The Concepts of Level of Detail in 3D Indoor Models

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Key words: Indoor, 3D Indoor Model, Levels of Detail, IndoorGML

SUMMARY

Demands on indoor services are increasing as people spend more time in indoor environment. However, IndoorGML, which is a navigation data model in indoor space has been standardized in OGC to satisfy these increasing demands, LOD (Level of Detail) of spatial data representing indoor space have not defined to provide indoor LBS. The LOD proposed by CityGML is defined based on details and sizes of geographical features in geometric feature. As well, indoor space is only represented by LOD 4 in CityGML. However, the representation of indoor space is required more detailed than outdoor space. Furthermore, LOD for indoor space should be defined diversely according to the types of indoor services. For example, detailed representation of geometry for all of features in indoor space such as LOD4 of CityGML is required to develop an application of indoor facility management. On the other hand, only simple geometric representation for indoor space can be used to provide services like indoor navigation. For these reasons, spatial features in indoor space should be represented in different levels according to types of indoor services. Therefore, indoor LOD model based on applicable services using indoor spatial information is required. In this research, we propose the basic concepts of Indoor LOD in 3D indoor models to be appropriate for indoor service and demonstrate the use-cases of indoor GIS applications based on the Indoor LOD model.

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1. INTRODUCTION

GIS applications in indoor space have been more popular, as much as human activities have expanded increasingly from outdoor space to indoor space. In this reasons, various services and systems based on indoor GIS applications also have gained greater attentions in many fields. For providing multiple services in indoor space, indoor data have generated in many ways: footprint, omni-directional image, etc. Using these kinds of data formats, indoor navigation, virtual simulation, or facility management can be serviced. We argue that it is required to define representation of indoor data based on ways of data generation. In case of providing simple services like showing indoor route, however, perfect virtual description for indoor space is not suitable in terms of data volume and cost. Therefore, the usage of different levels-of-abstraction is of great importance (Köninger, 1998). Features are described by this abstraction that is called levels-of-detail (LOD).

In outdoor space, LOD model can easily apply to representation of features. Since features of outdoor space are commonly classified by geographical scale, many researches for LOD models focus on this classification. Indoor Space, on the other hand, should be considered differently. It is hard to set up the criteria for indoor space like LOD model of outdoor space applying geographical scale. Additionally, differences for constructing data exist between outdoor space and indoor space. As a result, a concept of LOD model suitable for indoor space is required.

CityGML proposed LOD model, yet LOD for indoor space is only defined at LOD 4. This LOD is too detailed to provide simple applications. Indoor space can be represented geometrically simple in case of indoor routing, on the other hand, detailed information of indoor space is required for virtual simulation or facility management (figure 1). To take this into account, this study suggest LOD model for indoor space based on indoor application services.

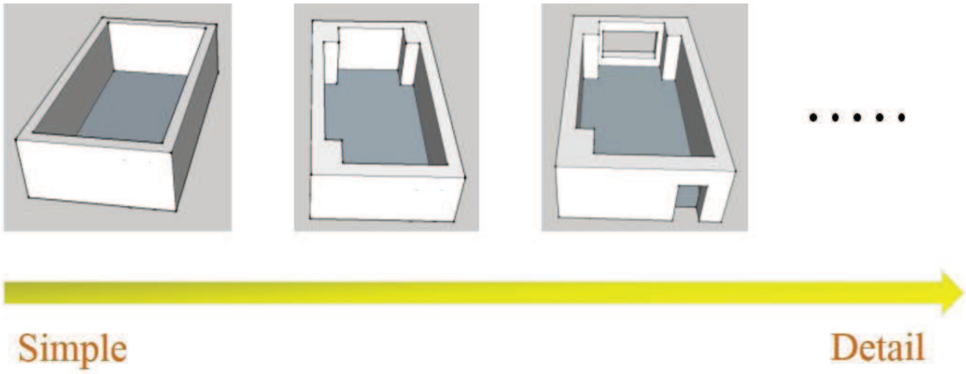


Figure 1. Indoor Space Representation(BuildingSmart,2015)

