Development of Application for Generation of Automatic 2D Drawings based on openBIM

Jungsik Choiª, Yongha Leeª and Inhan Kimª

ªDepartment of Architecture, Kyung Hee University, Republic of Korea

E-mail: jungsikchoi@gmail.com, stays1006@gmail.com, ihkim@khu.ac.kr

Abstract

This paper describes the development of an automated stand-alone application for generating 2D drawings using information from an IFC file, independent of existing BIM authoring tools. Using the application described in this paper, plan, section and elevation drawings can be extracted with no additional effort. The approach described in this paper, which is based on openBIM technology, will have a strong impact on the construction process especially from the perspective of enhancing productivity by providing a trade-off between conventional and new approaches.

Keywords –

Building Information Modeling (BIM); Industry Foundation Classes (IFC); 2D Drawings Generation

1 Introduction

With the increasing popularity of smart devices and the application of artificial intelligence and other automation technologies, technical applications for business innovations are being implemented in a wide variety of industries. In an attempt to improve productivity and quality in the construction field, openBIM was introduced for business innovation. openBIM can improve efficiency through construction cost reduction and work automation. Therefore, stockholders in the construction industry expect positive effects from the use of this technology. However, the high cost of facility investment and the re-education of users are hindering the introduction of BIM-related technology. In addition, compared with the expected effect, technology based on openBIM is still in the preliminary stages. In order to use BIM technology effectively throughout the construction process, the technology must be more advanced than its current state. Despite the high degree of interest and expectations for openBIM, there is a wide variety of BIM technology deployed in the construction industry because different groups introduced BIM at different periods and the use

of BIM is still in the preliminary stage. In the actual business environment, the construction process is changing from the use of 2D drawings to 3D BIM, but the BIM model and 2D drawings are expected to be submitted at the same time during the permit process. In countries where BIM is mandatory, the BIM model is submitted as an IFC file. The generation of drawings that do not rely on commercial software and that follow international standards (IFC) is very important.

Therefore, there is a need for openBIM-based automatic 2D drawing generation technology to avoid duplicating the work of creating both the BIM model and 2D drawings as well as to overcome limitations due to technical gaps, which are the current economic and technical difficulties hindering the adoption of BIM. However, the drawing generation module included in existing BIM authoring tools can only be used with specific tools. This makes it difficult to use BIM in the current environment, and leads to difficulties in BIM facility investment as well as technical gaps between users.

The purpose of this study is to analyze the architectural elements required to generate 2D drawings with the aim of developing an openBIM application capable of generating 2D drawings automatically. The goal is to maximize the effect of BIM to enable individuals undertaking the permit process in a design office to create IFC-based drawings for permit submission after completing the model. Permit officers can also generate the drawings they need and work efficiency can be improved by reducing duplication during the transition period of BIM introduction.

2 Literature review

2.1 openBIM

BIM is based on the concept of using electronic information to generate and express building information. BIM refers to the process and technology of acquiring and managing information electronically, which is important throughout the life cycle of building planning,

design, engineering, construction, maintenance, management and demolition [1]. Through BIM, information related to a building can be managed and used electronically, enabling application of the many advantages of computers, such as accuracy and storability. However, the construction industry is huge and complex and a wide variety of software is used by different groups in the industry to handle computerized information. The omission of information and errors in transmission can occur in the process of information exchange between these different programs [2]. To address this issue, buildingSMART proposed the concept of 'openBIM'.

openBIM is a concept focused on independence from specific software or product groups and ensuring interchangeability and interoperability of information between different kinds of software. For this purpose, the IFC format was developed as an international standard data format in buildingSMART and is actively being developed. In 2013, IFC was adopted and published as an ISO16739 standard [3]. IFC is an international standard neutral file format for BIM data exchange and information exchange between the BIM software used in many fields in the construction industry. In the IFC data structure, information about the building is expressed based on the relationship of the objects and the relationship of attributes owned by the objects.

