Online Modelling and Prefab Layout definition for building Renovation

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Abstract

This paper introduces a powerful semi-automated tool that efficiently creates detailed 3D building models and layouts of prefabricated modules with solar panels from building images and Open Street Map floor plans. The tool permits the generation of the existing building model and the layout of the prefabricated panels in an average of 25 minutes, depending on the complexity of the building geometry. The shape of the building and the number of solar panels that can fit on the building envelope are determined using the generated 3D models and layouts. With the use of prefabricated modules and solar panels, building upgrades can be made more affordable and energy-efficient.

Keywords –

Building model, renovation, prefabrication, semi-automated

1 Introduction

In building renovation, the use of prefabricated modules for energy saving and generation is often less competitive compared to manual procedures because of the need for more detailed and thorough planning. Among other aspects, building owners, promoters, or engineers should have a comprehensive understanding of the building's capabilities for generating solar energy, the costs of investment, and the need for insulation in the early stages of the project. To achieve this, it is necessary to have a geo-located 3D model of the building that can accurately depict the building's shape and structure and the ability to fit the prefabricated modules and solar panels on top of the building. This is where the layout of the prefabricated walls and solar panels comes into play. A proper layout can give a clear idea of how many solar panels can fit on the building envelope, how much insulation is needed, and how much investment is required.

This paper explains the latest updates on a tool that allows for semi-automated online building modelling and the layout of prefabricated modules with solar panels using a Python plugin for FreeCAD [1]. This tool generates a detailed 3D building model and layout of the prefabricated modules by using building images and Open Street Map floor plans [2]. In other words, the tool generates a building model (an .ifc file) without the need for on-site measurements. Moreover, the tool generates the layout of the prefabricated modules with solar panels. With this input, in the next step (that the authors haven't developed), it is possible to estimate costs and energy savings for building upgrades with prefabricated modules and solar panels This tool is an effort to continue to explore and improve the efficiency and cost-effectiveness of building renovation within the ENSNARE project [3].

2 Research Gaps

Economic feasibility [4]-[7] is an important factor for the efficient marketability of robotics and automated solutions in construction. According to the authors, there is a need for a faster and more detailed Building Modeling during the first stages of the project. An estimation is needed so the different stakeholders (building owner, engineers, contractors…) can decide if the project is feasible technically and economically before any relevant investment (material or services) is made. For that purpose, a building model is needed in the first stages. But it is necessary to avoid an on-site measurement of the building in order to diminish recurrent (travel) costs. For this reason, an online Building Modelling tool is necessary. Moreover, the tool must permit the automated layout definition of the prefabricated insulated modules that include the solar panels.

Previous research shows that the semi-automated solar panel grid generation was defined [8]-[9]. However, in these experiences a regular grid for roofs and with no insulation is generated. In the ENSNARE project, the idea is to cover facades (with windows, balconies…),

with waterproof and air-tight prefabricated modules that include solar panels which is more complex than the aforementioned solution.

In previous stages of the ENSNARE project [10], the tool was able to generate a Level of Detail (LOD) 3 model. The updated tool can generate models that include a wide range of features such as windows, doors, balconies, and roofs, all with a LOD 4 [11] and generate the layout of the new added façade.

By using the tool described in this paper, building owners, promoters, and engineers can make informed decisions about the installation of prefabricated modules with solar panels and make sure that the renovation project is economically viable and energy efficient.

3 Approach and Results

The tool is based on a Python plugin for FreeCAD that allows users to generate detailed 3D BIM/IFC building models quickly and easily from images of the building. Utilizing pyside2 GUI's and automating the information workflow for all phases of building renovation (data acquisition, generation of the layout, CAM generation for prefabricating the modules, and on-site marking of the connectors), this plugin streamlines the data acquisition process and reduces associated costs and time by up to 90% because it avoids the preliminary visit on-site.

The development process for the plugin involves the following steps. The Python plugin for FreeCAD was developed using a range of tools and technologies like: OpenCV, Python, Pyside2, PyTorch, ArcGIS, scikit-learn (sklearn), Timm, fastai, NumPy, SciPy [12]–[21].

These are some of the key libraries and technologies used in the development of the Python plugin for FreeCAD. Other libraries and tools were also used to provide a range of functionality and facilitate the data acquisition and processing process for building renovations.

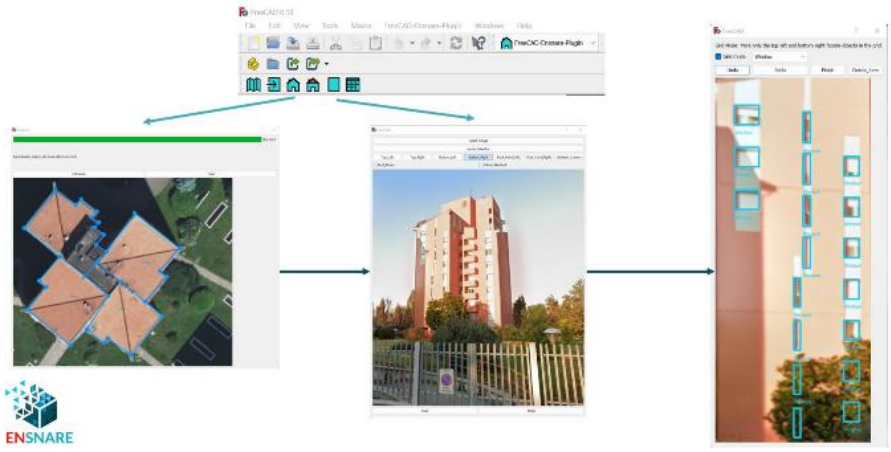

Figure 1. Corner and window detection by the plugin in the demo building in Milan (ENSNARE project)