2. RELATED WORK

For visualizing spatial data, researches for LOD model have been carried out. Researches can be divided to 2 parts: City model, and Indoor model. LOD of city model have been discussed by CityGML which is one of the representative city models. We examine CityGML and other LOD for city model representing and analyzing city features. Indoor LOD model also examines through this section, which visualizes indoor feature and provides indoor applications

2.1 Level of Detail in 3D city models

Purpose of LOD in 3D city models is to visualize city structure in terms of city plan process and make applications for city. As city space composed of several small, medium, and large structures, city features can be differentiated by specific map scale (Köninger ,1998). For example, city object building can be described detailed in large-scale, on the other hand, building is presented simple in small-scale. Köninger (1998) proposed 3 LOD based on map scale. First LOD presents building as a box object and second LOD includes position of building with more detailed building object. In most detailed LOD, building is described more detailed than other LOD using phototexture.

CityGML(OGC, 2012) is open data model published by OGC(Open Geospatial Consortium). It provides 5 consecutive level-of-details based on geographical scale for representation and application of city feature (figure 2). In CityGML, feature representation is provided for analyzing and visualization feature in each geographical scale. LOD 0 is 2.5D digital terrain model and presents building as a feature parts like floor or roof. LOD 1 consists of block model and LOD2 shows textured and differentiated roof structures. LOD 3 describes more detailed architecture like opening, window, etc. LOD 4 represents interior of building.

LOD model for representing city space is defined based on geographically scale, yet most study focus only on outdoor space except CityGML. However, only one level (LOD 4) is for indoor space but it is too detailed to implement some applications in CityGML. This problem may cause data generation and maintenance issues. Furthermore, data volume of LOD 4 is huge to use web application. Therefore, we argue that LOD model for indoor space is required based on indoor applications.

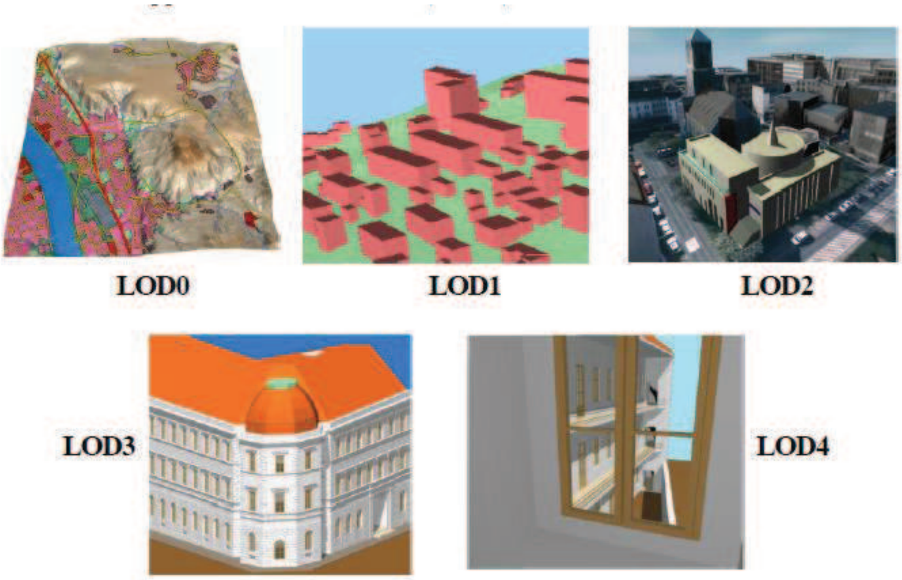


Figure 2. LOD of CityGML(OGC,2012)

2.2 Level of Detail in 3D indoor models

Researches for indoor LOD model discussed the classification of indoor features based on indoor application services. Kemec(2012) discussed indoor LOD model corresponding with LOD definition of CityGML. Additionally, this model concentrates on service for disaster situation and its purpose is to prepare disaster and implement virtual simulation.

Hagedorn (2012) suggests indoor LOD model for route visualization in indoor space (Figure 3). This LOD model is divided to thematic, geometry, and routing model and illustrates way to inform and visualize route for indoor service. Features to represent building like floor, wall can be described by thematic model. Geometry model specify indoor feature geometrically and connected space is defined by routing model providing routing network.

