

TRANSFORMING POINT CLOUD DATA INTO 3D BIM MODELS: A CASE STUDY ON SLABS

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ABSTRACT. We explore the automatized transition of point cloud data into a Building Information Model (BIM), an essential task for reconstructions, demolition plans, or auditing. In this study, we use point cloud data generated by 3D laser scanning. The research elaborates on the process of segregating and segmenting floor slabs from point clouds and the developed algorithms categorize point cloud subsets based on different height parameters (z -coordinates). Once slabs are identified, a function is applied to create envelopes for each slab level, accommodating any convex or concave shape. The resulting geometry, along with relevant auxiliary data, is exported in the Industry Foundation Classes (IFC) format, a standard for BIM data exchange. The exported entities can then be further processed using prevalent software such as Revit or ArchiCAD.

KEYWORDS: BIM, pointcloud, automatization, IFC.

1. INTRODUCTION

The conversion of point cloud data into 3D Building Information Model (BIM) has been predominantly accomplished through manual methods, which have served as a fundamental technique in the industry for the last decades. These manual methods involve precise tracing of the outlines of objects and structures within the point cloud data to create a comprehensive 3D model. While this process allows for greater control over individual elements and ensures the overall integrity of the model, it is time-consuming. Moreover, manual methods are often constrained by the expertise of the user, the limitations of the software, and the scale and intricacy of the scanned point cloud.

In recent years there has been significant progress in automated methods of transforming point cloud data into 3D models. These automated techniques use sophisticated algorithms and computer software to process data from the point cloud, greatly reducing the need for human intervention in acquiring data for a BIM model. By minimizing manual intervention, automated methods offer higher processing speeds. Nonetheless, they can also introduce a greater number of errors compared to traditional manual modelling techniques. Commercial solutions, such as Pointfuse, Faramoon, Aurivus [1–3], have emerged in the market, providing semi-automatic conversion capabilities for transforming point cloud data into accurate 3D models. Also, there was published many solutions which integrate state-of-the-art algorithms such as RANSAC [4–7].

In this work, we describe a methodology that utilizes all the past developments in the area and enables the extraction of 3D entities along with auxiliary data. The flowchart of this procedure is provided in Figure 1 and described in the following sections.

1.1. BUILDING INFORMATION MODELING

Building Information Modeling (BIM) is a process that has a major impact on how construction projects are planned, designed, constructed, managed, or what happens to them after their lifetime. BIM integrates various aspects of a construction project into a comprehensive 3D information model, including architectural, structural, and MEP (mechanical, electrical, and plumbing) systems.

The 3D model provides information that facilitates cooperation between construction participants, the investor, and building management throughout the project's life cycle. BIM enables accurate visualization, analysis, and simulation of building performance, leading to better decision-making, reduced errors, and increased efficiency. With BIM, all professions can access real-time information, coordinate designs, reduce collisions, generate detailed documentation, and simulate the construction sequence. Suppose there is no BIM model available at the end of the life cycle of a building. In that case, it can pose challenges and limitations for effective planning and decision-making during the deconstruction, demolition, or adaptive reuse process. For these reasons, it is good to create at least a partial BIM model containing as-built constructions and their materials. Conventional methods of creating 3D models from as-built documentation tend to be inaccurate, which is why digital scan technologies have begun to be used in recent decades.

1.2. POINT CLOUDS

Point clouds are large data sets that describe an object or space in a coordinate system using individual points. These points usually represent the surfaces of scanned objects and are described by coordinates

