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An Automated Process to Calculate Space Area by Space Boundaries of Wall Guide Lines Using IFC-BSED Bim Data

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Abstract

Using building information modeling (BIM)-based design information to analyze various engineering processes has been used extensively in construction projects. However, the current process that is used to design space area for buildings has a significant shortcoming in that it cannot directly use industry foundation classes (IFC)-based representation data that considers space boundaries of building elements' guide lines: rather, the space area has to be calculated by a polygon, which is modeling using a BIM-based computer aided design (CAD) program so that the space polygon is always exported by the inner-edge type. In this paper, we have proposed an automated process to calculate space area by space boundaries of wall guidelines using IFC-based BIM data. The proposed process consists of three steps, i.e., 1) extracting data from the IFC model, 2) recognizing the space boundaries, and 3) generating the orthogonal coordinates by the space boundaries' guidelines. The proposed process will enable engineers who are responsible for space management to use a BIM-based model directly in the space programming process without having to do additional work. The proposed process can help ensure that the space area is more accurate and reliable.

Keyword: BIM, IFC, Space area, Space boundary, Representation data

1. Introduction

In the architecture, engineering and construction (AEC) industry, research and development of building information modeling (BIM) applications are facing an increase in demand to manage building information. In this regard, various BIM-based computer-aided design (CAD) programs (e.g., ArchiCAD and Revit) have been developed in series to increase the efficiency of BIM-based design [1]. Since a construction project requires collaboration between various stakeholders, such as architects, engineers, authorities, contractors, suppliers, and trades [2], a building model must be integrated using BIM technology. BIM is currently the most common methodology for a collaborative approach to the design, engineering, construction and maintenance of a building [3, 4]. Recently, the benefits of using various BIM technologies in a real construction project have been focused on work efficiency and consistency [5].

Using BIM technology in a construction project to ensure the effectiveness of the collaborative work [6], a modeler must consider the format of the data used to exchange information about the building between various stakeholders. Since various specific BIM-based applications have been developed and used [7], a modeler must generate information about the building that can be imported by the other participants using international standards for the format of the data, such as IFC [8], as a model file format for the building. The IFC file format was developed by the international alliance for interoperability (IAI) in 1994. The IFC format can be used for any BIM-based applications anywhere in the world, since the applications can be read and written by IFC. Currently, IFC has been updated by version 2x4 as a common format to exchange information about a building in a construction project [9].

In this regard, there are various BIM-based guidelines to generate and use the building information within specific standards and regulations for each project's conditions, including location, usage, size, and other constraints [10]. However, since the specific standards or regulations are complex and different depending on the project conditions, it is very difficult to determine the correct and legal guidelines for each project. In addition, since several BIM-applications frequently are inadequate for supplying all of the guidelines for the conditions of a specific building, BIM modelers must generate their own, user-defined property dataset to describe the building's information. In this case, if a modeler generates correct and legal data using a user-defined property set, the other participants, who are using the other BIM applications, should not use the generated data.

The data of a space area are among the vaguest BIM-based building information. In general, BIM-based applications can generate space area as a user-defined property set, since the IFC-based space entity does not have an attribute related to the area, even it is the most commonly required data for various engineering analyses [11, 12]. Thus, when an engineer requires the

data of the space area, he or she must manually search the user-defined dataset from the IFC file format.

To solve this problem, in this paper, we proposed an automated process to calculate space area by space boundaries of wall guidelines using IFC-based BIM data. To that end, we analyzed the data related to the space information in the IFC schema and then, developed a process to generate the coordinates of a space polygon by space boundaries. The proposed process consists of three sub-processes, i.e., 1) extracting data from the IFC model, 2) determining the space boundaries, and 3) generating the orthogonal coordinates.

2. Related Work

2.1 Space Area

The architectural area of a building is the sum of the areas of each of the floors of the building, measured from the exterior walls or from the centerline of the walls that separate the buildings. In this regard, when a designer calculates the usable area of a building using an American national standard, he or she must consider three measurements, i.e., 1) the dominant portion, 2) the finished surface, and 3) the centerline. The dominant portion refers to the portion of the inside finished surface of the permanent outer wall of the building, which is 50% or more of the vertical floor-to-ceiling dimension, at the given point being measured moving horizontally along the wall [13]. For instance, three measurement methods are used to calculate the space area of the conference room in Figure 1.

