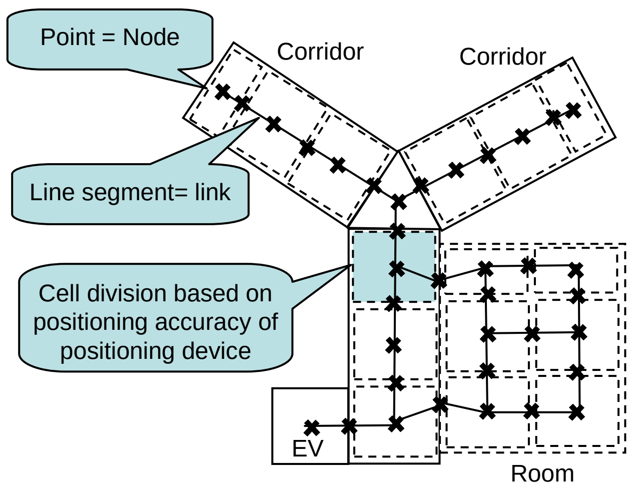

Figure 4: Network model 3.

5.2.4 Model 4: Network topology based on polygons

This model is based on the concept of the transition between the rooms. In general, nodes are related to points, and links are related to polylines. On the other hand, the concept of the nodes and links in this model is thought to be independent of the geometries. The polygons expressing the rooms are related to nodes, and the points at which the rooms are adjoined are related to links. The navigation symbols do not show the direction of the route but show the doors or the junctions to which the users should go next. This model is applied to the indoor map in Figure 5.

This model does not bother with how users move around inside the room but is concerned with in which room users are located, which room is next, and through which door users should go next. This model is easy for users to understand, and the numbers of nodes and links are fewer than those of model 3. The issue is the cost for implementation on the legacy GIS middlewares.

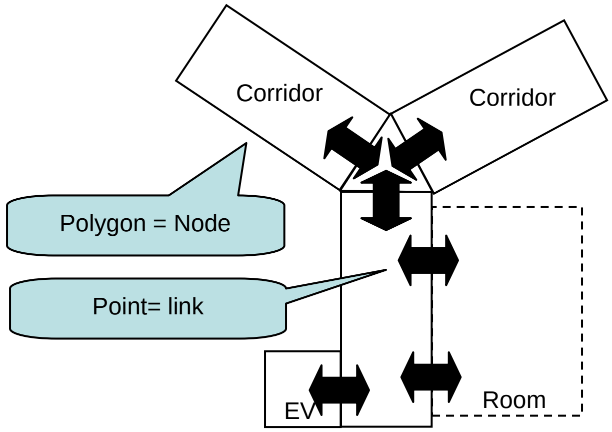

Figure 5: Network model 4.

5.2.5 Conclusion

Table 1 shows the result of comparison between the four models.

Table 1: Comparison between the four models.

Req. \ Model	1	2	3	4
Cost of preparing network topology	Bad	Good	Good	Good
Efficiency for searching and managing	Good	Normal	Bad	Good
Ability of trajectory analysis for users	Normal	Bad	Good	Normal
Usability of navigation information	Normal	Bad	Normal	Normal
Cost of development	Normal	Good	Good	Bad

According to this comparison, models 3 and 4 seem to have advantages over the others. Model 3 is easier on the legacy GIS middlewares to implement, so we adopted model 3 in this OWS-6 project.

5.3 Interface Specification

The Outdoor and Indoor 3D Routing Service interface supports two operations:

1. GetCapabilities

2. GetMap

5.3.1 GetCapabilities Operation

The GetCapabilities operation is identical to the WMS GetCapabilities operation (OGC 06-042).

No parameters are added on the GetCapabilities operation for this service.

Table 2: Parameters of the GetCapabilities request.

