

Development of Multi-slice Analytical Tool to Support BIM-based Design Process

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Abstract. This paper describes the on-going development of computational tool to analyse architecture and interior space based on multi-slice representation approach that is integrated with Building Information Modelling (BIM). Architecture and interior space is experienced as a dynamic entity, which have the spatial properties that might be variable from one part of space to another, therefore the representation of space through standard architectural drawings is sometimes not sufficient. The representation of space as a series of slices with certain properties in each slice becomes important, so that the different characteristics in each part of space could inform the design process. The analytical tool is developed for use as a stand-alone application that utilises the data exported from generic BIM modelling tool. The tool would be useful to assist design development process that applies BIM, particularly for the design of architecture and interior spaces that are experienced as continuous spaces. The tool allows the identification of how the spatial properties change dynamically throughout the space and allows the prediction of the potential design problems. Integrating the multi-slice analytical tool in BIM-based design process thereby could assist the architects to generate better design and to avoid unnecessary costs that are often caused by failure to identify problems during design development stages.

1. Introduction: Multi-slice representation in architecture

Architecture design process aims to represent the ideas of space to be materialized into built environment. Architecture is experienced by human being as a dynamic entity; it involves movement from one space to another, and it involves changes of spatial properties from one time to another [1]. One of the challenges in representing the architectural ideas is on how to depict architectural space as a dynamic entity, which have the spatial properties that might be variable from one part of space to another. The standard architectural drawings, which are primarily based on the projection of space at certain point and at certain time, are often insufficient to depict the dynamics of the space.

This paper attempts to extend the techniques of architectural representation through multi-slice representation approach. Multi-slice representation refers to the technique of tomography as practiced in medical science, in which the three dimensional human body is analysed by making a series of slices that together provide a comprehensive image of the human body [2]. The understanding of space as a series of slice is important in architecture, especially to analyse the types of space that involves dynamic movement, in which the change of spatial properties and the continuity of space could affect the performance of the space. As an attempt to apply multi-slice representation approach in the design process, a multi-slice analytical tool is developed and integrated into Building Information Modelling.



Building Information Modelling (BIM) approach transforms the documentation method in architectural production from two dimensional drawing information systems into three dimensional object information systems [3]. By using more integrated system, BIM approach could avoid the fragmentation and the duplication of data which could lead to confusion and inefficient workflow. As a result, BIM adoption in architectural and construction industry becomes important to increase productivity, efficiency, quality and sustainable development [4]. Motivated by such immense development of BIM approach in architectural design, we attempted to develop multi-slice analytical tool that is integrated with BIM environment in order to support architectural design process.

The purpose of this paper is to give a brief description of the development of BIM analytical tool that could represent architecture and interior space as a series of slices based on particular paths that are experienced along the space. This paper takes an example of the use of multi-slice analytical tool to analyse a hospital corridor space, in which the continuity of performance along the space is important. Through multi-slice representation, it is possible to gather detailed spatial information in each slice, which will be important to assist the design process in which the spatial continuity becomes the main consideration.

2. The development of multi-slice analytical tool

Rather than developing the analytical tool specifically for particular BIM-based modelling program [5], we used a more flexible approach by creating a stand-alone application to extend its functionality (Figure 1). The analytical tool uses Industry Foundation Classes (IFC) data that is exported from the Autodesk Revit modelling software. IFC is an open neutral format to describe industrial data from building and construction, developed by BuildingSMART based on ISO-STEP EXPRESS language and concepts [6]. Although improvement is still needed to reach fully effective interoperability, IFC currently becomes the state-of-the-art exchange file format among different BIM platforms [3]. IFC is developed as collections of various entities (data objects), property sets and data types that represent the geometrical and semantic richness of building information. IFC was designed to address all building information that could be used for different purposes, such as energy analysis, cost estimation and scheduling [6]. Such interoperability in BIM approach expands the possibility of BIM-based tool development that could address more specific tasks that could not be provided by generic BIM tools.



Figure 1. The general workflow of multi-slice analytical tool

The development of multi-slice analytical tool was done using Python scripting language due to its vast libraries and community. Most parts of the tool are built based on IfcOpenShell combined with PythonOCC to process the building information contained in IFC files. IfcOpenShell is an open source library that uses 3D CAD Kernel OCE (Open Cascade Community Edition) to convert the geometry information from IFC file into explicit geometry that can be understood by another CAD or modeling library. The resulted geometry and its relating information such as materials and its semantic are then processed and analyzed using PythonOCC robust modeling algorithm. PythonOCC itself is a 3D CAD development framework that also builds upon OCE.