2.2 Necessity of automatic generation of 2D drawings

Unlike the predicted disappearance of 2D drawings with the introduction of BIM, the requirements for 2D drawings have remained consistent. The results of a survey on BIM introduction status in Korea showed that "duplicate work due to creating BIM model and drawings separately" was the primary factor impeding BIM adoption, with 80% of users selecting this response. When introducing BIM to non-users, the ease of generating different sections, facades, and perspectives should be taken into consideration, as this factor has the highest influence on adoption with 62% of responses [4]. In the early stages of BIM introduction, though the duplicate work of generating 2D drawings simultaneously is necessary, it presents an obstacle to BIM adoption. The primary reason for the duplicate work is the difference in the technical levels of the participants in the construction process. Many participants are involved in different stages of construction, from design, permission, and construction to maintenance. However, when BIM is implemented from the design stage, all participants must use this method to complete the project.

Consequently, even if the BIM contract is expanded and the design work is performed using a BIM model, the current contract situation requires 2D drawings and duplicate work remains a necessity. An application

capable of generating 2D drawings automatically is needed to solve this problem. Such an application can eliminate the negative elements of BIM introduction by reducing the workload of users, improving productivity and reducing the technical gap.

2.3 2D drawing automatic generation application and research status

There are various methods for generating 2D drawings from BIM models. Drawings can be generated in combination with a 2D drawing generation module in commercial authoring tools. Choi et al. pointed out the limitations of having to use a 2D drawing module in BIM authoring tool to generate drawings. The problem lies in creating an execution design drawing at the same level as CAD, an inability to match the details with the construction level, and lack of a modeling function that can add detailed content [5]. Chae et al. noted that problems will occur in the process of generating 2D drawings using BIM authoring tools, so this method should be applied in parallel with the existing method of creating 2D drawings [6]. Lee et al. stated that drawings generated with a BIM model cannot meet the standards for construction sites. He proposed developing a module to create steel reinforcement construction drawings and process the schedule accurately according to the relevant criteria by using a 3D structure model and taking the architectural structure as the object [7].

The results of previous research on automatic 2D drawing generation using a BIM model show that most of the previous research stays on the stay at those stages, such as instructions to generate 2D drawings using BIM authoring tools, changes in the design process using templates and a module for automatic generation of drawings for use at construction sites. However, methods for generating 2D drawings using a standard such as the IFC optimization criteria or generating a BIM design document are nonexistent. There is also a lack of practical research on solving the problems of 2D drawing generation.

2.4 Summary

BIM can improve business efficiency by embodying real buildings in virtual space. In the initial phase of BIM introduction, both the 2D and 3D processes coexist, resulting in practitioners performing the duplicate work of creating both a BIM model and 2D drawings [8]. Although the practitioners are burdened by the additional work, existing methods for generating 2D drawings from BIM models are incapable of producing detailed technical drawings. The drawings generated currently cannot be used because they do not meet the standard. In addition, there is no complete study evaluating the use of optimization criteria to improve productivity or a

standard format to create drawings. In this study, the structure of the standard IFC format was evaluated to develop an application for automatic generation of 2D drawings based on openBIM that can be used for viewing the BIM model regardless of the type of authoring tool used. The goal is to enable users to generate drawings of required parts from the IFC model without inconveniences resulting from the level of BIM introduction and technical gaps.

3 Implementation of 2D drawing automatic generation application

3.1 Overview

3.1.1 Process for 2D drawing generation based on IFC

The process for 2D drawing generation based on IFC is shown in Figure 1. First, in order to visualize the IFC file, the IFC information must be parsed to distinguish the information for model shape expression and the object attribute information. After separation, the information is stored in memory. Solid shape information is generated using the shape expression information, then converted to mesh for 3D shape expression using the Open Cascade library. To visualize the transformed mesh information in 3D, the Direct X library is employed. For the generation of plan and section drawings, visual images for 2D drawings are generated using a mesh cutting algorithm. The remaining lines on the opposite side of the section generated by mesh cutting are unnecessary and are deleted by a removal algorithm before vector information is generated for output. To create annotated elements (such as dimension, grid, level, etc.) in the generated drawings, the information is first extracted from the IFC model and visualized in the generated drawings.
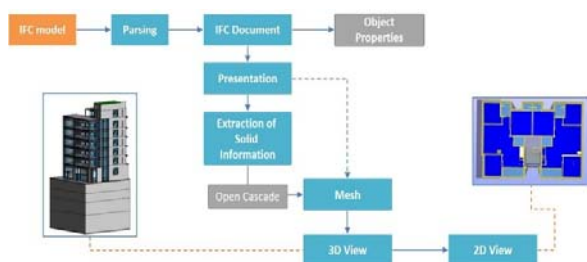

Figure 1. Process diagram

3.1.2 Structure of the application

The information generated from the IFC model is visualized according to the following structure. The structure refers to the classification of the basic structure

for IFC. The application was developed in C#, an object-oriented C language, and encapsulation was implemented to use information effectively. During classification, the part needed by Solid calculation calculated through the modular solid calculation is operated as data for visualization. Through the visualization module, the information can be visualized on a computer screen.

