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A methodology for observation-based measurement of accessibility

In transport planning, accessibility is a measure that is widely used in the literature to assess how well-connected specific places in a study area are compared to others. The general structure of an accessibility measure is given for location *i* as

$$a_i = \sum_j o_j \cdot f(c_{ij})$$

with o_j as the number of opportunities at a location j, c_{ij} as a cost measure between the locations i and j and f as a weight function, which penalizes high costs. Therefore, accessibility is the higher, the more opportunities can be reached with lower costs. While several versions of this measure have been proposed in literature, no universal definition has been given so far. A common choice is to interpret c_{ij} as the travel time between two locations, to define o_j as the number of work places at a location and to use $f(c_{ij}) = exp(-\beta c_{ij})$.

The acquisition of travel costs from each location i to every other location j may be obvious for certain kinds of traffic models and travel modes (such as car travel or public transit), but can get complicated for highly dynamic services, where travel times may depend on operator choices, such as waiting for, or picking up, further customers along the way. Especially in agent-based models, which have shown to be very much suited for the simulation for e.g. autonomous taxi fleets, fine-grained observations of origin/destination pairs and their associated costs are provided, rather than aggregated data. The problems that arise are cases where no or only few observations of a pair of locations (i,j) are available. There, the underlying travel costs must be defined in a sensible way.

The proposed paper will interpret the accessibility measure as a random variable, which, itself, is dependent on a specifically distributed cost. Expectation and variance of accessibility A_i are then defined as:

$$E[A_i] = \sum_j o_j \cdot E[f(C_{ij})] \quad \text{and} \quad Var[A_i] = \sum_j o_j^2 \cdot Var[f(C_{ij})]$$

If one defines $c_{ij} \sim Exp(\lambda_{ij})$, which would be the maximum-entropy distribution given a mean, one can define a prior distribution for the model parameter. In the sense of Bayesian inference, a Gamma distribution can be chosen as the conjugate prior, through which a prior assumption (i.e. a prior cost model) can be incorporated into the formulation. It will be shown that, either by analytical approximation or simulation, the aforementioned moments can be calculated. While the expectation of A_i is then a fusion of a (possibly coarse) cost model and data points, the variance gives insight on how much the final measure is based on actual data or model assumptions.

Using this procedure, the paper will analyse a number of different prior models for travel-time-based costs with data input form the agent- and activity-based traffic simulation framework MATSim. Specifically, this will be useful for future analyses of accessibility impacts of autonomous taxis and demand responsive transport. Furthermore, hints on further developments and possible extensions of the methodology will be given.