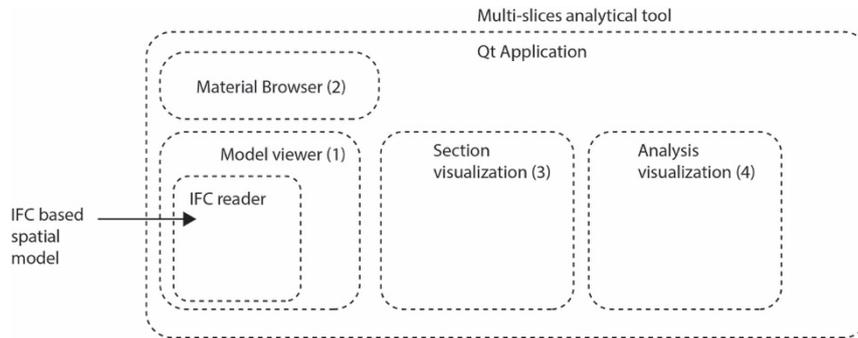


Figure 2. Multi-slice analytical tool modules

The analytical tool is developed as a stand-alone package that uses the spatial information from the IFC files provided by other modeling programs (Figure 2). The tool consists of three main parts; The Model Viewer (1), Section Visualization (3) and Analysis Visualization (4). Model Viewer reads the IFC file into memory and displays it on interactive three-dimensional display. In this part the user needs to determine which part of the model that would be analyzed by generating the series of sections. The Section Visualization module rearranges the generated sections into a parallel sequence. The tool thereby could perform some analyses from the series of section to assess its spatial continuity based on some properties such as spatial dimension, materials, position of elements, etc. The analytical tool visualizes the results of analyses in two-dimensional representation in Analysis Visualization module to provide better readings from the results of analyses.

3. The use of multi-slice analytical tool

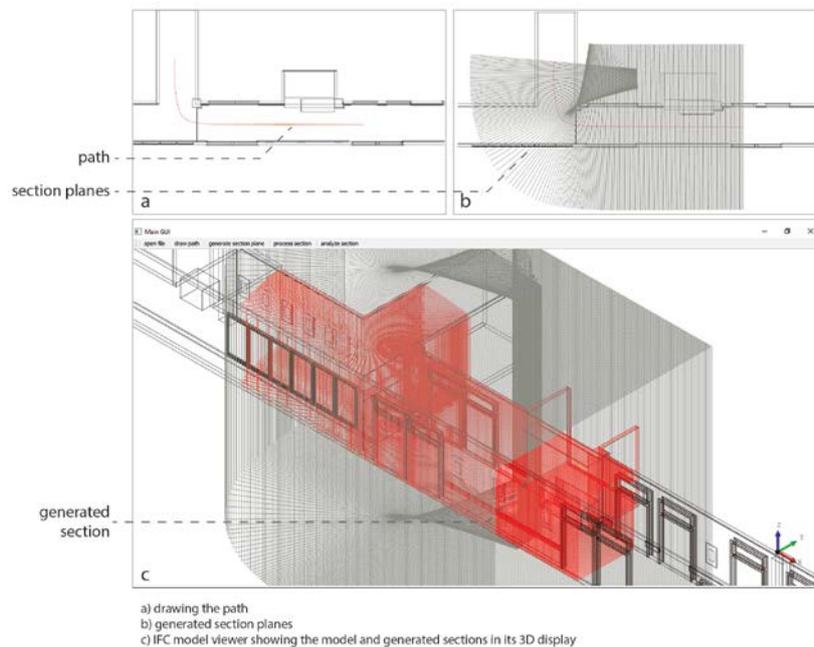


Figure 3. Series of slices generated on IFC model viewer screen

The following example demonstrates the use of multi-slice analytical tool to analyze the space of hospital corridor. Figure 3 shows how the slices are generated on Model Viewer. The analysis is performed by drawing the path as the main axis to generate the series of slices. The sections are

generated perpendicular to the path drawn by the user on the viewer. The following pseudo-code shows the process of generating the sections based on resulted section planes and building elements on IFC model.

