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A STUDY ON DEVELOPMENT OF THE IFC-BASED INDOOR SPATIAL INFORMATION FOR DATA VISUALISATION

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Abstract. MOLIT authorised Indoor Spatial Information as Basic spatial information in 2013. It became a legal evidence for constructing and managing Indoor Spatial Information. Although it has a little advantage to utilise as service level that Indoor Spatial Information by laser scan or measurement, it has a lot of problems such as consuming many resources, requiring additional progresses for inputting Object Information. In conclusion, it is inefficient to utilise for the maintenance and domestic AEC/FM field. The purposes of this study is to output Indoor Spatial Information by operating IFC model which based on open BIM and to improve availability of Indoor Spatial Information with data visualisation. The open-sources of IFC Exporter, an inner program of Revit, is used to output Indoor Spatial Information. Directs 3D Library is also operated to visualise Indoor Spatial Information. It is possible to inter-operate between XML format and the objects of Indoor Spatial Information. It can be utilised in various field as well. For example COBie linkage in facility management, construction of geo-database using air-photogrammetry of UAV, the simulation of large-scale military operations and the simulation of large-scale evacuation. The method that is purposed in this study has outstanding advantages such as conformance with national spatial information policy, high level of interoperability as indoor spatial information objects based on IFC, convenience of editing information, light level of data and simplifying progress of producing information.

Keywords. Indoor spatial information, data visualisation, open BIM, IFC.

1. Introduction

In 2013, the Ministry of Land, Infrastructure and Transport officially added the highly valuable and applicable '3D spatial information model' and 'indoor spatial information' to the 'essential spatial information' to build and maintain the key national spatial information. To this end, the revised enforcement decree of the Act on National Spatial Information was enforced as from June 19, 2013. Indoor spatial information concerns the interior of artificial structures including ground and underground infrastructure. National spatial information infrastructure serves as the foundation of all spatial information, enabling the diverse application, integration and convergence of multiple spatial information. The indoor spatial information added to the national spatial information infrastructure has laid the statutory foundation for implementation and maintenance of national indoor spatial information. Also, in January 2014, the Ministry of Land, Infrastructure and Transport and the Korea Agency for Infrastructure Technology Advancement published the "2014 Infrastructure Technology R&D Project Implementation Scheme" intended to develop the technology for analysis/application of big data about spatial information and application of open sources and thus to help people create some happy space. Specifically, the plan is focused on developing the technology for building urban infra information and indoor/outdoor spatial information conducive to setting up the urban environment safe against disasters by 2020. However, currently, indoor spatial information is built with GIS-based measurement and laser scanning, which calls for much time and human/material resources. In addition, in the current method of building indoor spatial information, the opening/closing of doorway objects cannot define the space for themselves. Instead, captured images are mapped onto simple 3D objects without any property information. In this context, the present study perceives the importance of building the indoor spatial information, seeks a method of extracting and visualizing the open BIM-based indoor spatial information, and designs and implements a relevant tool. Moreover, to enhance the applicability of indoor spatial information, IFC which is the standard model of building information is used to secure interoperability. This is consistent with the Ministry of Land, Infrastructure and Transport's 3D spatial information model. In addition to that, the Ministry of Land, Infrastructure and Transport has established a legal basis for building and maintaining the indoor spatial information by designating the 'indoor spatial information' as part of the 'spatial information infrastructure.' Although the indoor spatial information based on measurement and laser scanning is viable for service, it is inefficient in terms of maintenance and applicability to domestic ARC/FM because it consumes significant human and material resources and requires extra information processing for properties to be entered. Thus, the present study sets up the following objectives and proposes a method of visualizing the indoor spatial information: first, to develop a viable method of data visualisation that is capable of meeting the needs for both special (analysis) and general (service) aspects of indoor spatial information; second, to map out a method of visualisation facilitating the data generation and the adaptation of information; and third, to secure the interoperability of 3D indoor spatial information objects and lighten the data about indoor spatial information.

