Softly Constrained Agent-Based Models

An agent-based model (ABM) can be thought of as a computer program that implicitly defines a probability distribution $q(x)$ over all of its possible outputs x. The density $q(x)$ cannot be evaluated directly, but is represented by a set of samples $\mathbf{x} = \{x_n\}$, where each $x_n \sim q(x)$ is the output of an independent run of the ABM. We are typically after the expectation value $F := \langle f(x) \rangle$ of some interesting statistic $f(x)$, which can be estimated from the samples $\mathbf{x}$ in the usual way. To obtain the object of interest F, therefore, the ABM is run in what we define as the “forward” direction, schematically represented as $(\mathbf{x} \to F)$.

It is also possible to run the ABM “backwards” $(\mathbf{x}' \leftarrow F')$, where the object of interest is now the set of samples $\mathbf{x}' = \{x'_m\}$. In the backward direction the expectation $\langle f(x') \rangle := F'$ is *constrained* to take a given value $F' \neq F$ and now we solve for the probability distribution $p(x')$ which satisfies that soft constraint while still as close as possible to the prior $q(x)$. It turns out that the optimal solution to this problem can be approximated by a simple reweighting of the original samples $\mathbf{x}$, from which the $\mathbf{x}'$ can be obtained by standard resampling such that roughly each $x'_m \sim p(x')$.

By the same logic used in the first paragraph, the obtained $\mathbf{x}'$ then represents the probability distribution $p(x')$ of a new computer program automatically derived from the original ABM, which we call a softly constrained agent-based model (SCABM). To show that SCABMs are computationally feasible, we investigate the influence of softly constraining the global clustering coefficient on the convergence of a simple language game played on different network types.