SECTION-SLICES(*buildingElementList*, *sectionPlaneList*)

```

1 declare sectionList
2 for each sectionPlane in sectionPlaneList
3   sectionElements ← CREATE-SECTION(buildingElementList, sectionPlane)
4   section = [sectionElements, sectionPlane]
5   insert section to sectionList
6 return sectionList
    
```

CREATE-SECTION(*buildingElementList*, *sectionPlane*)

```

1 declare sectionElementList
2 for each buildingElement in buildingElementList
3   sectionGeom ← GET-INTERSECTION-CURVES(buildingElement, sectionPlane)
4   sectionElement ← [sectionGeom, buildingElement]
5   insert sectionElement to sectionElementList
6 return sectionElementList
    
```

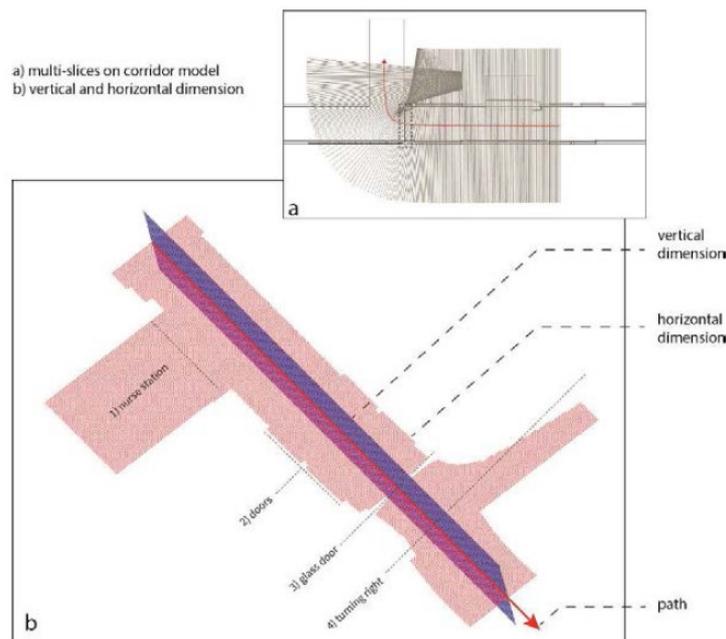


Figure 4. Parallel sequence of slices on Analysis visualization screen

The generated series of sections are then translated into parallel sequence to allow the spatial comparison between and within the sections [7] from the beginning to the end of the path (Figure 4). The red lines and blue lines are created from the center of section plane to measure the boundary of the space along its axis. The measurement is performed by finding the nearest intersection from origin point of the section plane to section curves along each axis. The resulted axis lines provide general measurement of corridor dimension but not showing the clearance dimension of corridor space.

Figure 5 shows the principle of calculating the space clearance on each *section_j*. The measurement of the horizontal clearance is performed by finding the shortest distance between the center and both left and right sides of each section from bottom k_{min} to the top k_{max} of the boundary. The *horizontal left_{jk}*

and *horizontal right*_{jk} denotes the horizontal clearance on index *k* on *section*_j. The vertical clearance measured by measuring the distance *vertical distance*_{ji} between bottom and upper side of each section from left *i*_{min} to right *i*_{max} of the boundary.