2. Developing a tool for visualizing the indoor spatial information

2.1. DESIGN

The present study develops a module for extracting IFC-based indoor spatial information and an IFC-based visualisation module for visualizing the extracted indoor spatial information objects using Autodesk's BIM tool, Revit, which has the highest domestic market share and is used most frequently in relevant literature. Revit provides an API based on .NET framework. .NET-based languages, e.g. VB.NET, C#, and Managed C++, are used to develop Revit's API. Revit is revised annually. As for Revit plug-ins, the API for program development and the structures and properties of object classes significantly vary with revised versions. The present study uses Revit Architecture 2014 version to develop a module for extracting the indoor spatial information. C# is used here for development. C# and Open Cascade are used to develop the IFC viewer as a stand-alone application. The system development environment includes the following:

- Microsoft Visual Studio 2010
- Microsoft .NET Framework 4.0.
- Autodesk Revit Architecture 2014
- Open Cascade Library
- Microsoft Direct 3D API

IFC4x1 has now been released since the first development in 1994. IFC Release 1.0 is defined as a distributed project model used for AEC/FM projects for the entire life cycle. Earlier releases include models supporting the processes within Architectural Design, HVAC Engineering Design, Facilities Management, and Cost Estimating, but partially represent the range of project models, which warrants the reinforcement of earlier releases. Therefore, Release 2.0 and later versions expand the domain scope of IFC Object Model, and include such domain processes as building, estimation, FM, infrastructure and laws. Release 2.X and later versions provide stable cores and platforms for extended development, and retain the scope of IFC Release 2.0 model to improve the quality of model. These features provide developers with higher investment values in relation to core development, whilst ensuring users can make the most of information. At present, Release 2.X version has been significantly developed into IFC4, whilst IFC4x1 is being improved.

2.2. A MODULE FOR AUTOMATIC EXTRACTION OF THE INDOOR SPATIAL INFORMATION

The present study develops a module from the Revit model to generate an IFC file of space and doorway objects needed to define the indoor spatial information. The representation of openings, e.g. windows and doors, is added in defining the indoor spatial information to increase the applicability of the built indoor spatial information. The indoor spatial information including openings-related information is applicable to evacuation, military strategies and human behaviour simulations. As the extraction module of indoor spatial information, the open source of IFC Exporter, a program exporting IFC files from Revit, is used. The open source can be modified freely for intended purposes. IFC Exporter has the classes. Amongst all, Exporter.cs is a class in charge of controlling all the export process and calling associated classes to proceed with IFC output.

Excluding the output of information about the objects other than space and exits, this study develops a module to get IFC output of objects matching the purpose of this study by modifying the IFC Exporter module. IFC Exporter subdivides all objects of Revit largely into five groups before exporting them: SpatialElements involving spatial objects, NonSpatialElements involving doorways, Containers, Grids and Connectors. Here, only SpatialElements and NonSpatialElements are considered for spatial and doorway outputs. The IFC Exporter's interface shows an export option for extracting the indoor spatial information (KBIM) as in Figure 1.

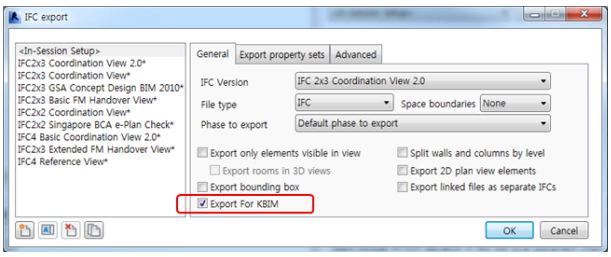


Figure 1. Added IFC Exporter Option

The present visualisation module of indoor spatial information reads space and door information from the output IFC (file) to identify the inter-space routes and represent them as 2D information. To visualise the IFC model, the IFC file is parsed and stored in memory in the format that can be read by the development program. For the 3D solid information operation, Open Cascade Library is used. For the 3D visualisation, Direct3D Library is used.

To extract IFC-based indoor spatial information, spatial location and forms, doorway location and directions of openings are defined using IfcSpace and IfcDoor, both of which are primary components for representing the indoor spatial information in IFC. Here, IfcSpace defines the location and volume (form) of indoor spatial information, whilst IfcDoor defines inter-space relations (connected routes). Minimizing the information usage increases data processing and the operation speed of the visualisation module. Also, the direction of openings available via IfcDoor is an indispensable component for dynamic simulation, e.g. evacuation and military training. The IfcSpace and IfcDoor information extraction modules developed here extract 2D and 3D information from IfcSpace and IfcDoor objects included in IFC and display information to users as requested. 2D information is applicable to the shortest path between locations, the emergency evacuation routes, and regulatory reviews. IfcSpace's form information is represented as FootPrint including 2D-based information and Body information including 3D information. The indoor spatial information visualisation tool is designed to embrace all approaches to form representation. The doorway information can be extracted from IfcDoor. Importantly, accurate information about the direction of openings need be extracted. Yet, IfcDoor includes information about location and direction of openings.