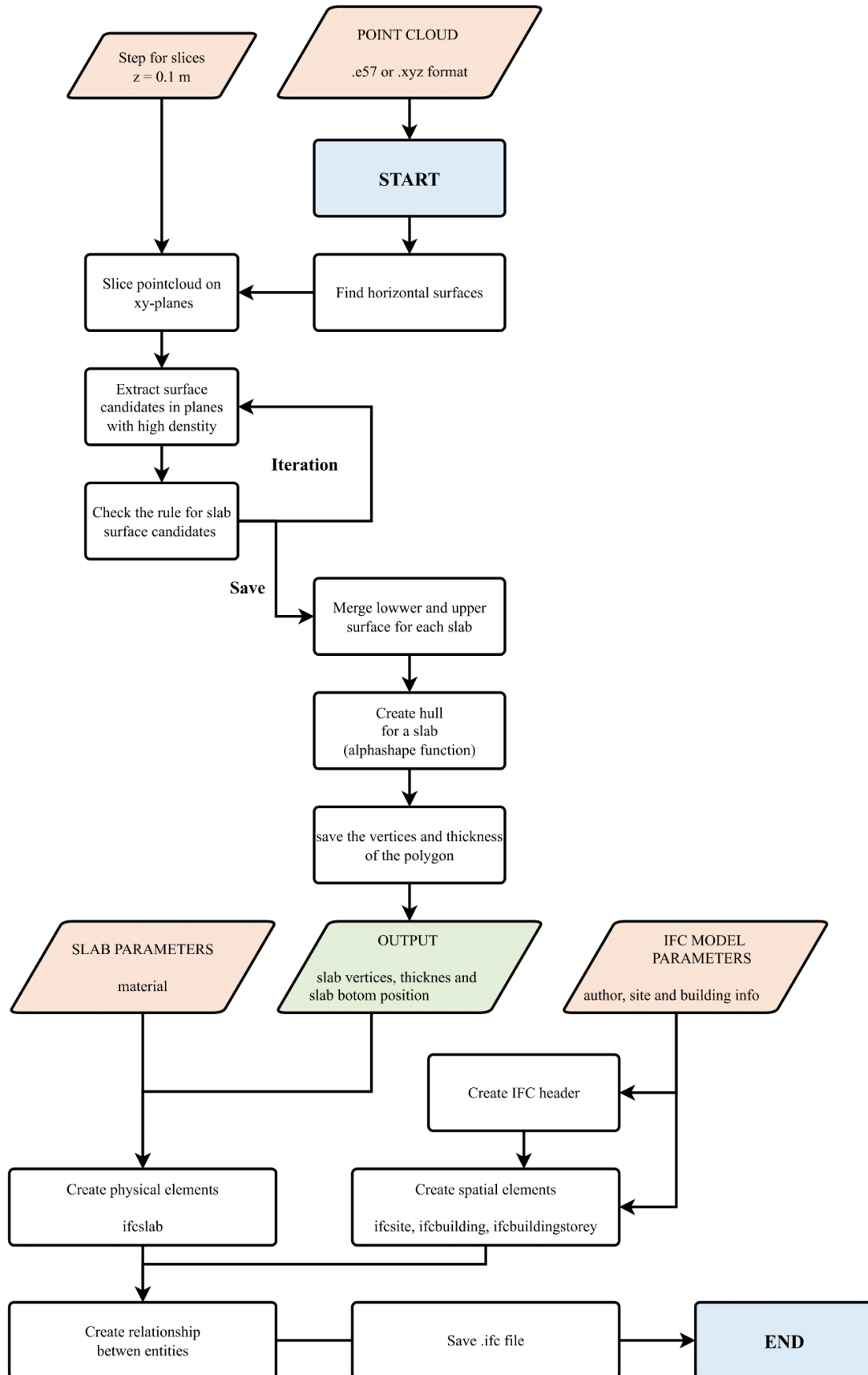


FIGURE 1. Flow chart diagram of the Python script used for extraction of floor elements from point clouds and their formatting into the IFC format.