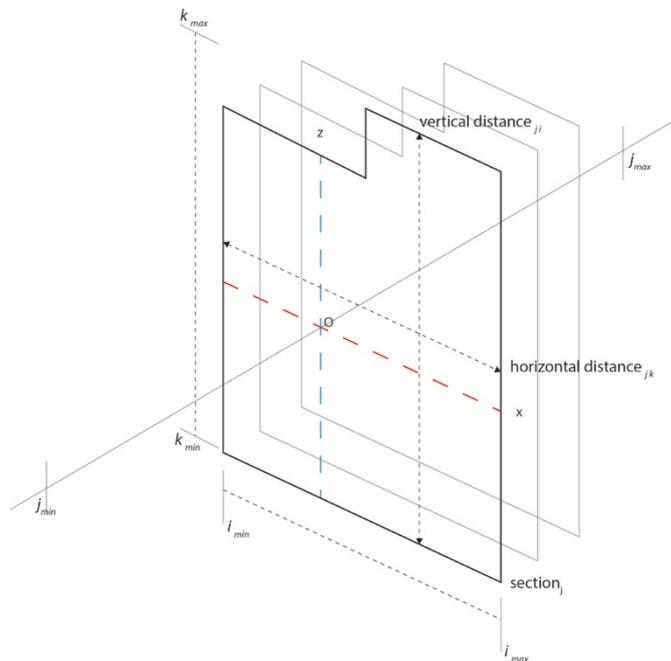


Figure 5. Measurement of space clearance on section

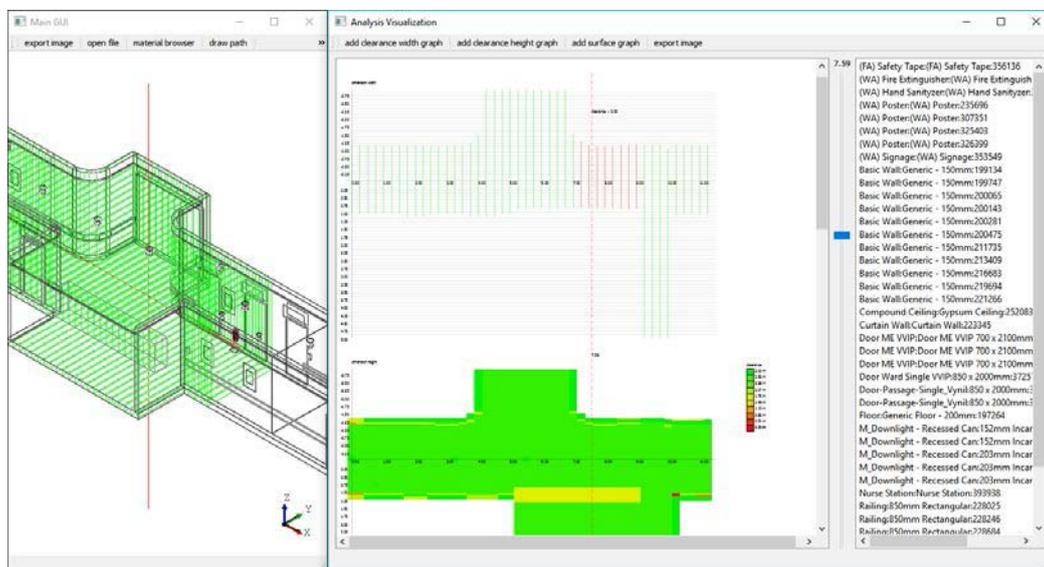


Figure 6. Visualization of space clearance analysis

Figure 6 shows the visualization of space clearance analysis of the corridor. The horizontal clearance is shown as a series of vertical lines spreading from zero axis that represents the clearance distance of each section. The green red lines indicate that the clearance is below the minimum clearance that is required by the standard, while the green lines indicate the opposite situation. The color-scaled graph represents the vertical clearance that shows the distance between the upper part and

the bottom part along the whole corridor. The distance is shown by the color-scale, in which red represents the shortest measured distance, while green represents the farthest measured distance. Both graphs show the void space that allows people to move along the corridor, which is difficult to illustrate on standard architectural drawings. By using the space clearance graph, the architects could have better feedback on the performance of the analyzed space.

4. Possible further development

The development of multi-slice analytical tool in integration with BIM allows the analysis of architectural space for its continuity of performance. This development is a part of ongoing research that looks into how the analytical tool could be used to assess the performance of hospital corridor, in particular to assess the spatial elements that could affect the spatial continuity of the space, such as handrails, finish materials, position of doors, and lighting.

Some further development is necessary to improve the quality of the multi-slice analysis to provide better feedback for design process. In multi-slice analysis, the distance between sections correlates directly with the resolution of spatial information that would be analyzed. Narrowing the distance between sections will result in larger number of section slices thus providing more complete representation but increasing the computational cost. Further study could attempt to find the relationship between distance between sections and collected spatial information in order to determine the optimal number of slices needed to perform the analysis.

Further development is also necessary to improve the features of the tool in order to better support design development process. The semantic richness of IFC opens the possibilities of more detailed analysis on every spatial element in their context. While the tool development currently focuses on the spatial analysis, the visualization of the analysis is also important since the multiplicity and density of displayed information [7] might affect how the analytical tool would give insight about the analyzed space. The development of such visualization will provide a valuable data to support the design development process.

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