URL parameter	Mandatory/ Optional	Annotation
VERSION=<*version*>	M	Request version
SERVICE	M	Comma-separated list of one or more map layers
REQUEST	M	Service type
FORMAT	M	Output format of map
UPDATESEQUENCE	O	Sequence number or string for cache control

5.3.2 GetMap Operation

The GetMap is the main operation of Outdoor and Indoor 3D Routing Service. This operation is almost identical to the WMS GetMap operation (OGC 06-042). The additional element was defined to provide the navigation information. Table 3 shows the parameters for a GetMap request. Parameters marked "M" are mandatory, and "O" means they are optional. In Table 3, the parameters emphasized in bold letters are expanded for this service.

Table 3: Parameters of the GetMap request (expanded).

URL parameter	Mandatory/ Optional	Annotation
VERSION =<*version*>	M	Request version
REQUEST	M	Request name
LAYERS	M	Comma-separated list of one or more map layers
STYLES	M	Comma-separated list of one rendering style per requested layer
CRS	M	Coordinate reference system
BBOX	M	Bounding box comers (lower left, upper right) in CRS units
WIDTH	M	Width in pixels of map picture
HEIGHT	M	Height in pixels of map picture
FORMAT	M	Output format of map
TRANSPARENT	O	Background transparency of map (default=FALSE)
BGCOLOR	O	Hexadecimal red-green-blue color value for the background color (default=0xFFFFFF)
EXCEPTIONS	O	The format in which exceptions are to be reported by the WMS (default=XML)
TIME	O	Time value of layer desired
ELEVATION	O	Elevation of layer desired
POSITION	**O**	**User's current position**
OVERLAYS	**O**	**The overlay information (POSITION/ARROW/PATH/ANALYZE)**
BUILDINGS	**O**	**Comma-separated list of numbers of the targeted buildings**
FLOORS	**O**	**Comma-separated list of numbers of the targeted floors**

The following are the parameters added to the GetMap request for this service.

5.3.2.1 POSITION

The optional POSITON parameter is a point value that indicates a user's current location. The value is a comma-separated list of x and y. If the POSITION parameter is not defined in the request, the center point of BBOX shall be used.

5.3.2.2 OVERLAYS

The optional OVERLAYS parameter indicates the overlay information. The value is a comma-separated list of one or more overlays. The value "POSITION" indicates that the user's current position shall be displayed. The value "ARROW" indicates that the navigation information that forms arrows on the route shall be displayed. The value "PATH" indicates that the route polyline shall be displayed. The value "ANALYZE" is reserved for future use.

5.3.2.3 BUILDINGS

The optional BUILDINGS parameter is the identification number of the targeted buildings. The value is a comma-separated list of one or more IDs. The layer of the buildings should be defined by the LAYERS parameter. If the BUILDINGS parameter is not defined in the request, all the buildings shall be searched.

5.3.2.4 FLOORS

The optional FLOORS parameter is the identification number of the targeted floors of the building. The value is a comma-separated list of one or more IDs. The sequence should be the same as those of the BUILDINGS. If the BUILDINGS parameter is not defined and only that of FLOORS is defined, the defined floors of the all buildings shall be searched.

5.3.3 Client Images

Figures 6, 7, and 8 show the images of the client when requesting the Outdoor and Indoor 3D Routing using the extended WMS interface defined in 5.3.1 and 5.3.2.

This system has the WMS interface and also has the interface for the cellular phone network in Japan. So in Japan, users can receive the navigation map of wherever they want through their cellular phones.