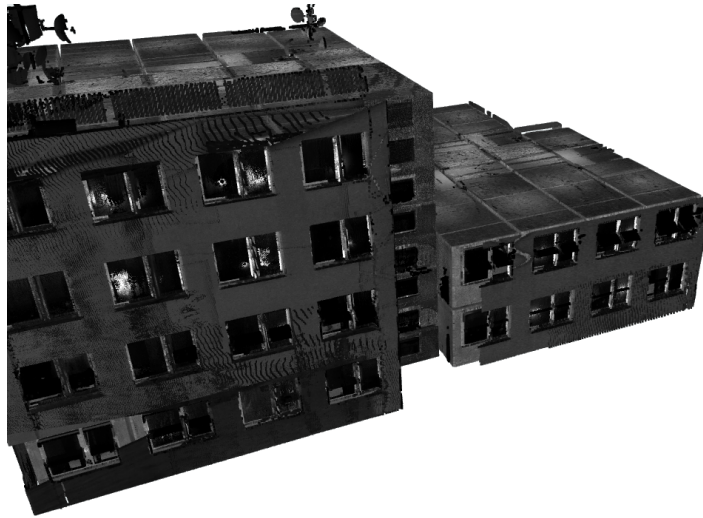


FIGURE 2. Laser-scanned data (point cloud) of a building that was used for testing of the presented algorithms.

(X,Y,Z), RGB values or brightness intensities. Figure 2 shows an example of a common point cloud containing a building. The essential parameter of each point cloud is the density, with a higher density value, texture, and finer details can be distinguished on the scanned surface. But this parameter also negatively enables the speed of the scan itself, the requirements for the computing power of the device on which the point cloud will be processed, and the resulting large file.

The most common way to obtain the point cloud is LiDAR (Light detection and ranging) technology. It works on the principle of the spatial polar method, which evaluates the position of individual points based on elevation angles and distances. The second method, also commonly used in surveying, is photogrammetry, exploiting images taken from different angles and positions [8, 9].

1.3. IFC

IFC was developed by the International Alliance for Interoperability (IAI), now known as buildingSMART International, with the aim of improving collaboration and communication among different software applications used throughout the life cycle of a building or infrastructure project.

IFC defines a common data schema and a standardized set of object classes, properties, and relationships to represent various aspects of a building project, such as building elements, spaces, materials, quantities, schedules, and more. The data model is based on a semantic representation, meaning that it captures not only geometric information but also the meaning and behaviour of the objects and their relationships.

2. ALGORITHMS

The algorithms for creating and placing slabs within a building can be divided into several parts. In the first step, the point cloud is divided into strips, which are planes parallel to the $x-y$ axes, and those strips with

a point density on the histogram higher than a certain percentage (set to 50% in our study) of the strip with the highest number of points are extracted. Figure 3 shows a section of the point cloud and a histogram on which individual horizontal surfaces are visible in places with maximum histogram values. In these strips, the median z -coordinate is taken based on the index and subsequently labelled as the lower or upper surface. Then, neighbouring surfaces formed by points are unified, creating the top and bottom surfaces of the slab.

The final step involves calling the function *create_hull_alphashape*. The alphashape function for a hull creation takes a set of 2D points as input and performs a Delaunay triangulation. It then removes edges longer than a specified alpha value, resulting in a non-convex polygon. The remaining edges form the boundaries of the hull polygon, and the function returns the set of vertices and edges that define the polygon [10]. An example of the Delaunay triangulation and the Alpha shape function with $\alpha = 5$ can be seen in Figure 4.

3. IFC FILE GENERATION

The IFC files presented in this study were generated according to the *IFC4_ADD2_TC1 structure* [11]. The library for Python, *Ifcopenshell 0.7.0*, was used to generate an *output.ifc* file [12]. The structure of an IFC file can be divided into two main parts. The first, which is called a header, contains basic information such as name, author, view definition, implementation level, and file schema. The example of the file header section in STEP (Standard for the Exchange of Product model data) format can be seen in Figure 5. The second part of the file is data section it is the main part of the IFC file and contains the actual data in a structured format. It consists of the IFC entities representing building elements, relationships, and properties.