To generate a plan drawing, elevation drawing and section drawing with the 3D model, the appropriate data structure for the model should be accurately defined. Section cutting must be applied effectively on the structure based on the cutting plane, and the section cutting results should be expressed accurately without errors. To express the 3D shape information, the structure of the object is mainly used in the triangulation mesh. In this study, we performed section cutting and the generation of section lines in the corresponding plane. However, a relatively complicated computation is required when using a triangular mesh and unnecessary lines may be generated in addition to the section lines. In this study, we mostly needed to generate the section shape. Consequently, we created the object structure as shown below, so that the related work can be completely effectively.

The basic structure of the object was defined as a polyline-made polygon with a hole. The example below shows the shape of one hole in the quadrilateral, but the method presented in this study involves several holes in the polygon. This method can be used to generate a mesh by using a triangulation network after cutting based on the cutting plane.

3.2 Automatic generation of 2D drawing

3.2.1 Generation of elevation drawing

The elevation indicates the elevation shape on four sides (left, right, front, and back). The lines expressed in the elevation can be divided into two types. In the first type, the intersections of the object surfaces form the lines. In the second situation, the intersections of the surfaces form no lines, but the boundaries of a prominent position become the outline. For example, in a curved surface, although there is no line formed by the intersection of surfaces, a section will be presented along the direction of the elevation as a contour line.

When elevation is displayed on the interface of the application, it turns the direction of the camera to the X (Left), -X (Right), Y (Front) and -Y (Back) axes and selects the projection mode as a right-angle mode to display on the interface. In the visualization of the IFC model, when the elevation is displayed, the objects behind the objects shown in the related elevation drawing are presented in an invisible form. In order to represent the elevation drawing on a computer screen, the triangular faces of the obstructed objects are drawn using

the background color. On the elevation drawing, the lines that are intended to be hidden should be drawn using the background color, which will make them appear invisible. Therefore, it is not necessary to use the delete calculus separately for obstructed objects. In addition, the elevation drawing can be displayed quickly and effectively.

3.2.2 Generation of section drawing

Generation of a section drawing is based on the plane of the user's desired section, created by cutting off the BIM model and creating an isometric projection in the vertical direction of the section. The section is made up of lines cut from the datum as well as uncut evaluation lines. The method of cutting the building by using the inference plane is as follows. This method is based on the coordinates of the cut-off reference plane, fixing the location of the camera, and truncating all the objects crossing the cross-section and perpendicular planes. The boundary lines of the cutting plane are marked as boundary lines on the screen. This is the same process used in generating the elevation drawing, in order to express section drawings quickly. When displaying a section drawing on the screen, a structure is needed to hide the objects behind the cross-section when the cross-section is displayed.

As shown in Figure 2, the cross-section provides an interface that allows users to set the reference line of the section drawing in the plan drawing for generating section drawings. Currently, the section line can only be created as a straight line.
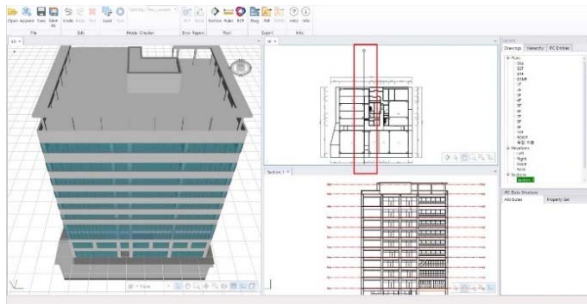

Figure 2. Selecting a section profile to generate any given section drawings of interest

3.2.3 Generation of plan drawing

The generation of plan drawing is a special method for generating the section drawing. It cuts off at the position based on the reference line which is 1.2 m in the upper direction from the surface of each layer, and uses the vertical downward projection method. In order to shorten the computation time for generating plan drawings, unlike the arithmetic method for generating section drawings, information about the object is used, such as the appearance lines on the bottom face.

