Replication of Torsten Hägerstrand's Spatial Innovation Diffusion Model

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OVERVIEW

Purpose

The purpose of this model is to understand the processes which create a "nebula-distribution," a common spatial pattern. This model explores the way that the diffusion of ideas across a social network might produce this pattern. The model attempts to recreate the chronologic and geographic patterns produced in a historical example, the diffusion of the adoption of government subsidies for improved pasture on farms in Sweden. Two related models were outlined and studied by the author. The first model, referred to as the *isotropic* model, begins with a uniform population number and a 5x5 grid. This model is designed to show how innovation might spread on a limited scale. The second model, the *anisotropic* model, initializes with different numbers of agents on each patch, a larger more complex spatial area and is intended to recreate a specific case study. The models were originally published in 1965 by Torsten Hägerstrand and are some of the first agent-based models ever created. They rely on real-world data to create some of the models' parameters (e.g. probability distributions used in the model are calculated from actual migration data and telephone call data) and attempt to compare real world distributions of the spread of ideas with those predicted by the model.

State Variables & Scales

Isotropic: This model is constructed on a 5 x 5 square grid with 30 agents on each square. One agent in the center of the model is initialized with an idea that will be spread to the rest of the agents. The probability of an agent spreading an idea is based upon the receiving agents' relative position to the agent spreading the innovation.

Anisotropic: The model represents the study region with a series of squares designed to mimic the geography of the region. Geographic boundaries such as lakes or rivers are represented as boundaries over which ideas cannot pass, or the probability of an idea spreading is reduced by half. The model uses a heterogeneous population of agents on each cell based upon actual population and begins with several initial adopters based upon historical data of government subsidy adoption.

Process Overview and Scheduling

At each time step each agent that has adopted an innovation looks to its neighbors to try and spread the innovation. The agent can spread to other agents on the cell that it occupies, or it can spread to agents 2 patches away in a Moore neighborhood. Each agent must spread to an agent other than themselves. Agents that have received an innovation to adopt can still have an innovation spread to them. The model continues until all agents have adopted the innovation.

Design Concepts

Emergence: The model is designed to study the spatial patterns of innovation adoption recreated by the model. The model attempts to create a "nebula-distribution," a common spatial pattern, by looking at the diffusion of ideas across a social network.

Sensing: Agents are able to sense the distance of other agents from them, in order to calculate the probability of an innovation spreading to them. In the anisotropic model, agents also use the number of agents on a patch to modify the probability that an innovation will spread to them. Also in the anisotropic model, agents are able to sense the existence of barriers when calculating if an innovation can spread to another agent.

Interactions
Agents strive to find other agents that they can spread an innovation to. In the anisotropic model, agents wishing to spread an innovation create a link to a cell to determine if boundaries will affect the probability of spreading an innovation.

Stochasticity
In both models the probability of spreading to another agent is determined by comparison to a random number. In the anisotropic model, the number of agents on each patch is stochastic. In the original model created by Hägerstrand, this number was based upon actual population data. However, these numbers were unavailable for this model replication. Specific populations can also be loaded from a file.

Observation (how data are gathered from the model)
The number of agents that have adopted an innovation is plotted in the model window.

DETAILS

Initialization
Isotropic: In this model 30 agents are spawn on each patch. One agent from the center patch is chosen to start with an innovation which it must spread to the other agents. The landscape of this model is a 5 x 5 grid.

Anisotropic: In this model randomly chosen amounts of agents are spawned on each patch. The model environment is recreated from Hägerstrand's model environment. This was based upon the geography of the study area and incudes barriers that are meant to model the effects of geographic features such as lakes and rivers. The distribution of initial adopters is static, and is taken from historic data.

Input
If specific population data are available for the anisotropic model, they can be input into the model from a file with x, y, pop on each line.

Submodels

Innovation Spread:

Each patch in the neighborhood has a probability (*P*) associated with it assuming that the agent spreading the innovation is located on the center patch. The probabilities in the chart below are symmetrical. They are based on historical data of telephone exchanges and migration data.

0.0096	0.014	0.0168		
	0.0301	0.0547		
		0.4431		
	and	so	on	

Isotropic: The spread of innovation in this model is represented by the equation below:

$$\sum_{\gamma=1}^{i-1} P_r < \gamma_i < \sum_{\gamma=1}^{i} P_r$$

A random number γ_i is chosen and locates the cell *i* according to the above equation.

Anisotropic: The spread of innovation in this model is represented by the equations below. In these equations, *Q* represents the probability of a hit in cell *i* with a population of *N.*

$$Q_i = \frac{P_i N_i}{\sum_{i=1}^{25} P_i N_i}$$

After the probability *Q* is assessed, the hit is located in cell *i* according to the following equation.

$$\sum_{\gamma=1}^{i-1} Q_r < \gamma_i < \sum_{\gamma=1}^{i} Q_r$$

The major difference between these two equations is that the probability of anisotropic spread is affected by the number of agents on a patch, whereas in the case of isotropic spread the population is uniform on all patches, in effect making population a non-factor.

For the purpose of anisotropic spread, the presence of barriers also can effect the probability produced by the equation above. There are two types of barriers present in the simulation, unpassable barriers and difficult to pass barriers. Unpassable barriers (black in the simulation) reduced the probability to 0, and are impossible to spread innovations across. The other barriers (gray in the simulation) reduced the probability from the above equation by half. In order to determine if a barrier is located between two agents, a temporary link is made between the agents and this link is checked to make sure that it does not intersect with any existing barriers. Then the barrier is removed.

The original model description and results are presented in:

Hägerstrand, Torsten (1965) 'A Monte Carlo Approach to Diffusion', Archives Européennes de Sociologie, 6(1), pp. 43-67.

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