Networks meet Geometry: The S1 model and beyond

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Hidden geometries underlying real networks appear to provide a simple and natural explanation for their structure[1]. Beyond the ability of these models to simulate the observed topologies, they enable a true cartography of real networks by mapping them to congruent metric spaces using an inverse method. In particular, the euclidean one-dimensional S1 model turns out to be an outstanding paradigm that is able to reproduce the topological properties (including scale-free degree distributions, high levels of clustering, and self-similarity[1]) observed in many real networks. Applications to real networks range from the metabolism of Escherichia coli[2], a bacteria typically found in the human gastrointestinal tract, to the Internet at the autonomous systems level. Besides coupling the topology of networks to geometry by placing the nodes in an underlying geometric space, the model assumes a newtonian-like connection probability such that nodes closer in space –that is, more similar– are more likely to interact and nodes with more connection –that is, more popular– can reach further neighbors. The S1 model has a pure geometric counterpart in terms of hyperbolic space, where the optimization of a certain trade-off between the two dimensions of popularity and similarity has been proved to capture the large-scale growth dynamics of different real networks[3].
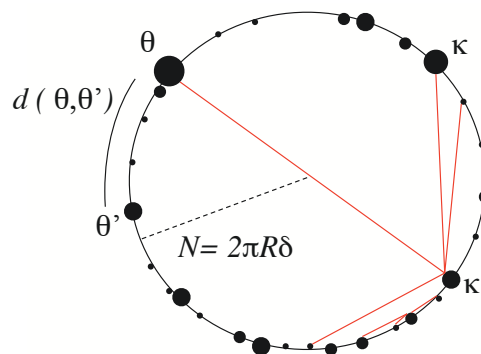

FIG. 1. A sketch of the S1 model. Nodes are randomly distributed in the circle and given expected degrees κ, symbolically represented by the sizes of the nodes. The distance between two nodes is computed as the length $d(\theta, \theta')$ of the arc separating the nodes. Due to the peculiar rescaling of distances by degrees in the model, a node can connect (red links) not only to nearby nodes but also to far apart nodes with large degrees.

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