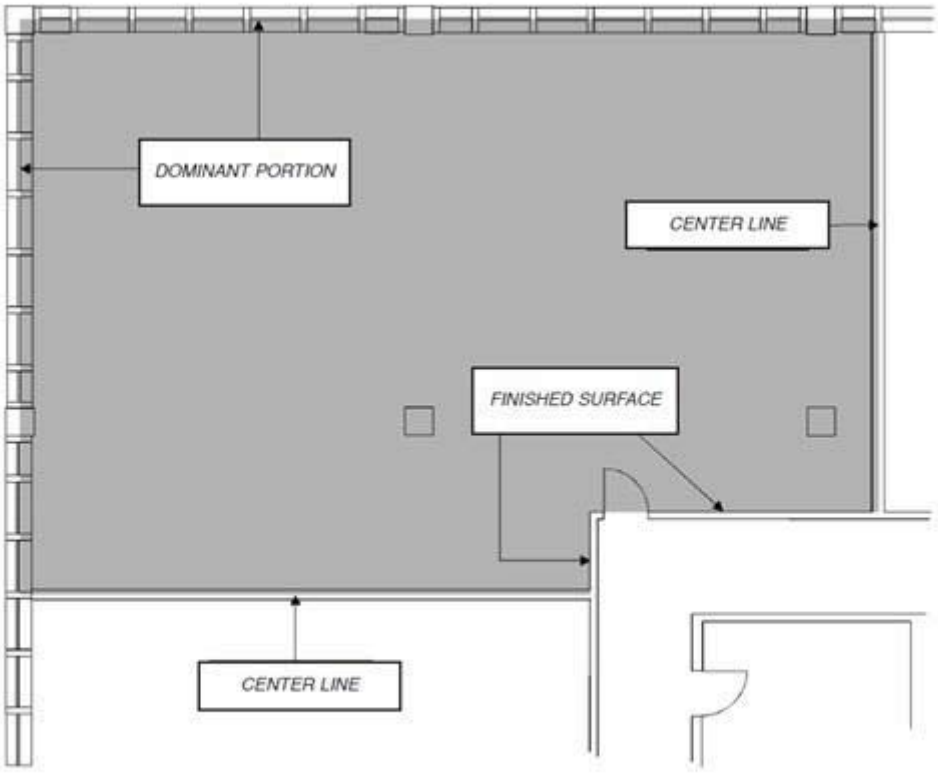


Figure 1. Various methods for measuring a space area [13]

2.2 Space Data in the IFC Schema

The IFC 2x4 schema has a specific data entity to describe a space as a building's component. According to the IFC 2x4 release candidate 4, the *IfcSpace* entity has 11 mandatory attributes with 17 optional attributes. The mandatory attributes include *ObjectPlacement* as the location coordinates about the space and *Representation* as a polygon about the space. Since the polygon described *IfcPolyline* using the two-dimensional coordinate system by the X and Y axis, in case of a rectangular shape, five coordinates are included to describe the space polygon (The first coordinates as a starting point and the last coordinates as an end point are the same.) Figure 2 shows the attributes and relationships of the specific dataset of *IfcSpace*.

