The Percolation of Innovation

This model description reproduces the text that appears in the "INFO" tab of the NetLogo model. It incorporates small changes to the "Fire" model in the NetLogo models library. It is built using NetLogo v.6.3 (Wilensky 1999) and available at the CoMSES Network via: SITE.

WHAT IS IT?

This model simulates the emergence of innovation in a discovery space. Innovation is conceptualized as a "concatenation" of individual discoveries, where discoveries sites (which may be known or unknown) are distributed around a 2D discovery space. It shows that innovation depends critically on the density of individual discoveries, as well as their connectivity. This is an example of a common feature of complex systems: the presence of a non-linear threshold or critical parameter (i.e.: a tipping point). The model is conceptually equivalent to percolation (ex: like rainwater percolating through the ground).

A discovery site can be in one of three states: when it is black, it represents a potential (but unkonwn) discovery; when it is white, it represents a known discovery; and when it blue, it represents a (white) discovery that has become part of the innovation. One can think of the change from black to white sites as a process of R&D, where investments are (or are not) made to discover something. One can think of the change from white to blue sites as a process of inventiveness, where investments are (or are not) made to learn about and incorporate new discoveries into an existing innovation.

HOW IT WORKS

Innovation starts on the bottom edge of the discovery space, and grows to include neighboring discoveries if they exist and are "seen" by the innovation. The base (the x-axis) represents proximate and non-proximate specialization domains (like the locations within the Dewey Decimal system, or the patent classification system). The vertical dimension represents increases in performance within a given location on the x-axis (like the improvement of bike propulsion from push-based (in the 1800s), to pedal-based (in the late 1800s), to gears (in the 1900s), to batteries (in the early 2000s). An innovation spreads in either four directions (to the adjacent discovery sites of the so-called "von Neumann neighborhood") or in eight directions (to all surrounding sites within the so-called "Moore neighborhood"). These two forms of connectivity represent low and high collaborative spirits, respectively.

The model assumes that discoveries and connectivity are given exogenously at setup. That is, there is no model of the process of research and development (i.e.: of turning black sites to white). Also, there is no model of collaboration (i.e.: of turning von Newmann neighborhoods into Moore neighborhoods). Large clusters of discoveries which are not connected to the innovation arising from the base may exist, but are not known (or "seen") by the innovation.

HOW TO USE IT

Select values for the DENSITY of discoveries, and for the percentage of sites that are HIGHLY-CONNECTED. Then, click the SETUP button to set up the discovery sites (white) and the initial innovation (blue along the base).

Click the GO button to start the simulation.

The DISCOVERY-DENSITY slider controls the density of discoveries in the space. The HIGH-CONNECTIVITY slider controls the probability that a given discovery site will be connected to all eight surrounding site, rather than only four adjacent sites.

THINGS TO NOTICE

When you run the model, how large does an innovation grow? If you run it again with the same settings, is the innovation the same?? How similar is the innovatoin from run to run?

Each turtle that represents a discovery is created and then incorporated into the innovation without ever moving. If the innovation is made of turtles but no turtles are moving, what does it mean to say that the innovation moves (i.e.: spreads)? This is an example of different levels in a system: at the level of the individual turtles, there is no motion, but at the level of the turtles collectively over time, the innovation grows.

THINGS TO TRY

Set the density of discoveries to 55% and high-connectivity to 0%. At this setting, there is virtually no chance that the innovation will grow large. Set the density of trees to 70%, and keep the level of high-connectivity at 0%. At this setting, it is almost certain that the innovation will grow very large. When high-connectivity is held constant at 0%, there is a sharp transition of innovation around 59% density. This reveals the existence of a tipping point in the system, which is known as Kalmagorov's Zero-One Law: in a hypothetical infinite square lattice constructed with von Neumann neighborhoods, densities below 59.3% will never percolate (p=0), and densities above 59.3% will always percolate (p=1).

Try setting density to a value below (but near) the critical value; for example, set it to 45%. Then, vary the level of high-connectivity from 0% to 100% in increments of 25%. Increasing the level of high-connectivity also reveals a tip. That is, the innovation will tip at relatively lower values of density at higher levels of high-connectivity.

The model includes a BehaviorSpace experiment (see Tools menu) that varies DISCOVERY-DENSITY and HIGH-CONNECTIVITY from 0 to 100 in increments of 5. Try running these experiments and collecting the data as a "table." Then, plot these data using a box-and-whisker plot in your preferred statistical program. What kind of curve do you get?

EXTENDING THE MODEL

Varying the neighborhood between von Neumann and Moore connectivity is only one way to change the level of connectivity between discovery sites. For example, an even more adventurous collaborator might look farther out in the discovery space for sub-innovations. Can you develop an alternative way to vary connectivity?

In this model, density and connectivity are set at "setup" and held constant (i.e.: they are set exogenously). Can you alter the processes of discovery and connectivity to allow for strategies of endogenous R&D? And for endogenous collaboration?

RELATED MODELS

- Fire

- Percolation
- Rumor Mill

CREDITS AND REFERENCES

- https://en.wikipedia.org/wiki/Forest-fire_model
- https://doi.org/10.1016/j.jedc.2003.05.005

HOW TO CITE

- [add citation to EPS when published]