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Conditional Modeling of vast Urban Buildings via a Generative Deep Learning Approach

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Background

The construction of Digital Twin City (DTC) is critical to the municipal management of urban planning, disaster prevention, and carbon-neutral development. As a significant component of urban scenes, researchers have been seeking an effective modeling approach with satisfactory performance to build up the architecture of a digital city. However, most existing methodologies based on reconstructing three-dimensional (3D) models suffer from the limitation of data retrieval. Under these circumstances, This research proposed a novel perspective to solve the data difficulties by involving the generative approach to synthesize building instances from parameters and conditions.

Objectives

- Develop a generative framework for synthesizing customized building instances based on user-defined parameters and geographic conditions
- Realize the modeling of LoD2 real-world buildings with the provided information about heights and geometries of roofs

Data sources

- 3D building dataset from the Project PLATEAU held and managed by the Ministry of Land, Infrastructure, Transportation, and Tourism (MLIT), Japan.
- 2D Map dataset from Zenrin, Inc., which provides the geographic information of nationwide buildings in Japan as vector footprint data

Methodology

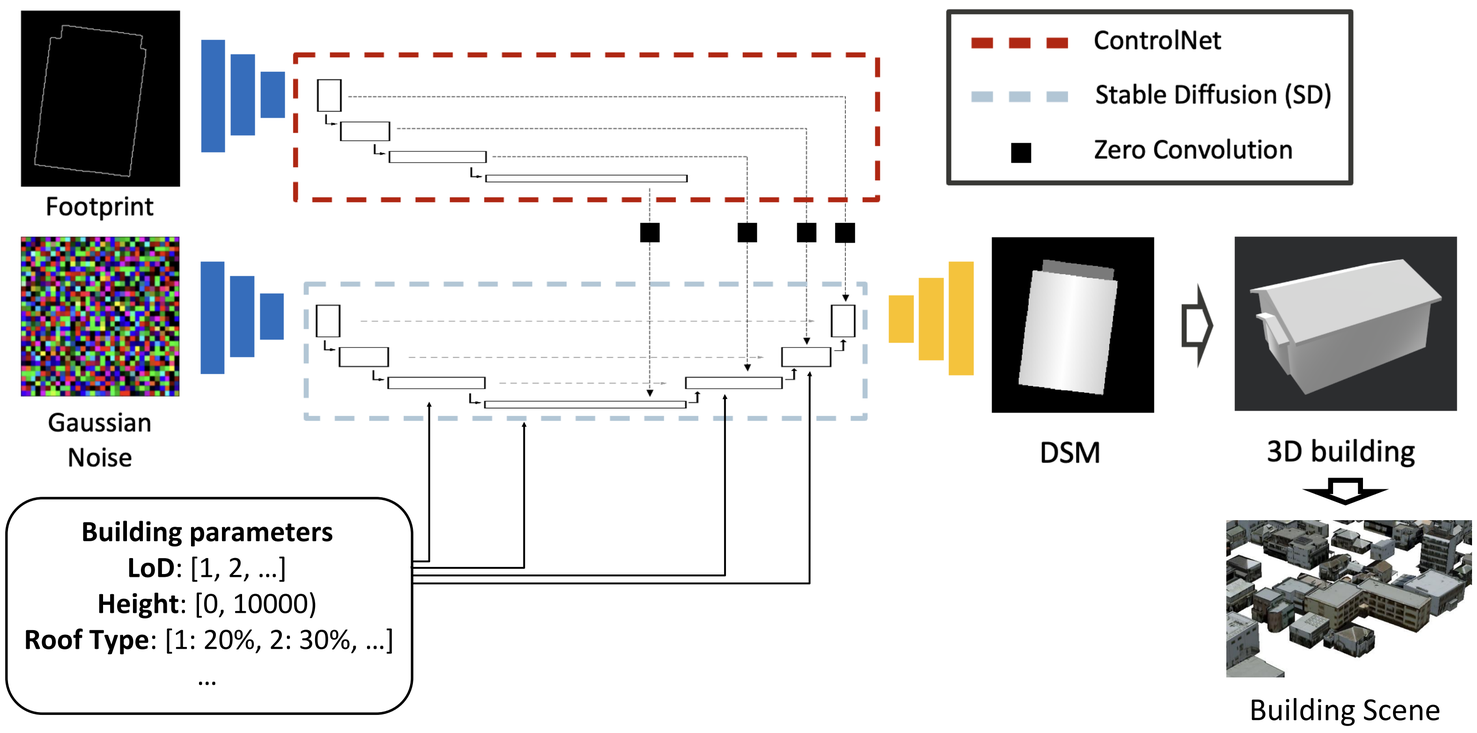

Figure 1: Overall framework of the proposed methodology for building modeling.