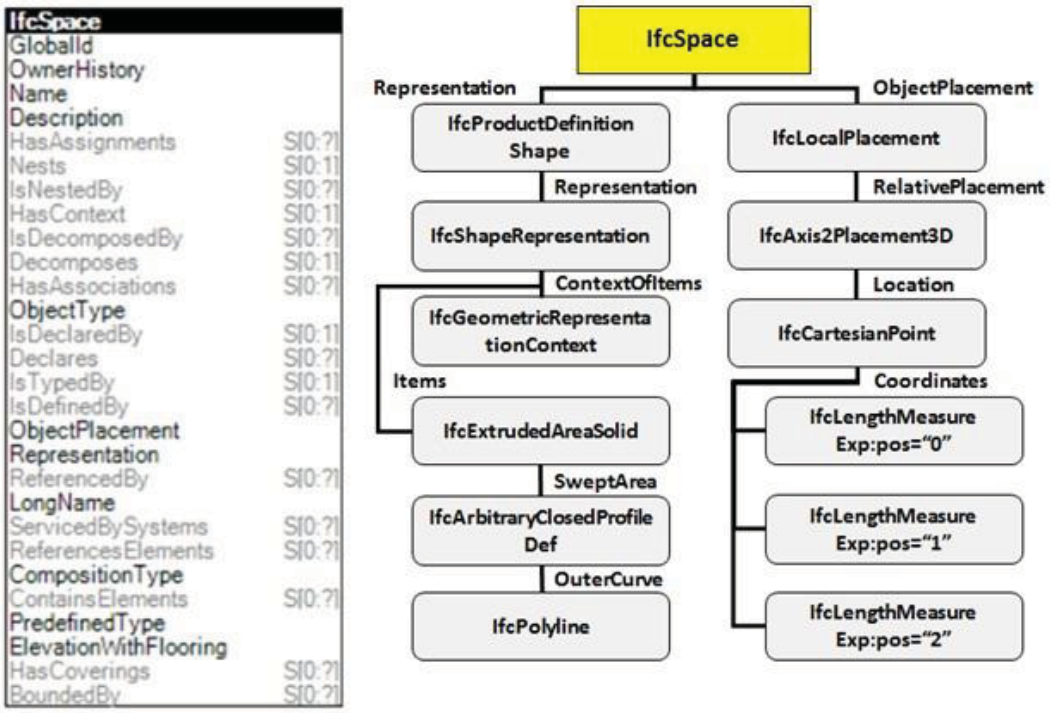


Figure 2. Attributes of the *IfcSpace* entity

In general, most BIM-based design applications can calculate the space area with the Representation attributes of the *IfcSpace* entity, since there is no specific property set about the space quantity [14]. In this case, however, the polygon always is generated by inner-edge types of the modeling method in the IFC file to avoid conflicts between building elements, such as the polygons of the space boundaries and the space. Therefore, there is a limitation to calculating the area of the space by the centerlines of the space boundaries without processing any data.

2.3 Space Boundaries

The space boundaries could be one of the building elements (e.g., walls, slabs or columns) in the model of a building. In this regard, when the space polygon is described in the two-dimensional coordinate system by a physical element, usually *IfcWall* (*IfcWallStandardCase*) entities are used in the IFC-based BIM data. In general, *IfcSpace* has identified several *IfcWall* entities as the space boundaries.