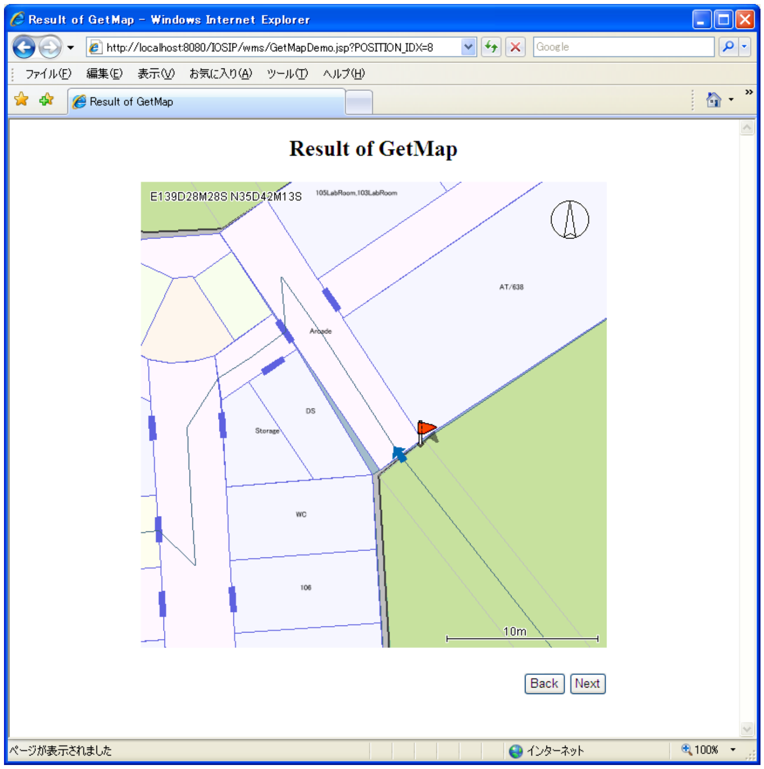

Figure 6: Client images (between outdoor and indoor).

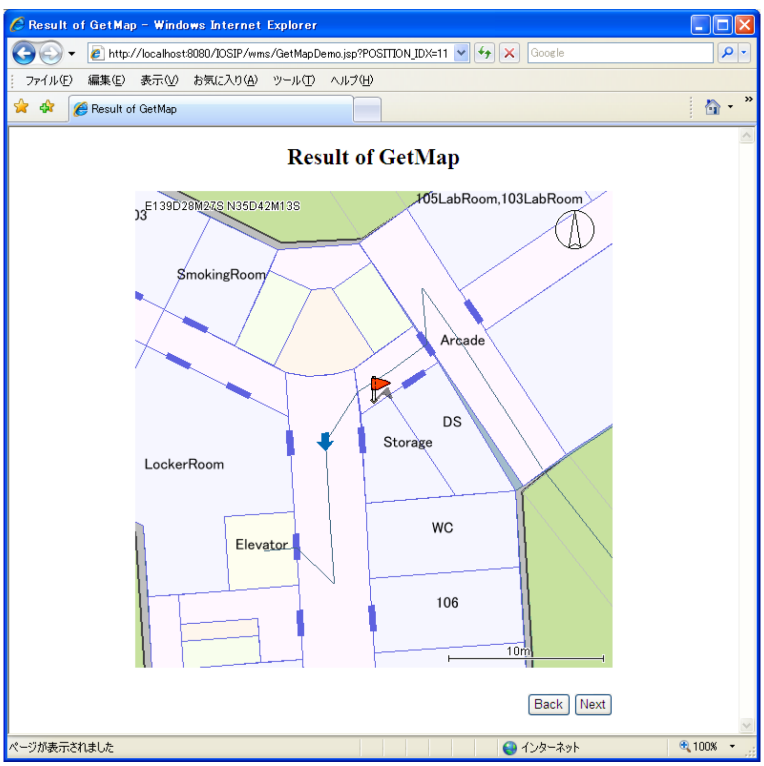

Figure 7: Client images (on the 1st floor).