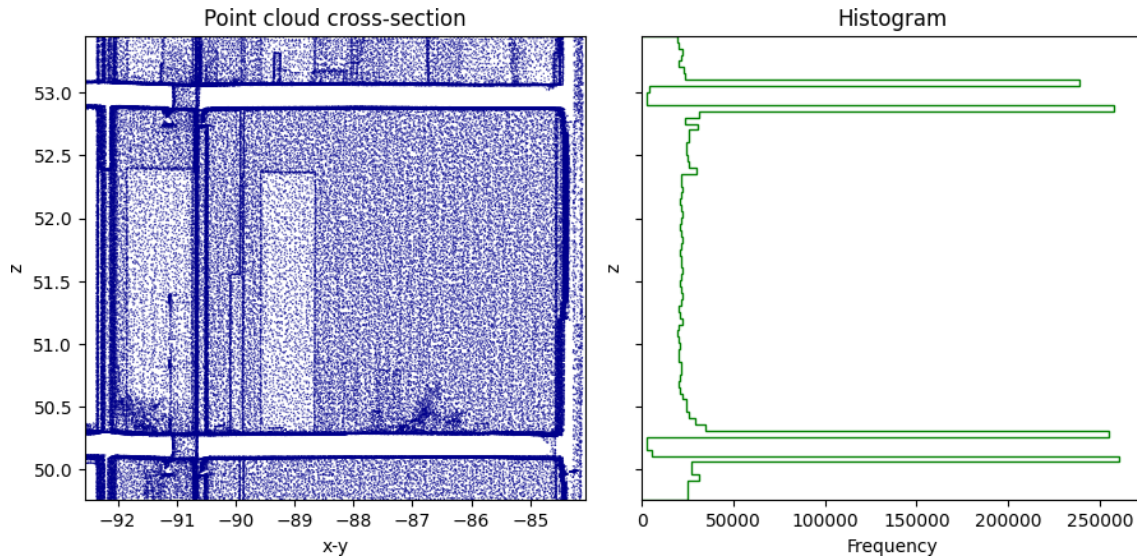


FIGURE 3. A z -coordinate histogram of point cloud data to detect slab surface candidates.

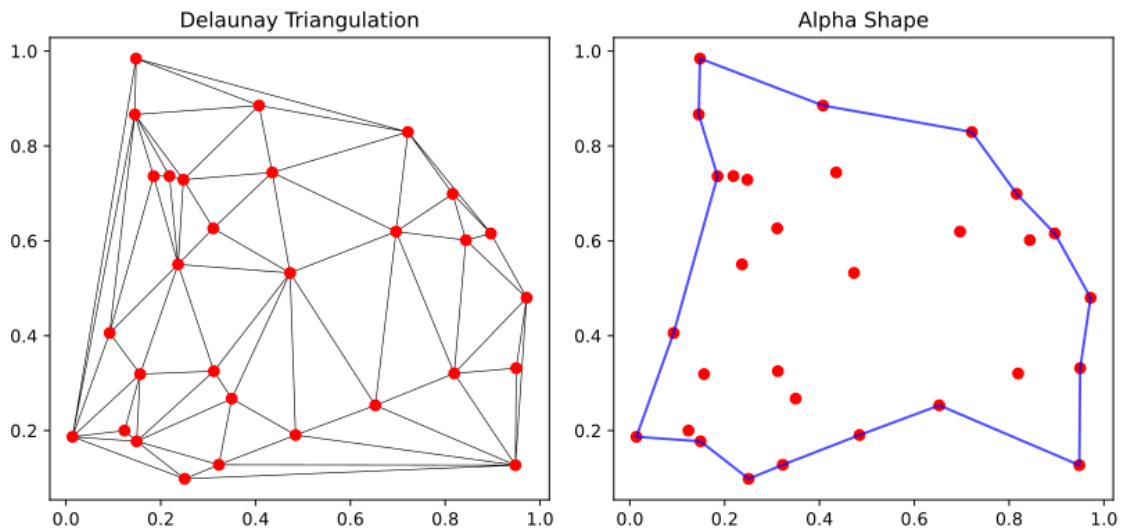


FIGURE 4. Alpha shape of a set of 2D points from the Delaunay triangulation; $\alpha = 5$.

