Agent Based Modelling with Applications in Economics

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09-03-2022

Overview

Parameter space sweeping

Running a model with different settings can lead to different behaviour in the system being modelled.
Patterns:

- DOE – Design Of Experiments
- LHS – Latin Hypercube Sampling (e.g. Sobol numbers)

Models library → Biology → Wolf Sheep Predation
Tools → BehaviorSpace

Parameter space sweeping

Tools $\rightarrow$ BehaviorSpace

every value from 100 to 1000 in increments of 50:
["number" [100 50 1000]]
only the values of 100, 200, 400, and 800:
["number" 100 200 400 800]

Parameter space sweeping

Let us try to define the parameter space:
["wolf-gain-from-food" [10 1 30]]
["initial-number-wolves" 40 50 60]
["initial-number-sheep" 50 100 150]
["sheep-gain-from-food" [1 1 10]]

Let us define reporters:
count turtles
count sheep
count wolves

Let us define stop conditions:
not any? turtles
Time Limit – 100

Preferential attachment

Social networks

Graph representation: objects – graph vertices (also called nodes), edge (also called link) – the related pair of vertices. Links can be directed or undirected.

Degree k – number of nodes connected to a given node (for undirected graph).

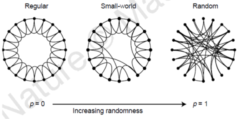
Power low: $P(k) \sim k^{-\gamma}$

Preferential attachment

Models library → Networks → Preferential attachment

Problem: In some networks, a few "hubs" have lots of connections, while everybody else only has a few. This model shows one way such networks can arise.

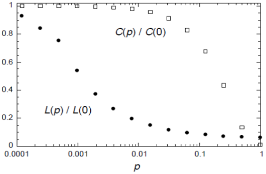
Small worlds



Random rewiring procedure:

- We start with a ring of $n = 20$ vertices, each connected to its $k = 4$ nearest neighbours by undirected edges.
- We choose a vertex and the edge that connects it to its nearest neighbour in a clockwise sense
- With probability p, we reconnect this edge to a vertex chosen uniformly at random over the entire ring, with duplicate edges forbidden; otherwise we leave the edge in place.
- We repeat this process by moving clockwise around the ring, considering each vertex in turn until one lap is completed.

Small worlds



Graph measures:

- Length: the distance between two vertices in a graph is the length of a shortest path between them, if one exists, and otherwise the distance is infinity.
- Clustering: local clustering coefficient is then given by the proportion of links between the vertices within its neighbourhood divided by the number of links that could possibly exist between them.

Small worlds

Models library → Networks → Small worlds

Problem: "Small worlds" – high clustering coefficients and limited length

El Farol

Models library → Social Science → El Farol

Problem: deductive vs inductive reasoning

El Farol is a bar in Santa Fe, New Mexico. The bar is popular — especially on Thursday nights when they offer Irish music — but sometimes becomes overcrowded and unpleasant. In fact, if the patrons of the bar think it will be overcrowded they stay home; otherwise they go enjoy themselves at El Farol.

Stability in competition

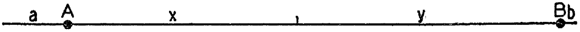


FIG. 1.

Market of length $l = 35$. In this example $a = 4$, $b = 1$, $x = 14$, $y = 16$.

Assumptions:

- We consider two shops: A and B placed along the "main street" – line, at the distances a and b from two ends of the line.
- Buyers are uniformly distributed along the line and a unit quantity is consumed per unit of time and unit of line.
- Buyer pays a price and purchases transportation cost, c per unit distance.
- Shop A sets a price p_1 and quantity q_1. Shop B sets a price p_2 and quantity q_2.
- There are no production cost.

Stability in competition

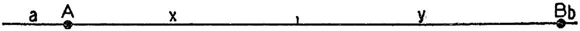


FIG. 1.

Market of length $l = 35$. In this example $a = 4$, $b = 1$, $x = 14$, $y = 16$.

- If a buyer goes to shop A she/he pays $p_1 + cx$ otherwise $p_2 + cy$
- $p_2 < p_1 + c(l - a - b)$ and $p_1 < p_2 + c(l - a - b)$
- To calculate x an y we must equate $p_1 + cx = p_2 + cy$ and use $x + y = l - a - b$
- $x = \frac{1}{2}\left(l - a - b + \frac{p_2 - p_1}{c}\right)$
- $y = \frac{1}{2}\left(l - a - b + \frac{p_1 - p_2}{c}\right)$

Stability in competition

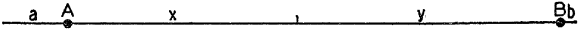


FIG. 1.

Market of length $l = 35$. In this example $a = 4$, $b = 1$, $x = 14$, $y = 16$.