Therefore, it is necessary to refer to the Profile Representation under the IfcDoorStyle parameter to see the details about shapes and types of doors. At the same time, the FootPrint representation identifier helps extract correct 2D forms. The extracted IFC-based indoor spatial information is visualised in the system structure shown in Figure 2. In view of main functions, it consists of 'Create IFC Structure' module for systematisation of IFC information structure, 'IFC Parsing' module for reading the selected IFC model information into the system, 'Solid Calculation' for performing operation on the parts of the parsed IFC information that need solid operation, and 'Visualisation' module for visualizing and displaying information on computer screens.

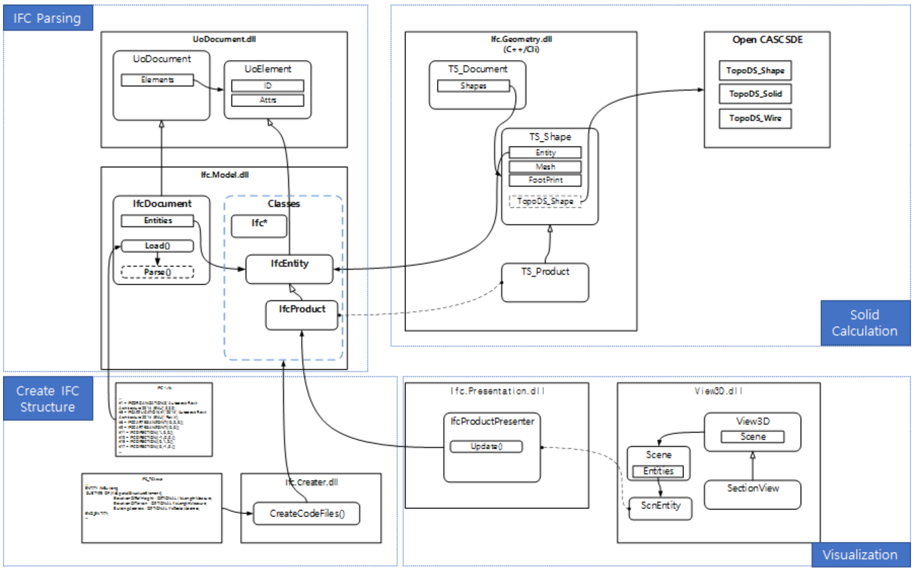
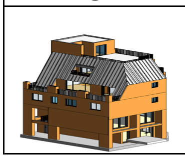
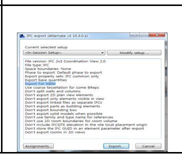
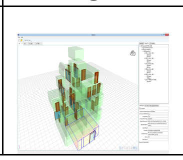
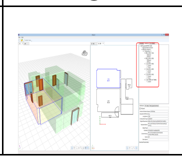
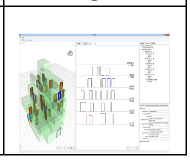


Figure 2. Visualisation Structure of IFC

2.3. VISUALISATION OF INDOOR SPATIAL INFORMATION

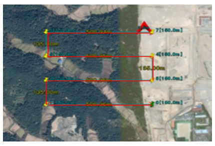
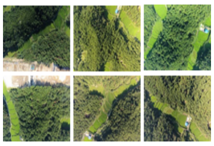
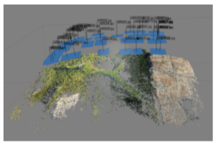
TABLE 1. Process of Indoor Spatial Information Visualisation

①	②	③	④	⑤
				

The visualisation of indoor spatial information goes through the following phases. ① Buildings are modelled with Revit 2014 version. As the test model, a random building designed for neighbourhood facilities which account for the highest percentage of all buildings is chosen. ② The automatic module for extracting the indoor spatial information based on Revit IFC Exporter developed here is used to generate the indoor spatial information objects with an IFC extension. ③ The indoor spatial information objects IFC file generated through the automatic extraction module is opened with the tool for visualizing the indoor spatial information developed here (the visualisation tool is designed to freely enlarge/reduce and rotate the indoor spatial information in 3D environment). Buildings' indoor spatial information is visualised as translucent boxes whose inner parts are visible. Given that commercial IFC viewers distributed for free represent the indoor spatial information objects opaquely, the present study attempts the translucent visualisation for the sake of intuitive spatial perception. Also, windows and doors including directions of openings are represented as separate objects for intuitive viewing, with the information about the properties of IFC objects being fully implemented. The property information is placed at the lower right corner of the interface for the indoor spatial information visualisation tool. ④ At the upper right corner, each floor and object can be selectively viewed and converted from 3D to 2D display. ⑤ The conversion to 2D display enables component-specific selective visualisation of indoor spatial information objects from the perspective of floor plans and elevation formats.