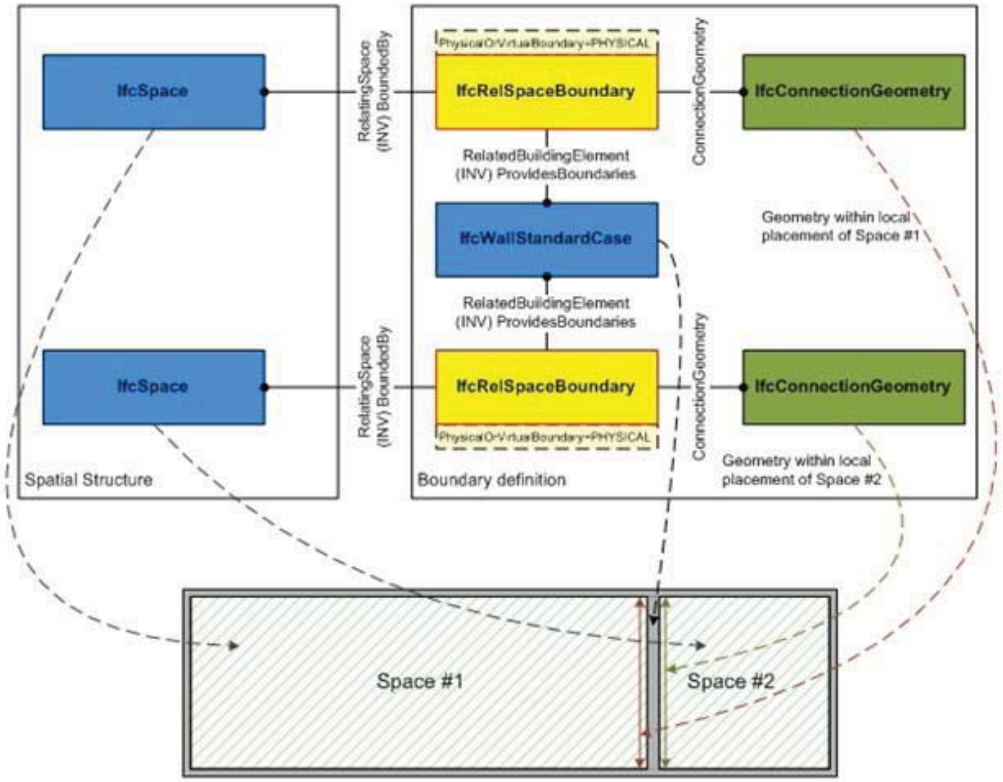


Figure 3. Relationships of the IfcRelSpaceBoundary entity [9]

In an *IfcRelSpaceBoundary* entity on the IFC 2x4 schema, there are nine mandatory attributes, including *RelatingSpace* by the space entity and *RelatedBuildingElement* by the space boundaries.

3. Proposed Approach

As mentioned earlier, a designer can use the inner-edge type of the space modeling using BIM-based design applications to calculate the space area from IFC-based BIM data. In this case, the designer must process the data of the coordinates of the space polygon as the orthogonal coordinates between centerlines of the space boundaries. To automate the data-processing procedure, we developed a process for calculating the space area by the wall guidelines using IFC-based BIM data. The proposed process has three sub-processes, i.e., 1) extracting data from the IFC model, 2) determining the space boundaries, and 3) generating the orthogonal coordinates by the space boundaries' guidelines. The Figure 4 shows the overall process.

