Virtual city generation

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We propose using the Latent Space modeling approach for generating our representative street networks. The Latent Space Model was introduced by **hoff2002latent** for modeling social networks. The formulation was further extended by **zhou2015generating** 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 $D_{i,j}^L$.

Following the approach of **zhou2015generating** 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.