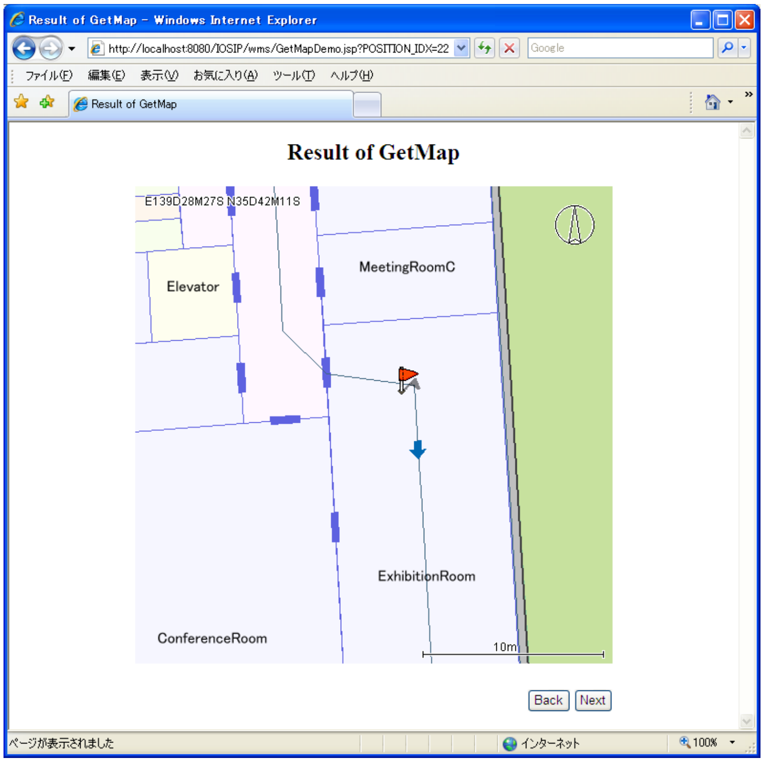

Figure 8: Client images (around the goal on the 6th floor).

5.3.4 WMS demo server

We have developed the server providing the WMS interface: GetCapabilities and Getmap defined in 5.3.1 and 5.3.2. To access this server, the Basic Authentication will be needed. If a non-Hitachi member wants to try this, please let us know. We will send the URL, ID and password.

Akiko Sato (akiko.sato.td@hitachi.com)

6 CityGML data sets

In DSS, the geographic content is provided and stored as CityGML data sets.

- Background

The building model described in above chapters is based on the OpenGIS CityGML Encoding Standard (OGC 08-007r1).

The main purpose of this building model is to provide a geometric description of a building and its interior structures for other applications, e.g. indoor navigation. Therefore we generated this building model complying with the baseline of CityGML specifications while the most of non-geometric related information and features are intended to be vacant for further modifications by other applications. This information includes “creationDate”, “function” of building, “id” of building etc.

Since the interior of a building can only be represented in the Level of Details 4 (LOD4), which is the highest level of resolution of the building model, this building model is generated as a LOD4 CityGML building model.

- Data Source

The raw data source of this building model is a set of 2D building plans in ESRI shape format, which are converted from a CAD data set, as shown in Figure 9.