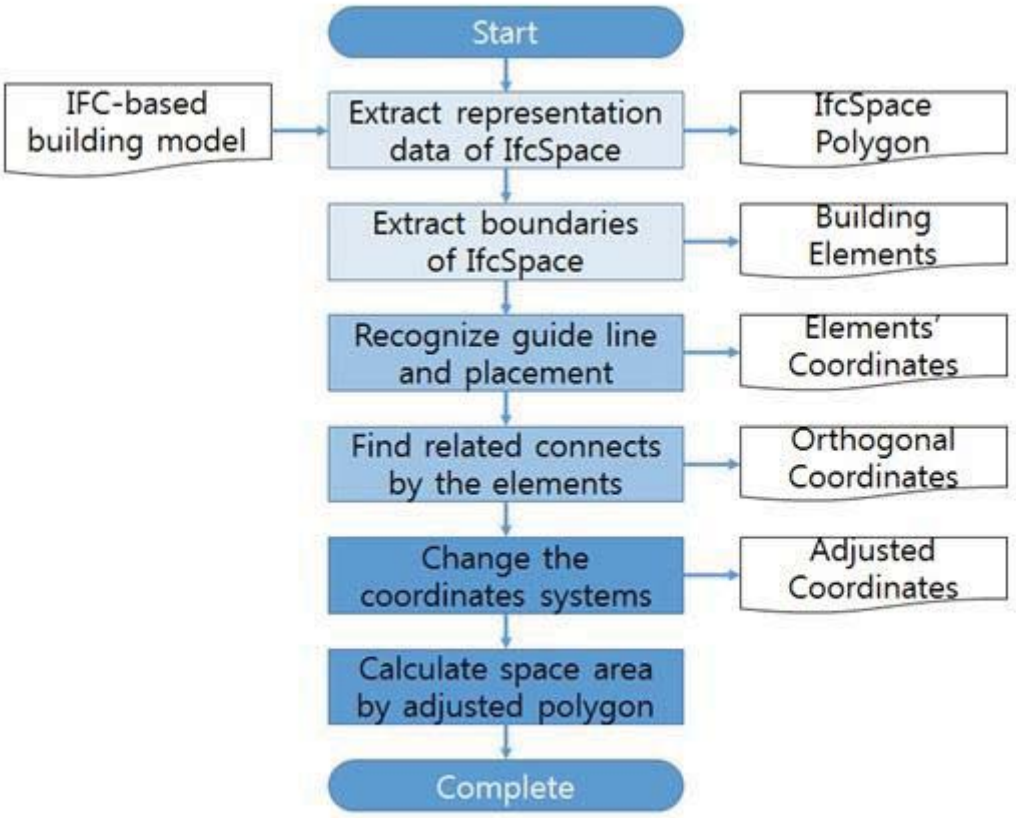


Figure 4. Overall Proposed Process for calculating the space area

1) Extracting Data from the Building Model

Two different types of data are extracted from the building model, i.e., 1) the coordinates of the polygon about the space and 2) the coordinates of the guidelines about the space boundaries. First, the coordinates of the *IfcSpace* are extracted from an IFC-based building model. The number of the extracted coordinates is 'n+1' of the number of angles about the space polygon. In this regard, the coordinates of the polygon describe the space area by the finishing lines of the space boundaries. After that, the building elements that are related to the extracted *IfcSpace* are extracted to determine the guidelines of the space boundaries. In this regard, the coordinates of the *ObjectPlacement* attribute also are extracted to adjust the coordinates of the space polygon.

2) Determining the Space Boundaries

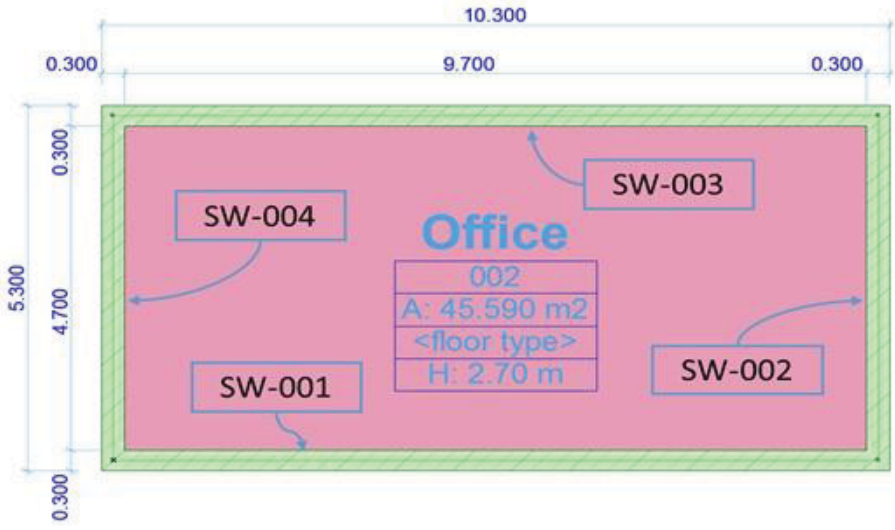
To determine the orthogonal coordinates of the guide lines for the space boundaries, in this case, the guide line of the wall should be a centerline of the subject, otherwise the orthogonal point of the guidelines does not mean the centerline measurement of the space area calculation standard. The space boundaries have the information of the connections using the *IfcRelConnectsPathElements* entity. Thus, depending on which building elements are connected to each other, the starting point of the relating element can be an orthogonal coordinate of the two related guidelines.

3) Generating the Orthogonal Coordinates

To generate the orthogonal coordinates, the specific system of coordinates must be considered. Since the *IfcSpace* has each specific local coordinate system, the orthogonal coordinates are changed to the specific local coordinates system by the *ObejctPlacement* attribute of the *IfcSpace*. Then, the generated orthogonal coordinates replace the coordinates of the polygon about the subjective space.

4. Case Study

To use the proposed process, a sample model was modeled by ArchiCAD version 16 with a gross interior floor area of 45.59 m^2 surrounded by four walls. The space is named 'Office' as an example, using the inner-edge type of the modeling method in ArchiCAD. The surrounding four walls have a guide line as a centerline on their own. When we exported the sample model in an IFC file, one *IfcSpace* entity and four *IfcWallStandardcase* entities were included. Figure 5 shows the sample model and the context of the IFC file.




```
#155= IFCWALLSTANDARDCASE('(GlobalID)',#13,'SW - 001',$,$,#152,#225,'(TagID)');
#341= IFCWALLSTANDARDCASE('(GlobalID)',#13,'SW - 002',$,$,#338,#411,'(TagID)');
#555= IFCWALLSTANDARDCASE('(GlobalID)',#13,'SW - 003',$,$,#552,#625,'(TagID)');
#769= IFCWALLSTANDARDCASE('(GlobalID)',#13,'SW - 004',$,$,#766,#839,'(TagID)');
#1047= IFCSPACE('(GlobalID)',#13,'002',$,$,#1044,#1029,'Office',.ELEMENT.,.INTERNAL.,$);
```

