AI, DX, Smart City

Development of an automated synthetic dataset generation method for realistic fictional cities

Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering
Associate Professor Tomohiro Fukuda
Researchmap https://researchmap.jp/tomohirofukuda?lang=en

Abstract

As AI performance and expected accuracy improve, the scale of training datasets must also increase. However, as datasets grow, so do the costs associated with creating them, leading to potential shortages of data available for training. Our previous research focused on generating synthetic datasets by combining virtual objects or 3D digital twin models with images (Zhang et al., 2022). Although effective, this approach had limitations, such as relying on pre-existing real urban data and restrictions on data variety. To address these challenges, we developed an automated synthetic data generation method for building instance detection. This approach integrates procedural modeling, which creates realistic but fictional 3D urban models, with deep learning-based image transformation techniques capable of producing lifelike images.

Background & Results

Figure 1 provides an overview of the process, where large volumes of training data are automatically generated through procedural modeling and image transformation techniques. By entering parameters for a desired city, a base 3D urban model is generated, which then serves as the foundation for extensive training data. The ultimate objective is to train a deep learning model that can detect objects in real-world images.

For a more detailed explanation, in Step 1, parameters defining city characteristics are entered to automatically generate a 3D urban model. In Step 2, this model, along with settings like image size, is input into a game engine to produce annotation data and segmentation image pairs for generating landscape images in Step 3. In Step 3, image transformation techniques convert these segmentation images into realistic landscape images. Finally, in Step 4, the annotation data is linked to the generated landscape images.

Figure 2 shows results using a prototype system developed with our proposed framework. The second row of Figure 2 illustrates detection results in real-world images by an instance segmentation model trained on a dataset generated using this method. This approach achieved comparable or even superior detection performance relative to models trained on manually created datasets of real-world images, as seen in the third row of Figure 2.

Significance of the research and Future perspective

The method presented in this paper holds significant potential to reduce dataset preparation costs and shows that synthetic data generated from realistic but fictional urban models can effectively support tasks involving complex structures, such as urban landscapes. We believe that this approach is applicable not only to urban landscape analysis but also to other fields where AI applications are anticipated.

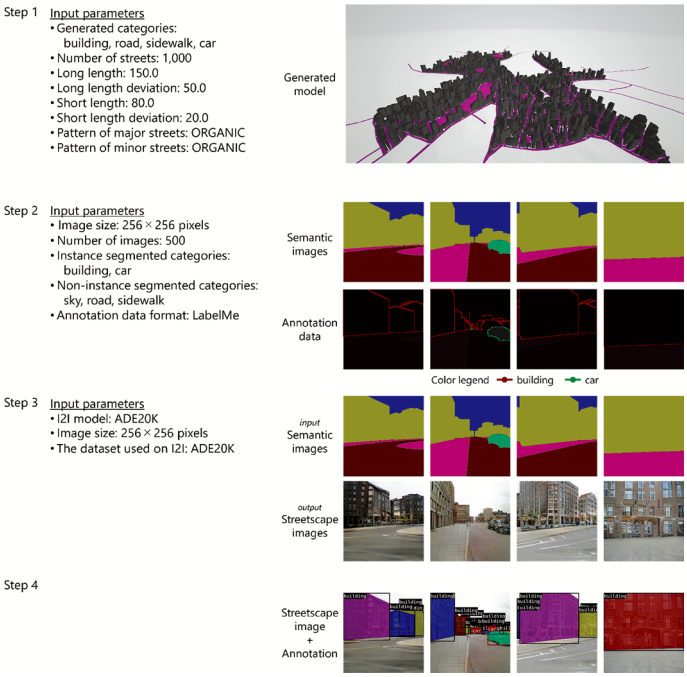

Figure 1 Overview of the proposed method.

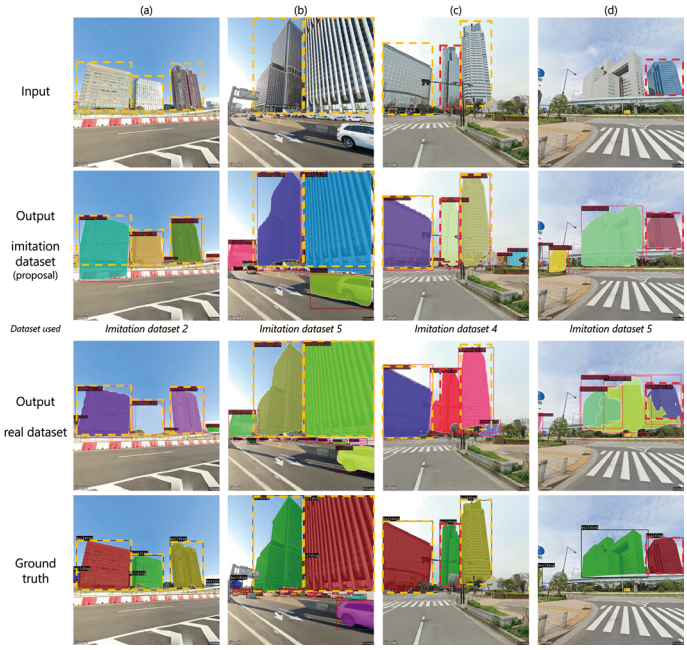

Figure 2 Comparison of the detection accuracy of models trained on datasets generated by the proposed method and models trained on real images

Patent	
Treatise	Kikuchi, Takuya; Fukuda, Tomohiro; Yabuki, Nobuyoshi. Development of a synthetic dataset generation method for deep learning of real urban landscapes using a 3D model of a non-existing realistic city. Advanced Engineering Informatics. 2023, 58, 102154. doi:10.1016/j.aei.2023.102154 Zhang, Jiaxin; Fukuda, Tomohiro; Yabuki, Nobuyoshi. Automatic generation of synthetic datasets from a city digital twin for use in the instance segmentation of building facades. Journal of Computational Design and Engineering. 2022, 9(5), 1737–1755. doi:10.1093/jcde/qwac086
URL	https://resou.osaka-u.ac.jp/en/research/2023/20230921_3 https://y-f-lab.jp/index_Eng.html
Keyword	AI, deep learning, synthetic data, built environment, digital asset, systemization