There is some information in the plan drawing that

cannot be expressed by a 3D shape alone. For example, in a swinging door, the direction of the door opening and the door trajectory should be represented. Information regarding the entrance and exit for the opening direction of the door can be generated in IfcDoor. However, IfcDoor only contains information about the location and the direction of the opening. To see the shape and type of the door in detail, the Profile representation in the IfcDoorStyle parameters should be used. In addition, the representation identifier can be used to generate the shape of the 2D accurately. IfcDoor has a separate attribute called Footprint. Although this attribute cannot be expressed in a 3D form, it contains information about the opening and closing of the door, which can be displayed in 2D drawings.
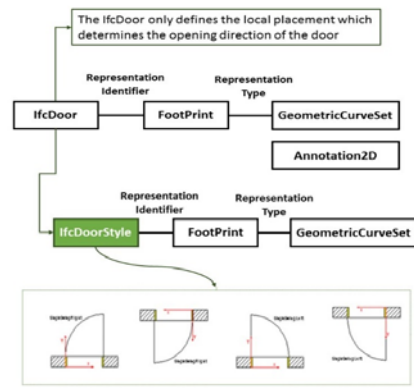

Figure 3. Derivation process to use IfcDoor data

The developed application makes use of related attribute information for creating the plan drawing for the door object. Details of the plan drawing generated in this manner are shown in Figure 4. It is not a 2D scene but rather a 3D Scene, which is created using the Direct X 3D library to express and display the information on the screen quickly. There are many limitations to the rich expression of 2D information, but significant improvements are anticipated in the future.
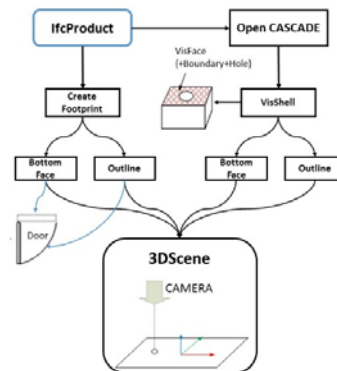

Figure 4. Fundamental algorithm to generate the plan drawing

4 Utilization of 2D drawing automatic generation application

4.1 IFC viewer and the confirmation of information specification

The application developed in this study aims to improve productivity by generating 2D drawings of required parts according to the needs of users after creating a BIM model. The goal is to reduce the duplication of design work and generate accurate drawings according to requirements to improve the efficiency of the work. The application in this study uses the international IFC standard format. The BIM model is based on LOD 300 for permits. The application can generate drawings of any position required by users without the need to consider whether specific authoring tools are available or not. Even if there are differences in the technical level of the users in different stages of the construction process, the IFC file can be used to generate the drawings of the desired parts.

Information in the IFC file can be confirmed using the IFC viewer. The performance of this study based on IFC can inform the users about the location and specification of the information for confirming the accuracy of the IFC files produced in the authoring tools. Therefore, errors in information transmission can be reduced by using the standard format. This is not only to meet the requirements for the permit and construction stages as well as to resolve difficulties because of technical differences, it can also be used to check the accuracy of information when using different kinds of BIM inspection tools to check design proposals at different phases of the design process.
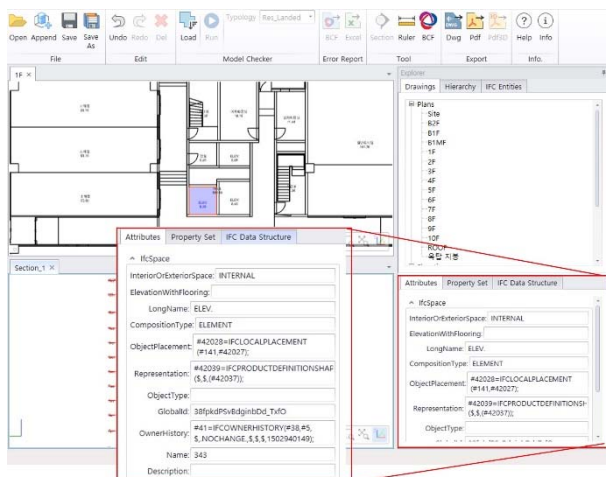

Figure 5. Fundamental algorithm to generate the plan drawing

4.2 Reflecting the optimization criteria of BIM design document generation

In this study, an application for generating 2D drawings based on openBIM was designed according to optimization criteria for BIM design document generation [9]. This means that the documents required in the future building permission process can be incorporated into IFC files using the application developed in this study. This application can generate 2D drawings automatically for submission according to optimization criteria. Therefore, users can utilize the application to generate the drawings necessary for the permit process without knowledge of the optimization criteria for BIM design document generation. This will reduce the amount of the work required by eliminating the duplicate work of creating a BIM model alongside 2D drawings for the permit. It can also reduce the time required to correct errors by generating accurate permission drawings automatically to shorten the time required to obtain permits.