Figure 5. Sample model

Using the *IfcRelSpaceBoundary* entity in the IFC file, we can determine from the building's elements which walls are surrounding the space, as shown in Table 1. Therefore, the positions of the four walls were defined as the point order of a polygon about the space.

Table 1. Extracted IFC-based BIM data

Point Order of Polygon (IfcSpace)	Local Coordinates (X, Y)	Space Boundary (IfcWall)
0	(0, 0)	#555=IfcWallStandardCase (SW-003)
1	(4700, 0)	#769=IfcWallStandardCase (SW-004)
2	(4700, 9700)	#155=IfcWallStandardCase (SW-001)
3	(0, 9700)	#341=IfcWallStandardCase (SW-002)
4	(0, 0)	

After extracting the IFC-based BIM data, a guideline can be determined from each of the space boundaries (e.g., SW-001 to SW-004). Since there are four entities to recognize the connection information defined *IfcRelConnectsPathElements* entity from the IFC file, we can determine the orthogonal points that crossed each other between the space boundaries. In this regard, if the *RelatingConnectionType* attribute value of the *IfcRelConnectsPathElements* is 'AtStart,' the orthogonal coordinate is defined by the starting point of the relating element's guideline. Moreover, if the *RelatingConnectionType* attrite value of the *IfcRelConnectsPathElements* is 'AtEnd,' the orthogonal coordinate is defined by the starting point of the related element's guide line.

Table 2. Generated Orthogonal Coordinates

IfcRelConnectsPathElements Entity ID (RelatingType)	Related Element	Relating Element	Orthogonal Coordinates
#442 (AtStart)	#341 (SW-002)	#155 (SW-001)	(0, 0)
#656 (AtStart)	#555 (SW-003)	#341 (SW-002)	(10000, 0)
#870 (AtStart)	#769 (SW-004)	#555 (SW-003)	(10000, 5000)
#898 (AtEnd)	#769 (SW-004)	#155 (SW-001)	(0, 5000)

According to Table 2, the coordinates of the space's polygon can be replaced by the generated orthogonal coordinates. After the data are processed as specified in the proposed process, the origin space area value was 45.59 m^2, but this was changed to 50 m^2 when the coordinates of the polygon about the space changed.

5. Conclusion

Since there has been increasing interest in developing BIM-based design applications for the

last decade, various BIM-based building modeling guides and regulations also are provided considering their own project conditions. However, a measurement of space area is the vaguest issue to accurately and correctly calculate floor area in a building. Because there are many measurement methods of space area in a space, many designers must manually consider the correct and legal standards. In this case, it depends on the types of the space boundaries, even if there are different types in the space. To solve this problem, in this paper, we proposed an automated process to calculate space area by the space boundaries of a wall's guideline using IFC-based BIM data. We reviewed the IFC-based data entity related to space and space boundaries. In addition, we developed three sub-processes to extract BIM data, to determine guidelines of the space boundaries, and to adjust the coordinates of the generated orthogonal coordinates. Also, we applied the proposed process to a sample model to replace the coordinates of the space polygon from the inner-edge type of the polygon to the centerlines of the space boundaries.

The contribution of this work is the elimination of mistakes that are made when space areas are calculated manually without a user-defined property set related to the space area. The proposed approach can be developed to automatically define the measurement of the space by the types of space and the different space boundaries. In addition, using the computerized calculation method, the value of the space area can ensure consistency and accuracy simultaneously.

We have identified three future research areas that would be beneficial. First, the proposed approach should be developed so that it could address more than two spaces in a floor using the interior space boundaries. Second, since the connections of the space boundaries are used differently in various measurement methods for a space by types, an algorithm of this issue should be considered for the proposed approach. Third, calculation tool should be developed that would allow the proposed process to be more focused from a practical perspective.

Acknowledgment

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