13th Dec 2021

To the Editor-in-Chief, *Computers, Environment and Urban Systems*

Dear Professor T. H. Grubesic,

We are delighted to submit our manuscript entitled “***Simulation of large-scale urban land-use using U-Net***” for consideration for publication as a **Research Article** in *Computers, Environment and Urban Systems*. The primary objective is to simulate urban dynamics with deep learning (U-Net model) technology. We described and assessed the pattern-identification process of the U-Net algorithm and discussed the advantages and limitations of applying advanced deep learning in the simulation of urban development.

Previous Cellular Automata (CA) models are built on transition suitability, neighborhood status, constraint variables, and stochastic factors (Roodposhti, Hewitt, & Bryan, 2020; Wang, Guo, Zhang, & Zeng, 2021). Such models are flexible given the large array of parameter settings. However, 1) the difficulty in calibrating the many parameter choices (Feng & Tong, 2020) and 2) the oversimplifying of the spatial complexity to the driving factors (Gao et al., 2020; Newland, Zecchin, Maier, Newman, & van Delden, 2018) challenges their ability to mimic complex urban dynamics. More recent studies applied machine learning algorithms, Convolutional Neuron Network (CNN), or special simulation techniques (e.g., geographical zoning, temporal profile incorporation) to retrieve transition rules automatically or integrate complex spatial features to simulate urban development. But those studies did not take full advantage of the pattern-recognition ability (e.g., reconstruct a human face from linear, circular, or triangular (Krizhevsky, Sutskever, & Hinton, 2017)) of Deep Learning technology.

We applied a complete deep learning model (U-Net) to automatically simulate the large-scale urban dynamics. U-Net is a unique deep learning structure that first abstracts low-level features (lines, circles, or triangles, etc.) into high-level features (human faces, fruits, or animals), and then reconstruct the high-level features to precise shapes/patterns using the learned low-level features (Ronneberger, Fischer, & Brox, 2015). U-Net has been deployed in multiple geographical applications (Ji, Wei, & Lu, 2019; Nezla, Mithun Haridas, & Supriya, 2021; Singh et al., 2021), but have seldom been used in urban dynamic simulation.

The simulation urban maps show that U-Net learned the gravitational effects and linear development of urban dynamics. The landscape metrics reveal that the shapes of the urban patch in the simulation map are similar to the reference map. The accuracy metrics indicate that the simulation map has a close performance to previous CA models that went through a length calibration process. U-Net succeeded in identifying urban dynamic patterns automatically, with a limitation of difficult to explain the transition rules.

This research has not been published, accepted for publication, or under consideration for publication in another journal or book. All authors have agreed to the submitted version of the manuscript, and all persons entitled to authorship have been so named.



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