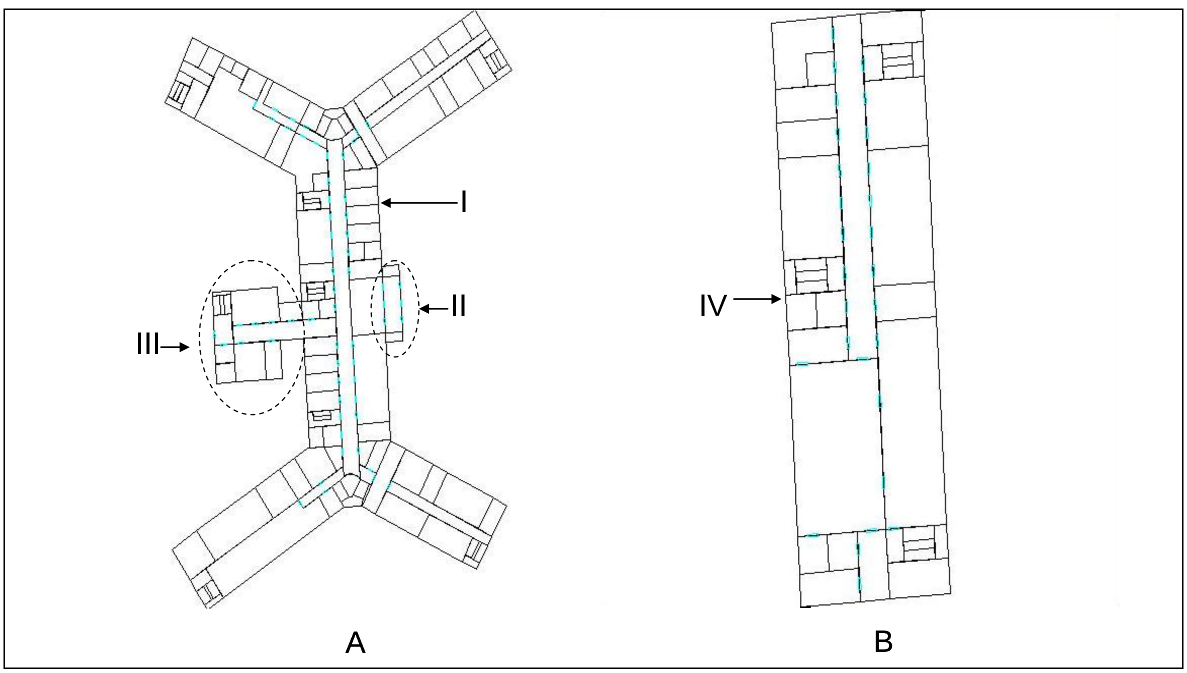

Figure 9: 2D plans of Hitachi building. A and B are the plans of first and sixth floors respectively. Rooms are closed black polygons, and doors are light blue rectangles.

The plans contain only two types of building parts, rooms and doors. A room is represented as a closed polygon, and a door as a small rectangle. Data of room and door are independent, and there is no link between them. The 2D coordinates of data are in Tokyo Datum coordinate system [1]. Unfortunately, the actual floor height is unavailable and we simply define a value (5 meters in this case) as the floor height in our building model.

- Building Structure

The building is a complex structure, as shown in Figure 9. There are three building parts in the plan of first floor (A). Part I is the main building with two wings and both of them are four-floor structures. Part II is a one-floor reception room. Part III is a five-floor building part. Part IV in floor plan (B) indicates two floors (the fifth and sixth) above Part I of the main building.

- LOD4 3D Building Model

A building could be represented as an aggregation of building parts in accordance with arbitrary, user-defined criteria. On the basis of the data source available, we represent our building as the aggregation of roofs, floors, walls, and doors.

  - Roofs and floors are represented as the horizontal planes that cover and separate floors. They are defined by using bldg:lod4MultiSurface.

  - Walls are represented as the vertical planes that separate rooms, and are defined by using bldg:lod4MultiSurface. To allow passage through, the polygons of doors are caved into walls to make holes in walls.

  - Doors and windows are represented as the class openings on walls and are defined by using bldg:lod4MultiSurface. Because doors and windows are not explicitly associated with walls in our data set, a dummy wall is created as a container to include all doors and windows.

- Visualization of 3D Building Model

Our 3D CityGML building model has been smoothly imported into Autodesk LandXplorer©[2] and Aristoteles CityGML viewer[3], and the screen snaps of visualization are shown in Figures10 to 13.

- Summary

A 3D CityGML building model in LOD4 is generated on the basis of a set of 2D building plans and is able to provide a reasonably good 3D interior building model for visualization and navigation applications.