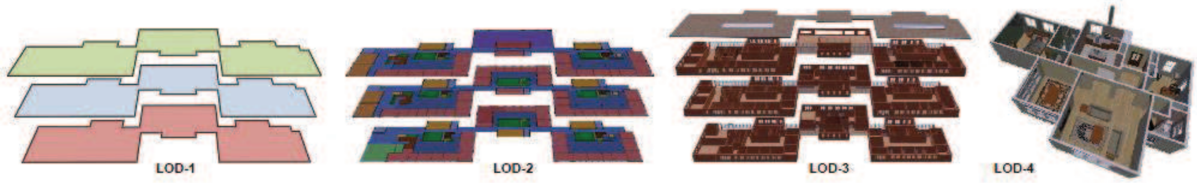


Figure 3. LOD of Indoor Model Instances [Benjamin]

Indoor LOD model proposed by Kang(2014) applies these geometry model and thematic model. Indoor space data can be distinguished by way to generate data: image data, and geometry data.

Kang (2013) consider generation of data for LOD classification. Keeping in view the same idea, this work focuses on indoor LOD model based on way to generate indoor space data.

3. CONSIDERATIONS IN INDOOR LOD MODEL

For indoor space representation, we have to reflect four considerations to indoor LOD mode; Geographical scale issues, data capture methods, application issues, and data types.

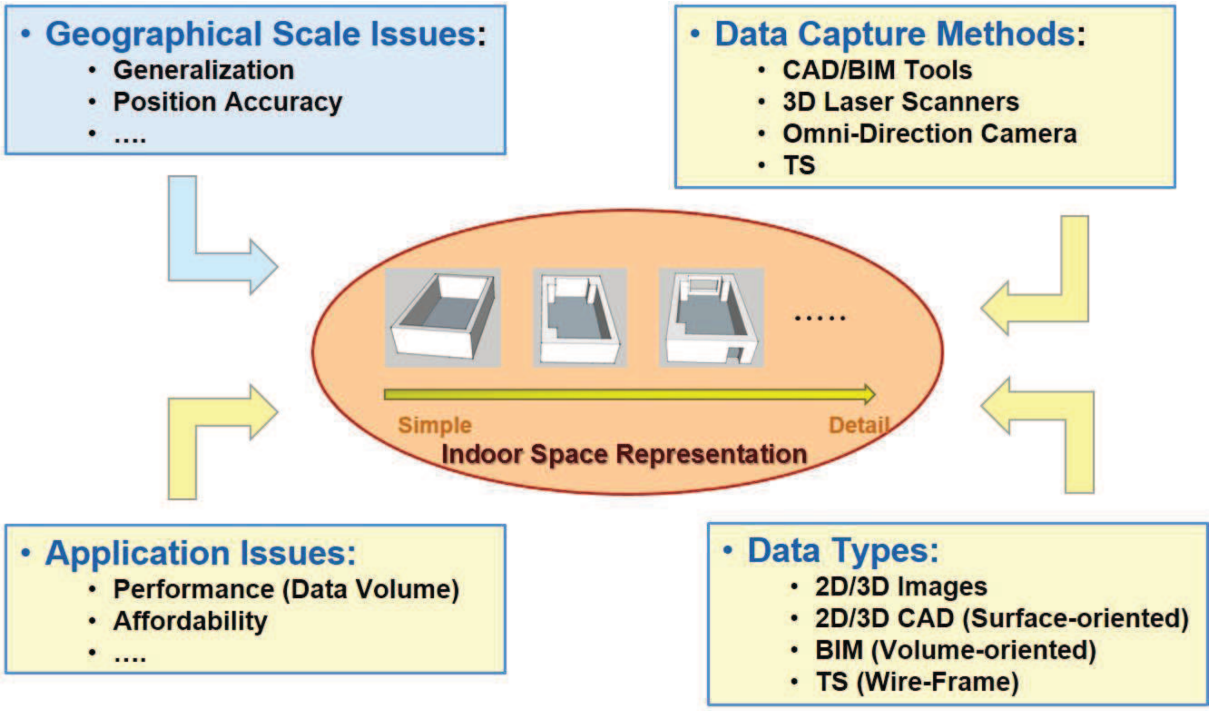


Figure 4 Considerations for Indoor Space Representation

3.1 Geographical Scale Issues

First consideration is geographical scale issues. Generalization of geometric features based on geographical scale has to be considered as LOD model is commonly defined by geographical scale. However, indoor LOD model should be considered differently since geographical scale is always large-scale in indoor space. According to situation or application in indoor space, demanded position accuracy may differ.