- $\pi_1 = p_1 q_1 = p_1(a + x) = \frac{1}{2}(l + a - b)p_1 - \frac{p_1^2}{2c} + \frac{p_1 p_2}{2c}$ and
- $\pi_2 = p_2 q_2 = p_2(b + y) = \frac{1}{2}(l - a + b)p_2 - \frac{p_2^2}{2c} + \frac{p_1 p_2}{2c}$

Each shop sets its price in an optimal way:

- $\frac{\partial \pi_1}{\partial p_1} = \frac{1}{2}(l + a - b) - \frac{p_1}{c} + \frac{p_2}{2c}$ and
- $\frac{\partial \pi_2}{\partial p_2} = \frac{1}{2}(l - a + b) - \frac{p_2}{c} + \frac{p_1}{2c}$

Finally we get $p_1 = c\left(l + \frac{a-b}{3}\right)$ and $p_2 = c\left(l - \frac{a-b}{3}\right)$

Stability in competition

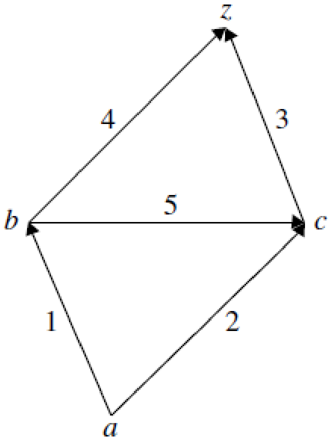
Models library → Social Science → Economics → Hotelling's Law

Problem: This model is a representation of Hotelling's law (1929), which examines the optimal placement of stores and pricing of their goods in order to maximize profit. This model replicates and extends Hotelling's law, by allowing the stores to move freely on a plane.

Braess Paradox

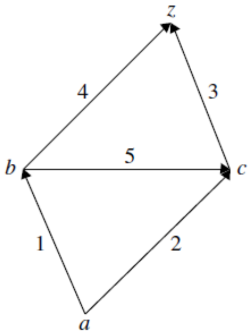
Assumptions:

- We want to get from a to z but travel times depend on the traffic ϕ intensity.
- $t_1(\phi) = t_3(\phi) = 10\phi$
- $t_2(\phi) = t_4(\phi) = 50 + \phi$
- $t_5(\phi) = 10 + \phi$



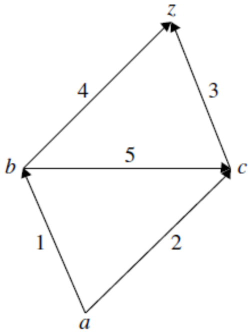
Braess Paradox

- $t_1(\phi) = t_3(\phi) = 10\phi$
- $t_2(\phi) = t_4(\phi) = 50 + \phi$
- $t_5(\phi) = 10 + \phi$
- If total flow $\mid \Phi \mid = 2$ then optimal solution is $\Phi_{abcz} = 2$, $\Phi_{abz} = \Phi_{acz} = 0$ and $\mid T(\Phi) \mid = 52$.
- If total flow $\mid \Phi \mid = 6$ then optimal solution is $\Phi_{abcz} = 0$, $\Phi_{abz} = \Phi_{acz} = 3$ and $\mid T(\Phi) \mid = 83$.
- If total flow $\mid \Phi \mid = 20$ then optimal solution is $\Phi_{abcz} = 0$, $\Phi_{abz} = \Phi_{acz} = 10$ and $\mid T(\Phi) \mid = 160$.



Braess Paradox

- $t_1(\phi) = t_3(\phi) = 10\phi$
- $t_2(\phi) = t_4(\phi) = 50 + \phi$
- $t_5(\phi) = 10 + \phi$
- If total flow $\mid \Phi \mid = 6$ then optimal solution is $\Phi_{abcz} = 0$, $\Phi_{abz} = \Phi_{acz} = 3$ and $\mid T(\Phi) \mid = 83$.
- A possibility to deviate for a single driver and take Φ_{abcz} with $\mid T(\Phi) \mid = 70$.
- A critical flows for the total flow $\mid \Phi \mid = 6$ are $\Phi_{abcz} = 2$, $\Phi_{abz} = \Phi_{acz} = 2$ and $\mid T(\Phi) \mid = 92$.



Braess Paradox

Models library → Social Science → Economics → Braess paradox

Problem: This is an agent-based model intended to demonstrate a phenomenon from game theory (a subfield of economics) called Braess' paradox. The paradoxical aspect of Braess' paradox arises when an additional route is added to a traffic network that allows for very rapid transit. When this is done the traffic pattern can be changed to one that has both worse individual and global outcomes (travel times.) In short, we can open more roads and actually make traffic worse.