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('ViewDefinition [DesignTransferView_V1.0]'),2;1);
FILE_NAME('output-2.ifc','2023-07-03T13:32:25.969496',
('Slavek Zbirovsky'),('CTU in Prague'),'IfcOpenShell v0.7.0-476ab506d',
'Cloud2BIM','None');
FILE_SCHEMA(('IFC4'));
ENDSEC;
```

FIGURE 5. Example of the IFC STEP file header section structure.

In addition to the slab geometry, the data part also describes the structure of the project. An essential part of every ifc file is the *ifcproject*. This instance represents the main project entity. It is a fundamental concept within the IFC schema that serves as a container for various building-related information and acts as a starting point for organizing and representing the entire building or construction project. The tree structure *ifcproject* > *ifcsite* > *ifcbuilding* > *ifcstorey* is created in the file. This structure makes it possible to place and assign individual elements to

different buildings and floors. The generated floor structures can be seen in Figure 6.

4. SLAB IFC GEOMETRY

By combining the profile definition and the extrusion parameters, the *IfcExtrudedAreaSolid* entity creates a 3D solid geometry that represents the slab. The profile shape which is described by *IfcArbitraryClosedProfileDef* entity is extruded along the specified direction to form the solid shape. The resulting solid represents the volume of the slab in the specified dimensions and position. The main IFC entities for the slab are provided in Figure 7.

5. CONCLUSION

In this study, an algorithm was developed to automate the conversion of point cloud data into a 3D BIM model, with a specific focus on slabs. The code was implemented in Python and at the moment it

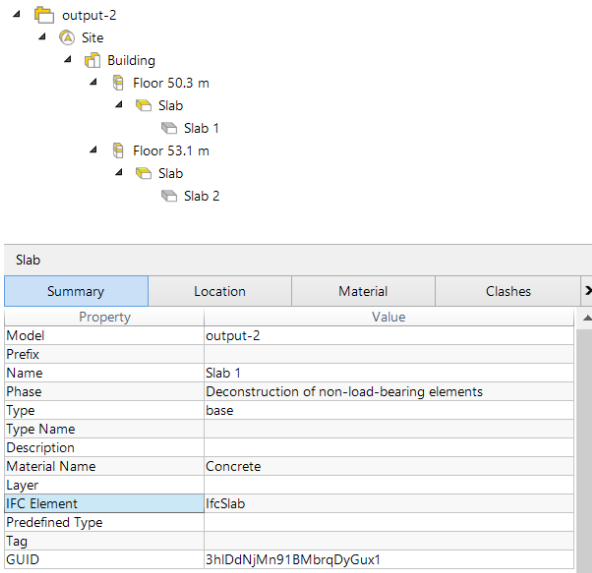


FIGURE 6. IFC tree structure with assigned slabs.

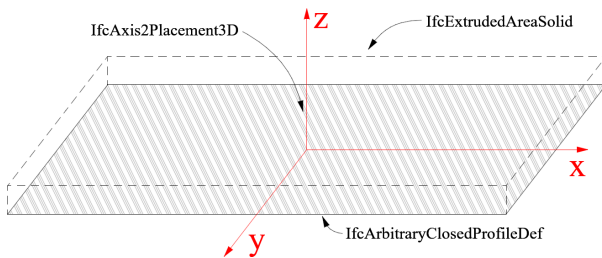


FIGURE 7. IFC entities used to create the slab geometry.

is capable of autonomously assessing individual floor levels in a point cloud and identifying floor slabs. Subsequently, the information about these slabs is written into an IFC structure, enabling compatibility with commercial software such as ArchiCAD, Revit, and other user-friendly software tools. This algorithm significantly expedites the process of working with point cloud data during the creation of a 3D BIM model for existing buildings.

This research showcases the successful development and implementation of a Python-based algorithm that automates the conversion of point cloud data into 3D BIM models, with a particular emphasis on slabs. The seamless integration of this algorithm with commercial BIM software makes it a valuable asset for streamlining the modelling process of existing structures. The significance of this advancement lies in its potential to save time, reduce manual effort, and enhance the overall accuracy of 3D BIM models, ultimately contributing to the advancement of the industry.

LIST OF SYMBOLS

BIM	Building information modeling
LiDAR	Light detection and ranging
IFC	Industry foundation classes
IAI	International Alliance for Interoperability
STEP	Standard for the Exchange of Product model data

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