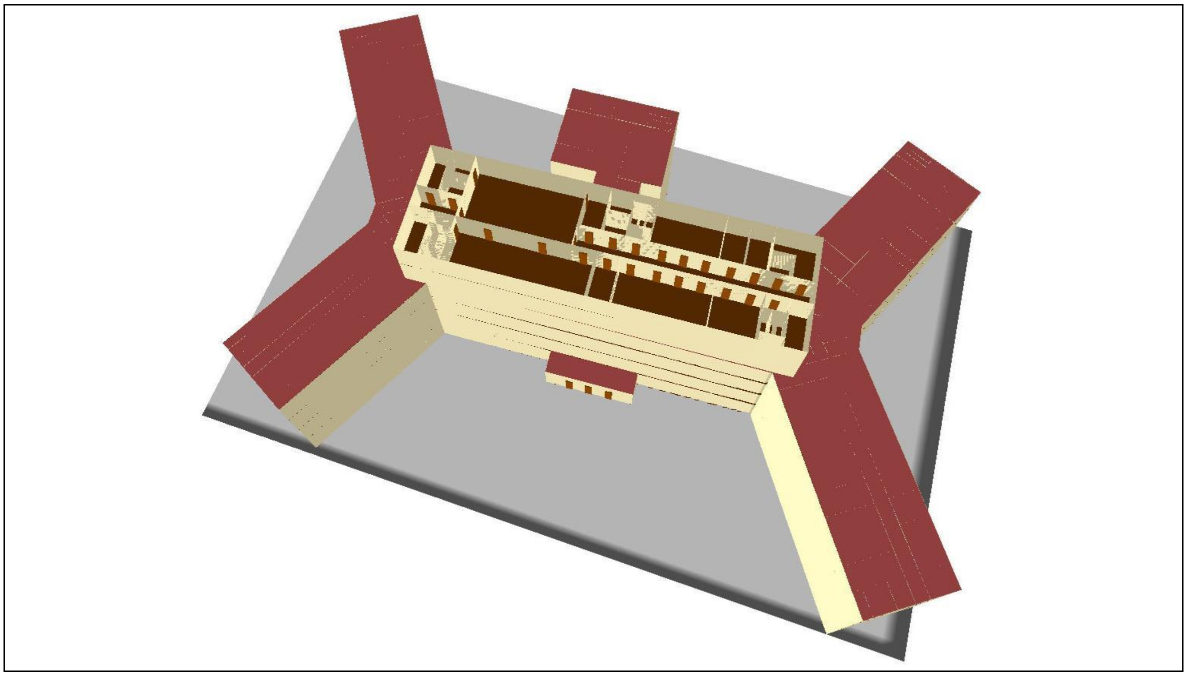

Figure 10: Visualization of our building model using Autodesk LandXplorer©.