3.2 Data Capture Methods

Data capture for indoor space is implemented by various methods. Most common method is to use CAD/BIM tool or LiDAR. Omni-directional camera or 3D laser scanners are also used currently. These methods for generating data cause diverse data types of indoor space. Accordingly, data capture methods should be considered for indoor LOD model.

3.3 Application Issues

Application issues are also important. According to applications purpose, affordability and performance can differ. For example, LOD 4 of CityGML is not appropriate for web applications because of data volume. It is required to define LOD model considering cost and performance of data generation.

3.4 Data Types

Data types of indoor space can be divided by dimension: 2D and 3D. 2D and 3D data divide to image data and vector data again. Therefore, various types of indoor data should be considered for LOD model.

4. LEVEL OF DETAIL IN 3D INDOOR MODELS

This study proposes indoor LOD model reflecting four considerations previously discussed (Figure 5). First, this LOD model divides to 2D representation and 3D representation. 2D representation is composed of indoor LOD 0 and LOD 1. In these levels, indoor space is showed simple. 3D data represent geometric modeling features. These levels consist of indoor LOD2, LOD 3, and LOD 4. These LOD show features more detailed than 2D representation.

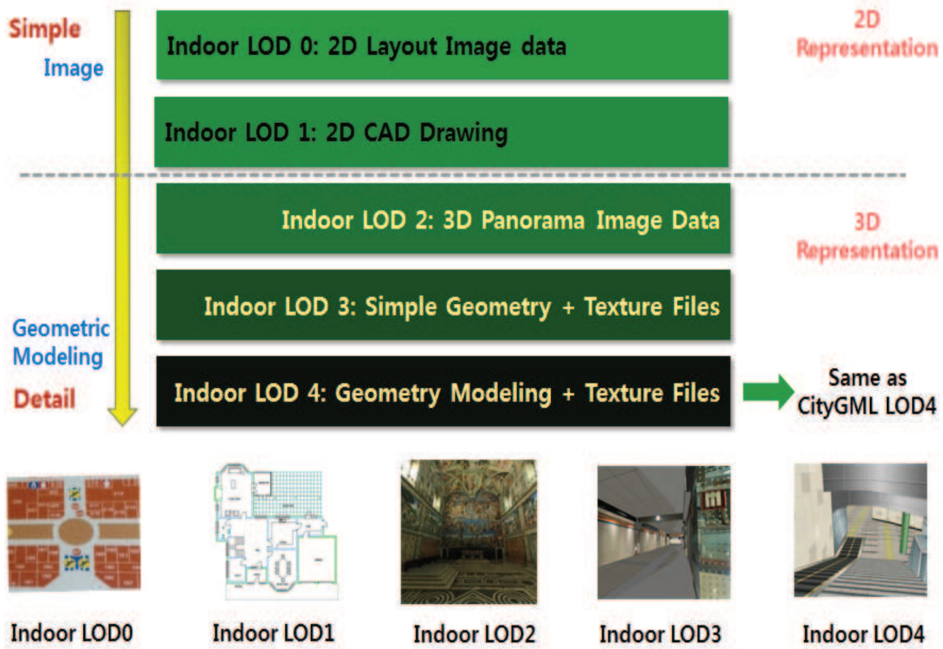


Figure 5. Proposed Indoor LOD Model

Proposed indoor LOD model can be applied to various indoor applications. Indoor LOD0 and LOD 1 can generate indoor data rapidly and store low volume. Accordingly, these levels are appropriate for simple indoor routing. Indoor LOD 2 applies to virtual simulation, or store view using omni-directional image to represent 3D indoor space. Indoor LOD 3 describes indoor space from boxes of 3D geometric features to surface of space. In this level, virtual indoor simulation, indoor navigation, and facility management can be serviced. Indoor LOD 4 presents space most detailed. This level is derived from CityGML LOD4 and applies to indoor facility management and disaster simulation. Proposed indoor LOD have characteristics such as geometry, visualization, application filed and data format based on dimension of data (Table 1).