Our plugin has a range of features as seen in Figure 1 that allow users to gather and analyze data for building renovations. These features include:

1. Facade selections: With this feature, users can upload images of a building and can either manually select its corners from the image or let the plugin do it for them. The image is then subjected to a perspective transformation by the plugin to obtain the right aspect ratio for additional processing, which includes the automatic detection of facade objects like windows, doors, and balconies. It's important to remember that automatic corner detection may not always be accurate.
2. BuildingEdit: With the help of the aerial view of the building, users can modify the OSM data. This is helpful if the OSM data is not always accurate or correct.
3. Floors: This feature enables users to add floor slabs to the structure, giving them a more accurate and detailed view of the building. The plugin now can add roofs and façade elements like doors and balconies. Additionally, it can detect objects and approximate objects.

Overall, these features provide a range of functionality for gathering and analyzing data for building renovations, allowing users to create detailed and accurate 3D BIM/IFC models of the building.

The following features can now be added on the plugin:

- Pitched roofs

- Windows
- Doors, Balconies (both inside and outside)
- Floors

Given a FreeCAD building model, the plugin extracts relevant information (position, orientation of walls, roofs, windows, doors, and balconies) as JSON files. Then, it projects each facade in 2 dimensions. This is illustrated in Figure 2.

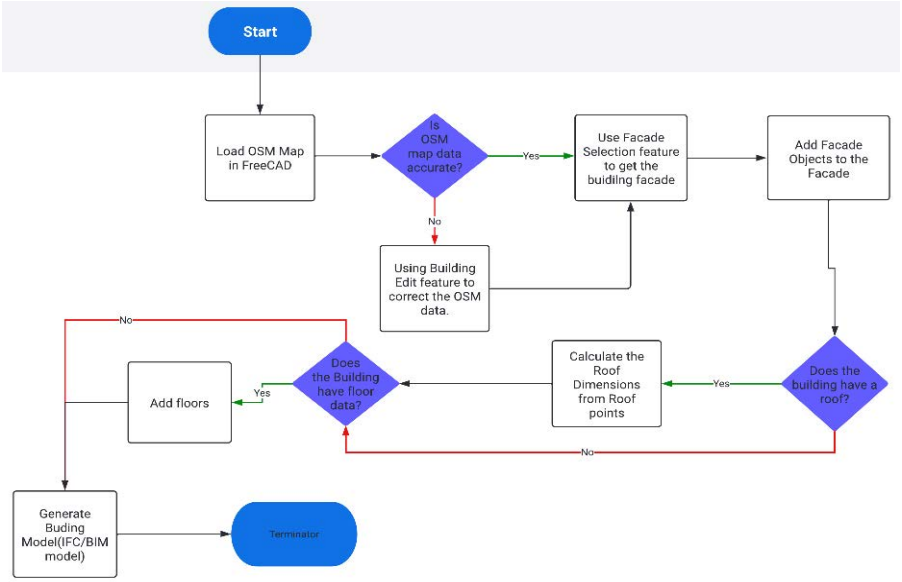

Figure 2. Process Map of the plugin application

After applying the algorithm, the optimum distribution of solar panels in each facade is generated as shown in the figure below in Figure 3. The 2D distribution of solar panels is then projected back to 3 dimensions and placed on the existing building models.

Figure 3. Left, Demo Building model in Milan. Right, building in Milan with added prefabricated façade with solar panels (ENSNARE project)

It is important to note that the Python plugin for FreeCAD has some limitations and issues that may affect its functionality and accuracy. These include errors or inconsistencies in OpenStreetMap (OSM) data which can affect the accuracy of the 3D BIM/IFC model generated by the plugin, automatic corner detection and facade object detection may not be perfect due to limitations in computational resources or data, and the current user interface is not very user-friendly. It is crucial to be aware of these limitations when using the plugin for building renovations.

4 Conclusion

The Python plugin for FreeCAD is a tool for gathering and analyzing data for building renovations, providing a cost-effective and efficient way to create detailed 3D BIM/IFC models of buildings. The plugin has several key features, including the ability to load OSM map data, perform facade selections and automatic detection of facade objects, make corrections to the OSM data using BuildingEdit, and add floor slabs to the building model. The average time for defining the building model and the layout is about 25 minutes, which reduces considerably the amount of time in the first stages, especially if travel time to the site is considered. There are a few known limitations and issues with the current version of the plugin, including the potential for incorrect OSM data, tricky roof implementations, difficult angles for perspective transformation, and

limitations in the accuracy of automatic corner detection and facade object detection.

Several areas for further research and discussion could enhance the functionality and accuracy of the Python plugin for FreeCAD:

1. Development of wall extrusions and adding facade objects to them: One potential area for further research is the development of algorithms or techniques for creating wall extrusions and accurately placing facade objects on them. This could improve the realism and detail of the 3D BIM/IFC models generated by the plugin.
2. Web app for better user experience: Another possibility is the development of a web app version of the plugin, which could provide a more convenient and user-friendly interface for gathering and analyzing data for building renovations.
3. Improved perspective transformation algorithms: Improving the algorithms used for perspective transformation could enhance the accuracy of the 3D BIM/IFC models generated by the plugin, especially in cases where the client takes pictures of the building at difficult angles.
4. Improved building modelling accuracy: Further research and development of techniques for improving the accuracy of the 3D BIM/IFC models generated by the plugin could make it an even more valuable tool for building renovations and related projects.

Overall, these are just a few examples of the potential directions for further research and discussion that could enhance the capabilities of the Python plugin for FreeCAD.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 958445.

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