In the workflow, the provided footprint of buildings would be used as input hints, which guides the synthesis of building instances in the ControlNet model. Three available parameters for conditionally regularizing the generation are Level of Detail (LoD), height, and ratio of roof types (5 in total). After generating the Digital Surface Model (DSM) for buildings, we implemented a novel reconstruction framework to rebuild the 3D building models and align them into the corresponding locations.

Results

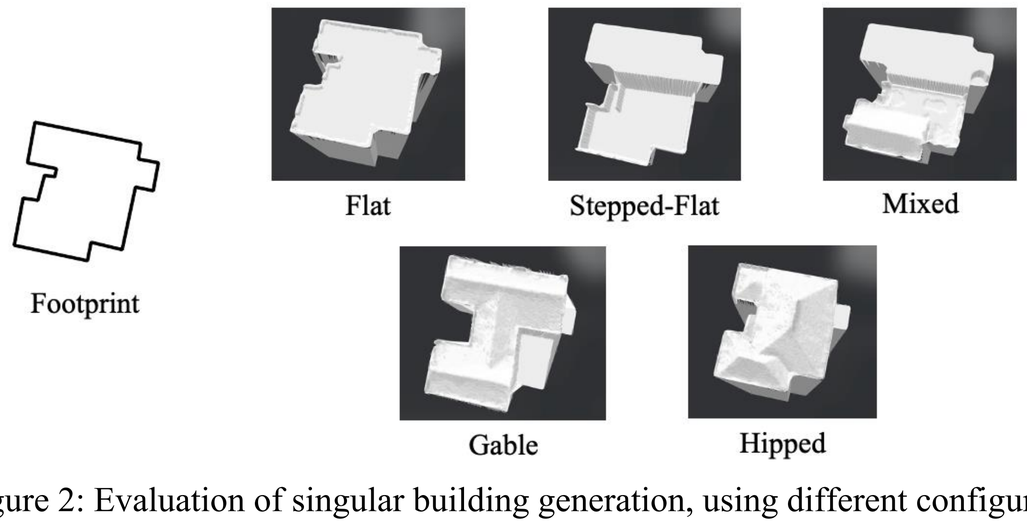

Figure 2: Evaluation of singular building generation, using different configurations of roof type parameters.

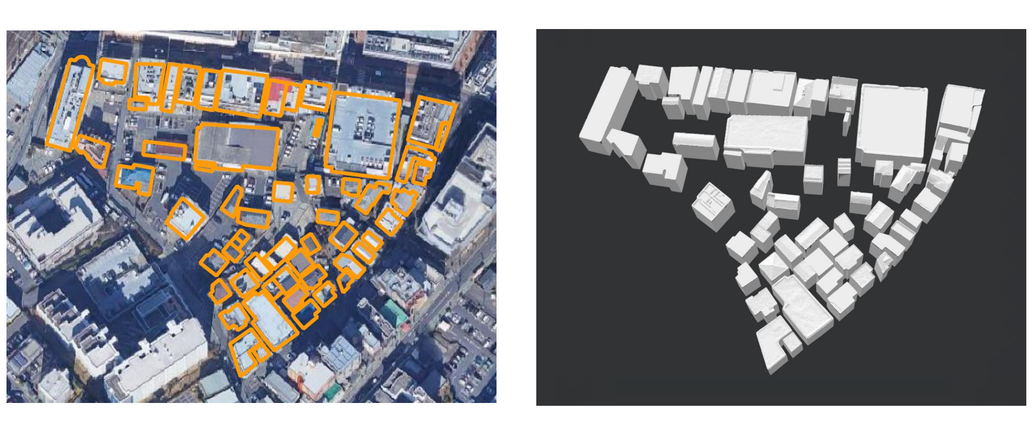

Figure 3: Test area (Left) and the scene-based generation of LoD2 building instances (Right), indicating the combination of various roof types and types.

Conclusion

We proposed a novel generative framework for modeling wide-range building instances based on the ControlNet model for image synthesis, which reveals the potential of reconstructing real-world buildings without specific data.