Table 1. Characteristics of proposed Indoor LOD Model

	Image Representation		Geometric Representation		
	Indoor LOD 0	Indoor LOD 1	Indoor LOD 2	Indoor LOD 3	Indoor LOD 4
Spatial Object Geometry Information	-	-	2D Curve	3D Solid (Representing vertical protrusion and sink of surface and slope)	3D Solid (Including sophisticated structures of surface)
Accuracy Classification (location(/height))	Low (1m)	Medium (1m)	Low	High (0.4/0.4m)	Very High (0.2/0.2m)
Visualization data	footprint	2D CAD Drawing	Panoramic Image	True Ortho Imagery	True Ortho Imagery
Application Field	Route Guidance	Route Guidance	Store-view, Virtual Indoor Experience, Route Guidance	Facility management, Virtual simulation, Disaster simulation	Facility management, Virtual simulation, Disaster simulation

4.1 Indoor LOD 0

Indoor LOD 0 represent indoor space as 2D image like 2D footprint. In this level, indoor features are described as a simple image rather than a detailed geometry. Furthermore, indoor components like stairs can be founded only if images represents those components. This kind of simple 2D indoor data is already constructed in large building and is easy to generate. However, its accuracy is low to provide various applications. Indoor LOD 0 is suitable for indoor information maps since connectivity among rooms' shows in image maps.

4.2 Indoor LOD 1

Indoor LOD1 represents indoor space as 2D vector data like CAD drawing. Floor plan using CAD is essential for constructing building legally. For this reason, indoor data in indoor LOD 1 is sufficient to generate. This level has much higher geometric accuracy than indoor LOD 1. Indoor routing with calculating distance or time can be provided in this level as 2D CAD data represent various components of indoor space. However, these data types are hard to presents indoor data as geometric features. Therefore, more complicated services cannot be provided.

4.3 Indoor LOD 2

Although indoor LOD 1 use image data for representing indoor space and indoor features, it is not sufficient to represent real features. Indoor applications like indoor virtual simulation require realistic representation for indoor space. In case of virtual simulation services like Google art project, services don't need to provide same function with real space. Omni-directional image is suitable for providing these kind of services in spite of low accuracy. Indoor LOD 2 proposed in this study use omni-directional images to present indoor space and indoor features. Indoor LOD 2 can be applied to services like Google street view or Daum road view. It also can provide simple route guidance using a panoramic image.

