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A stochastic model of urban structure

Abstract:

One of the great challenges of 21st-century science is to gain insights into the behaviour of complex interconnected systems. Such insights can be obtained by formal mathematical modelling of these systems. A contemporary example of major practical importance is urban structure, which is relevant to areas as diverse as public health to crime to retail. The evolution of urban structures depends on a choice mechanism, which we posit will follow a spatial interaction model, and may be described by a system of coupled stochastic differential equations. An understanding of the choice mechanism can give insights into the incentives (and disincentives) relevant for urban planning, policy and decision making.

We infer parameters in a Bayesian setting by assimilating data into the mathematical model. Based on socio-economic theory the Bayesian prior belief is defined to favour stable system configurations, which are summarised with a probability distribution derived from the stochastic differential equation model. We proceed by performing statistical inference employing stochastic computation, which poses a number of challenges due to an analytically intractable term in the prior. We demonstrate our methodology by inferring attractiveness and inconvenience parameters for the London retail system and airport passenger traffic in England.