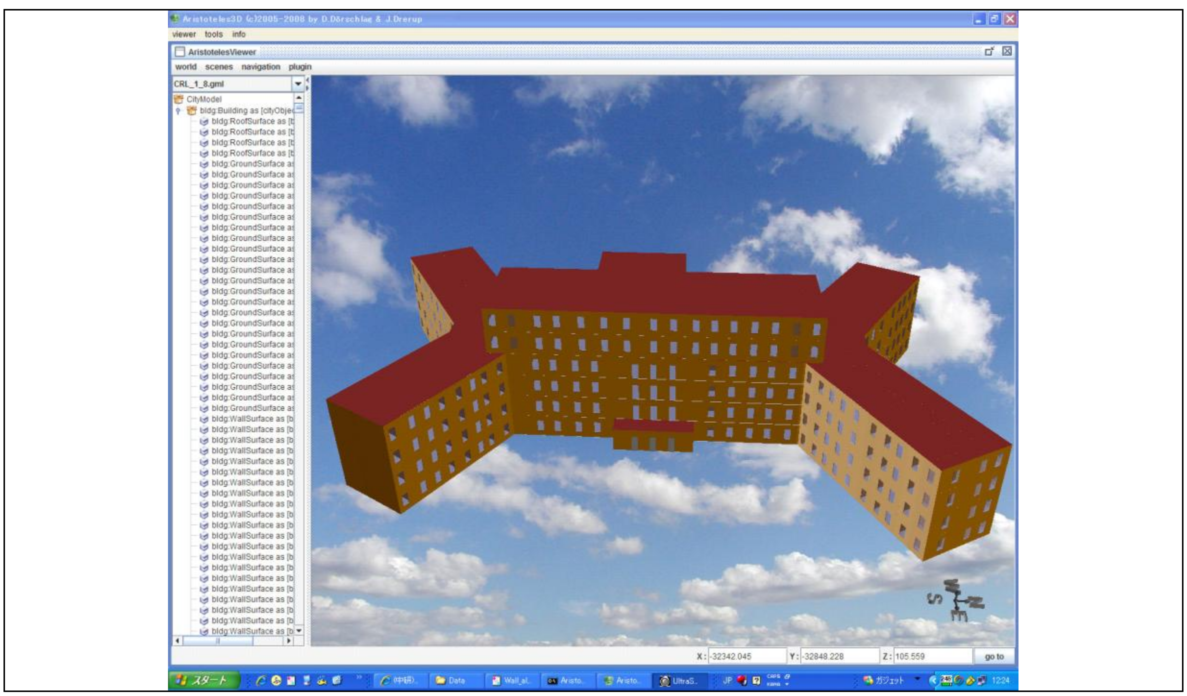

Figure 11: Front view of our building model using Aristoteles CityGML viewer.

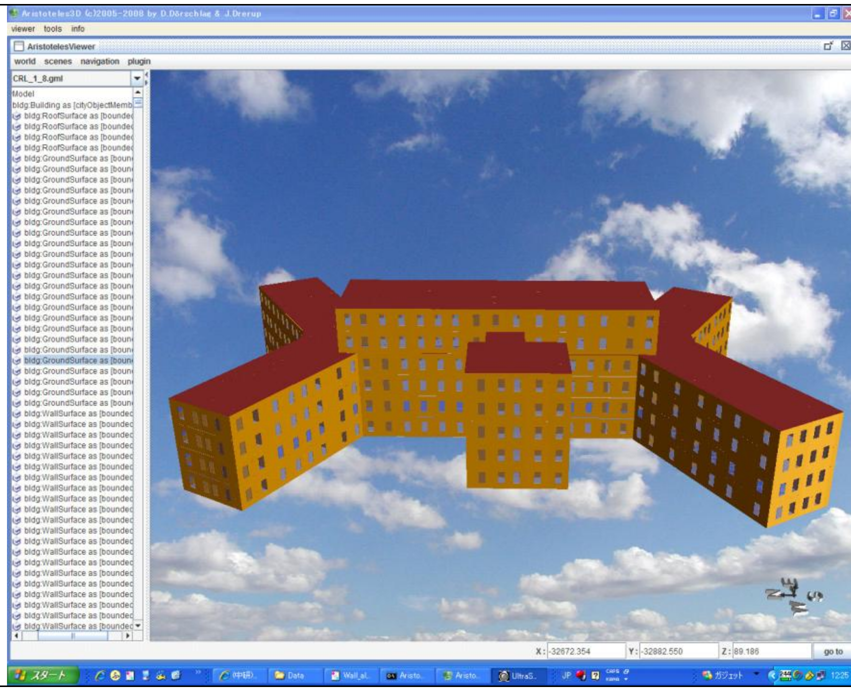

Figure 12: Back view of our building model using Aristoteles CityGML viewer.