3. Applicability to GIS-based UAV

TABLE 2. Status of BIM-based drawing guidelines

①	②	③	④
			
Fright Route Set-up	Images Collect	Point Cloud24)	3D Object

Currently, to build spatial information about an expansive area, GIS-based UAV or low-altitude drones are used. Noted for superior functionality and portability, UAV is widely used for urban planning maps, bush fire surveillance, reconnaissance, combat missions, meteorological observation, coast defence, marine pollution detection and planetary exploration. Table 2 shows the process of creating the 3D spatial information via UAV. Spatial information generated with GIS-based UAV is effective for building 3D spatial information of an expansive area. As the spatial information is created based on real images captured, separate mapping is not needed. Yet, as the generated spatial (surface) objects are limited to coordinates and shapes, they are far from involving the information about buildings and infrastructure. Hence, the proposed integrated spatial information in connection with indoor spatial information is expected to exert significant effects. The conceptual schema of the integrated spatial information is shown in Figure 3. Likewise, it is viable to incorporate the spatial information produced via measurement and laser scanning of underground infrastructure.

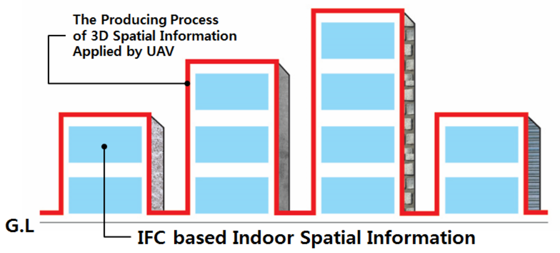


Figure 3. The Concept of Integrated Spatial Information (Section)

4. Conclusion

Given the importance of building and maintaining indoor spatial information and the need to retain the strengths of existing methods (e.g. accuracy of measurement/image capturing and laser scanning as well as relevant service provision) and to remedy the weaknesses (e.g. missed property information as well as time and cost taken to build such information), the present study uses the open BIM-based IFC standard format to design modules for extracting the indoor spatial information and develop a tool for visualizing the information. In addition, this study implements the indoor spatial information as 3D spatial objects, which are consistent with the infrastructure technology R&D project, or the open BIM-based technological environment development plan. The developed visualisation tool for indoor spatial information facilitates intuitive understanding of 3D indoor spatial information by applying data visualisation technology, and selectively displays information to users as necessary. The indoor spatial information objects are characterised by the following. First, lightness of data is secured by selectively extracting and defining the information on demand from IFC. Therefore, the information is applicable to urban and national simulation databases not just to small-scale buildings and infrastructure. The IFC original file size generated with LOD 200 equivalent to BIM modelling level is 14,765KB in comparison to 967KB of the indoor spatial information generated here, or approximately 1/15 times lighter than the existing file size. Second, information is easily produced and edited. There is no need to do extra work for indoor spatial information because the indoor spatial information is extracted from the open BIM-based IFC model, which facilitates the production and edition of information. This is attributable to IFC's structure where objects' properties can be edited. Editing properties is as simple as attaching memos to notebooks. Moreover, as the Ministry of Land, Infrastructure and Transport plans to replace the Seumteo System for building-related licence/permission with an open BIM-based 3D Seumteo and be supplied with IFC, there seems to be no need to build separate indoor spatial information using devices such as

3D scanners for building the indoor spatial information in case any building environment requires developing a BIM model. Third, the indoor spatial information objects using IFC are XML-based, having a high interoperability with other formats (CityGML, LandXML) in the field of AEC/FM. Also, they are applicable to spatial maintenance of infrastructure in connection with COBie and GIS-based UAV, as well as diverse simulations including evacuation routes and military strategies. To build and apply the indoor spatial information in near future, it is necessary to define and extract objects relevant to informal indoor space, to extract the information about inter-space routes (stairs, elevators) and about openings available for evacuation/escape for an accurate analysis of evacuation simulation and to visualise relevant data for intuitive representation. Furthermore, a specific process need be clarified regarding the interoperability with COBie for the space-based maintenance of infrastructure.

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