5 Conclusion

In this study, an application for generating 2D drawings from a BIM model by analyzing IFC files was developed. The application can be applied not only in the design stage but also throughout the construction project. As the BIM technology matured, various authoring tools were developed. However, the data specification for each authoring tool is different, which reduced the efficiency of BIM [10]. To ensure that data from various BIM tools are compatible, a standard format must be used [11]. In countries where BIM is mandatory, the BIM model is submitted as an IFC file. The generation of drawings that do not rely on commercial software and that follow international standards (IFC) is very important.

In this paper, the authors use the concept of openBIM unrelated to specific authoring tools. In order to improve the usability, an automatic generation method for submission drawings was developed using optimization criteria for BIM design document generation. In this paper, the description was focused on generation of plan, section and elevation drawings from an existing 3D model. The generation of 2D drawings programmatically is achieved by using the background color for the part behind the cutting plane selected by the user to achieve a hidden effect. However, in order to extract the generated drawings in DWG or PDF format, the drawing lines corresponding to the cutting plane must be generated and an algorithm must be used to remove hidden lines to extract the drawings. In addition, for the presentation of the door object mentioned above, a cross-section of the 3D shape may not contain all the information provided by a 2D drawing (such as the grid, dimension line,

expression of void, space information, etc.). Therefore, research on the generation of separate information in the IFC should be continued.

If the developed application can be used in the BIM environment throughout the process of design-permission-construction-maintenance to expand the application scope of BIM, the effect of BIM can be maximized. The application eliminates the need for duplicate or repeat work resulting from the type of authoring tools used or differences in BIM technical level. Unlike the previous process of using specific authoring tools or creating 2D drawings and BIM models separately, the developed application can improve the efficiency of the entire construction process under the BIM environment by generating 2D drawings using openBIM. Therefore, the application is expected to provide support for construction participants, facilitating efficient BIM usage.

Acknowledgements

References

[1] Kim, I., Kim, M. and Choi, J. Improvement of Open BIM-based Building Permission Process Using EPI (Energy Performance Index), *Korean journal of construction engineering and management*, 16(6):124-135, 2015.

[2] Choi, J. *A Study on the Development of Code Checking System for Building Administration Process Applying Open BIM-based Process*, M.A. Thesis, Kyung Hee Univ., 2014.

[3] buildingSMART, http://www.buildingsmart.org, Accessed: 28/12/2017.

[4] An, Y. and Lee, G. Survey on the Status of BIM adoption in Korea, *The BIM*, 2016 spring, pages 8-12.

[5] Cho, Y. and Lee, H. A Study on the Possibility of 2D Design Drawing Implementation by Revit Architecture, *Journal of the Korea Academia-Industrial cooperation Society*, 14(10):5243-5250, 2013.

[6] Chae, K., Lee, E., Jun, H., Lee, M, Kim, K., Choi, J. and Yoo, S. A Research on Drawing Representation for BIM (Building Information Modeling), *The Computational Structural Engineering Institute*, 470-475, 2008.

[7] Lee, B. and Kim, C. Design and Implementation of the Quantity Surveying and Shop Drawing System for Structures, *Proceedings of the Computational Structural Engineering Institute Conference*, pages 132-135, 2011.

[8] Seo, H., Oh, J. and Kim, J. The Analysis of Job Stress of Workers in the Architectural Design Firm After the Introduction of BIM, *Korean journal of construction engineering and management*, 13(4):120-131, 2012.

[9] BIM guideline for architectural design drawings, Architectural Institute of Korea, 2016.

[10] Moon, H., Kim, B. and Ju, K. The Developing Strategy of BIM Library for Road Facilities based on Detailed Standard Drawing, *Korea Institute of Construction Engineering and Management*, 36-43, 2013.

[11] Oh, H., Jung, J. and Lee, J. A Guideline for Structural Drawings Based on BIM, *Journal of the architectural institute of Korea: Structure & construction*, 29(3):39-46, 2013.