4.4 Indoor LOD 3

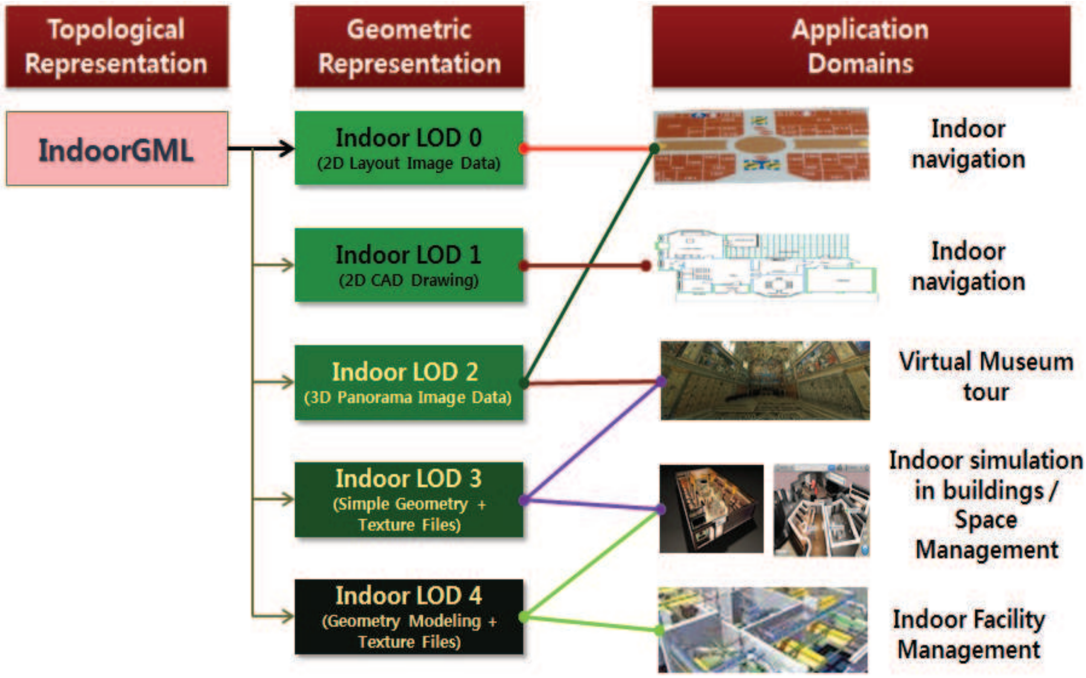
Indoor LOD 3 represents indoor space using 3D Solid feature, 3D surface, and texture file. Indoor space is described by 3D geometry and also, look like real space using texturing. In this level unlike indoor LOD 0, 1 and 2, selection for spatial features and queries can be implemented by high accuracy. Indoor space defined by realistic 3D geometry features also can offer various applications, yet indoor LOD model may become more complicated and have problem with data volume and high cost. Indoor data generation should differ from generalization of geometry features. For this reason, all of indoor space is represented as a simple box style of 3D geometry features in indoor LOD 3. In case of using simple box features for representation, indoor navigation like indoor LOD 2 can be serviced. On the other hand, facility management and simulation service can be provided in case of using texturing data instead of detail description.

4.5 Indoor LOD 4

Indoor LOD 4 has the most detailed representation, and this level offers the highest geometric accuracy. Basically way to represent indoor space using 3D geometry and texture file is similar to indoor LOD 3. However, this level doesn't implement generalization and have similarity using real image texturing. Therefore, sophisticated structures of surfaces are presented in this level. Representation of indoor LDO4 is same with LOD 4 of CityGML.

5. CONCLUSION

We discussed Indoor LOD model to represent indoor space. Indoor space data is hard to apply geographical scale and also generated in various ways. For these reasons, data types and applications can differ. This study proposed indoor LOD model considering these cases. Figure 6 is examples of indoor applications based on proposed indoor LOD model in this study. Indoor navigation can be serviced by Indoor LOD 0, 1, and 2. Virtual museum tour like Google art project can be provided by Indoor LOD 2, and 3. Complicated services such as simulation and space management can be offered by LOD 4. In the future, we will specify proposed indoor LOD model. Additionally, generation of indoor data will be implemented based on proposed model.



Figur 6. Examples of Indoor Applications Based on Proposed Indoor LOD Model

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REFERENCES

BuildingSmart Alliance. www.buildingsmart.org

Hagedorn, B., Trapp, M., Glander, T., Dollner, J. (2009). Towards an indoor level-of-detail model for route visualization. In Mobile Data Management: Systems, Services and Middleware 2009, Tenth International Conference , 692-697.

Kang, H., Lee, J. (2014). A study on the LOD(Level of Detail) Model for Applications based on Indoor Space Data. Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography, 32(2), 143-151.

Kang, H., Hwang, J. R., Hong, C. H. (2013). A Study on the Development of an Indoor Level of Detail(LOD) Model for the Linkage between BIM and GIS : Focusing on the Indoor Facility Management. Journal of Korea Spatial Information Society, 21(5), 73-82.

Kemec, S., Zlatanova, S., Duzgun, S. (2012). A new LoD definition hierarchy for 3D city models used for natural disaster risk communication tool. In Proceedings of the 4th International Conference on Cartography & GIS, Volume 2, 17-28.

Köninger, A., Bartel, S. (1998). 3D-GIS for urban purposes. Geoinformatica, 2(1), 79-103.

OGC. (2012). OGC City Geography Markup Language (CityGML) Encoding Standard. Available online http://www.opengeospatial.org/standards/citygml.

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