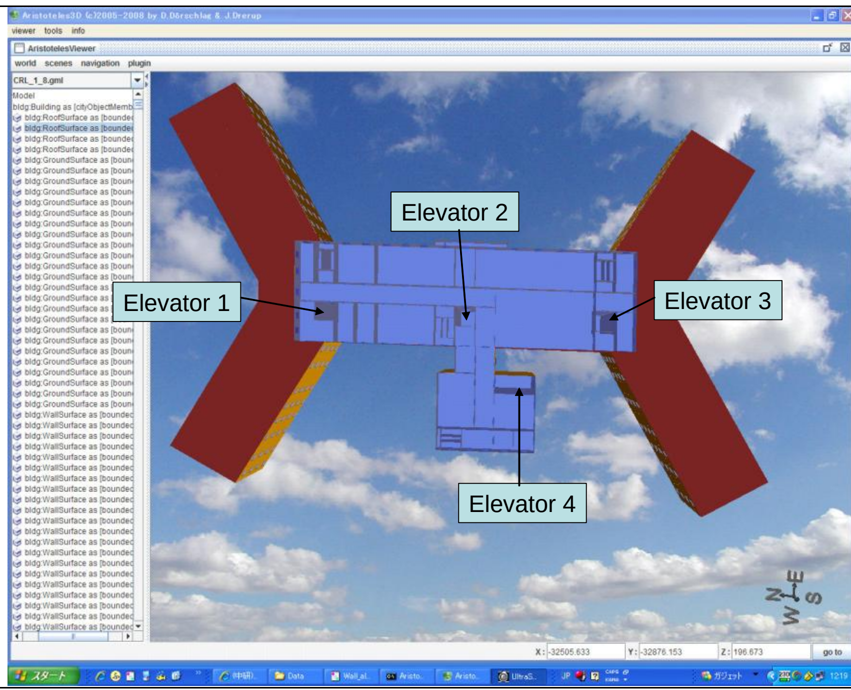

Figure 13: Location of elevators using Aristoteles CityGML viewer.

7 Technical Issues and Suggestions

- To support network topology for CityGML

To manage indoor spatial data, there are some requirements from the application point of view. CityGML network topology capability is especially essential for indoor environment applications such as indoor/outdoor seamless routing, emergency evacuation, and autonomous mobile robots.

As we mentioned in this ER, network topology for indoor environment should be different from that for outdoors. According to comparisons between the four models proposed in clause 5.2, models 3 and 4 seem to have some advantages over the others. As the current version of CityGML does not support network topology, our network topology is represented by our original manner in this OWS-6 project. We suggest that the next version of CityGML should support network topology for indoor environment applications.

- Distribution of network topology for Indoor routing

In this OWS-6 project, our system can be accessed by WMS interface, and we did not prepare the interface for distributing network topology. We extended WMS interface so that it can distribute the route information and the navigation information such as “arrow image” at the crossings on the indoor map. To handle the distribution of network topology, we suggest the following:

  - Support WFS for CityGML LOD4 and/or
  - OpenLS compatible

- Location reference system for connecting different coordinate systems

To seamlessly provide spatial service both in outdoor and indoor environments, the “connecting point (place)” between outdoor and indoor is important. Basically, the outdoor information provider and the indoor information provider are different, and the “connecting point” is managed in different location reference systems. So to define some specific place seamlessly, we should share some location reference systems. In Japan, mainly two reference system specifications are now being proposed: Place Identifier [5] is promoted by the Ministry of Economy, Trade and Industry and ucode[6] is promoted by the Ministry of Internal Affairs and Communications.

On the other hand, in the ITS field there are also specifications of a connecting point among different transportation systems such as cars, trains, buses, planes, and so on. ISO/TC 204 WG8 is now discussing Identification of Fixed Objects in Public Transport (IFOPT) [4] to solve this issue.

Therefore, to share CityGML data both in outdoor and indoor environments seamlessly and regardless of domains, we need some location reference systems compatible with CityGML.

Acknowledgment

This work was partially supported by a consignment research from the Ministry of Internal Affairs and Communications, Japan.

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[2] Autodesk LandXplorer Studio Professional. http://www.3dgeo.de/getstudiodemo.aspx Access on March 12th.

[3] GML3 3D viewer application Aristoteles (Version 1.2.01). http://www.citygml.org/1538/ Access on March 12th.

[4] IFOPT (Identification of Fixed Objects in Public Transport) http://www.naptan.org.uk/ifopt/

[5] Place Identifier. http://www.dpc.jipdec.or.jp/gxml/contents/pi/index-e.html

[6] Ucode. http://www.uidcenter.org/index-en.html

