Virtual city generation

April 27, 2017

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1 Introduction

1.1 Review of previous work

Weber et al. (2009) present a detailed procedural generation model that evolves in time. In their framework, a city is defined as a planar graph $G(V, E)$ with set V nodes and E edges. Induced cycles on the graph form blocks (faces in G), which are also subdivided into lots. The following hierarchies and attributes are defined:

$node[i].pos \in R^2$	location in 2D
$node[i].hierarchy \in \{major, minor\}$	
$node[i].growth \in \{unfinished, finished\}$	
$street[j].nodesin\mathbb{N}^2$	indices
$street[j].status \in \{planned, built\}$	status flag
$street[j].hierarchy \in \{major, minor\}$	classification
$street[j].width$	meters
$lot[k].lut$	land use type
$lot[k].luv$	suitability of lot

Further, quarters are the faces in the graph induced by major street cycles.

In their system pipeline, the following are the parameters listed as the most important user input:

$heightmap$	terrain as floating point image
$citycenter[i]$	one or multiple city centers $\in \mathbb{R}^2$
$growthcenter[i]$	one or more grwoth centers $\in \mathbb{R}^2$
$avgprice[t]$	average annual land price
$streetpattern[i]$	patterns defining street expansion
$landusetype_t$	set T of land use typologies
$goal_t$	land use percentages for all $t \in T$
$setback_t$	construction setback values
$shapegrammar_t$	building generation rules

The pipeline sequence is given as follows:

- topography input (height map/water map/forest map)

- initial urban layout configuration (single street up to entire city)
- land-use typology definitions
- other user input data for simulation control

Weber et al. (2009) describe their street expansion methodolgy thus:

- Of existing nodes, sample which to expand based on the probabilistic function
$$e^{-f||node[i].pos-growthcenter[j]||^2} \tag{1.1}$$
- Ratio of major nodes with valence 2 and those with valence 4 must remain within user-specified threshold (which is a factor of street pattern).
- If a new quarter is produced, then the aboves steps are repeated within tha tquarter until expansion is finished (measured by a valence of 4 or greater for the node)
- Edge creation is constrained to three directions (straight, left or right) and parametrized by deviation ϕ and length l. The value of ϕ

2 Network synthesis approach

We propose using the Latent Space modeling approach for generating our representative street networks. The Latent Space Model was introduced by Hoff et al. (2002) for modeling social networks. The formulation was further extended by Zhou et al., 2015 to develop urban network models. Essentially, given a relationship specifications between actors $y_{i,j}$ in a network at positions z_i and z_j, then the probability of pairwise connections is

$$P(Y, Z, \theta) = \prod_{i \neq j} P(y_{i,}|z_i, z_j, x_{i,j}, \theta) \tag{2.1}$$

where $x_{i,j}$ are possible covariates for pairing tendencies. This probability is parametrized by a logit model, which, for now, ignoring any covariates, is given by

$$P(y_{i,j}|z_i, z_j, \theta) = \frac{1}{1 + e^{\lambda D_{i,j}}} \tag{2.2}$$

where $D_{i,j}$ is the distance metric specified.

For urban street networks, the Euclidean distance (i.e. $|z_i - z_j|$) is not the only measure of interest. The accessibility of one node from the other is of overall importance and one means of capturing this is by using the shortest distance between the pair of nodes in the network.

Further, the distance or similarity matrix must be generated on a latent space using a kernel approach in order to reduce dimensionality. A readily applicable one is multi-dimensional scaling (MDS). Similar techniques, such as exploratory factor analysis or auto-encoding approaches may be applied to uncover the latent structure in the pair-wise nodal relationships. The similarity matrix in the latent space can thus be denoted $D^L_{i,j}$.

Following the approach of Zhou et al., 2015, the model can be evaluated and tuned (via the parameter λ) by comparing the following properties of the synthesized networks to the actual ones in our clusters:

- connectivity
- diameter

- path length
- triads, clustering coefficient
- degree distributions

Besides accessibility, we will also explore the encoding of other information into the latent space model.

References

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