Agent-based Models

Monte Carlo Simulation

- a method for simulating behavior, typically accomplished with the aid of a computer
- utilizes random numbers

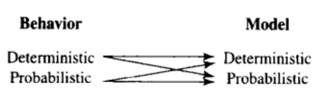
Random numbers - is a sequence of numbers with no apparent pattern, where each number can appear with equal likelihood.

Monte Carlo Simulation

Processes with an element of chance involved are called probabilistic, as opposed to deterministic processes.

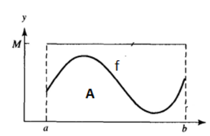
Monte Carlo simulation is therefore a probabilistic model.

Monte Carlo simulation can be used to approximate both a deterministic behavior and a probabilistic one.



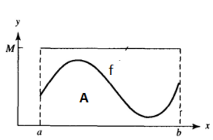
Simulation of deterministic behavior: Area under a curve

Suppose $y = f(x)$ is some given continuous function satisfying $0 \leq f(x) \leq M$ over the interval $a \leq x \leq b$.



Notice that the area we seek is wholly contained within the rectangular region of height M and length $b - a$.

Simulation of deterministic behavior: Area under a curve



Select a point $P(x, y)$ at random from within the rectangular region. We will do so by generating two random numbers, x and y, satisfying $a \leq x \leq b$ and $0 \leq y \leq M$.

$$\frac{\text{area under curve}}{\text{area of rectangle}} \approx \frac{\text{number of points counted below the curve}}{\text{total number of random points}}$$

Simulation of deterministic behavior: Area under a curve

Input. Total number n of random points to be generated in the simulation.

Output. AREA = approximate area under the specified curve $y = f(x)$ over the given interval $a \leq x \leq b$, where $0 \leq f(x) < M$.

S1. Initialize: COUNTER = 0.

Simulation of deterministic behavior: Area under a curve

S2. For $i = 1, 2, \ldots, N$ do Steps 3-5.

S3. Generate random coordinates x_i and y_i, satisfying $a \leq x_i \leq b$ and $0 \leq y_i \leq M$.

S4. Calculate $f(x_i)$ for the random x_i coordinate.

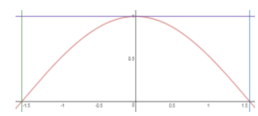
S5. If $y_i \leq f(x_i)$, then increment the COUNTER by 1. Otherwise, leave the COUNTER as is.

S6. Calculate $AREA = \frac{M(b-a)COUNTER}{N}$.

S7. OUTPUT (AREA). STOP.

Illustration

Perform Monte Carlo approximation to determine the area under the curve $\boldsymbol{Y = \cos x}$ over the interval $-\frac{\pi}{2} \leq x \leq \frac{\pi}{2}$.



Random Number Generation

Computer-generated random numbers are not random!

A computer does not really generate random numbers but pseudorandom numbers because computers employ deterministic algorithms.

But for all practical purposes, these pseudorandom numbers can be considered random.

What are agent-based models?

Agent-based model (ABM) is a kind of microscale model used to mimic multiple operations and interactions among agents with the purpose of re-creating/predicting their complex behavior.

Characteristics of ABMs

- Agents that model intelligent behavior, usually with a simple set of rules.
- The agents are usually situated in space (or in a network), and interact with each other locally.
- They usually have imperfect, local information.
- Often there is variability between agents.
- Often there are random elements, either among the agents or in the world.

Time to Think: Herding Behavior

In 1987 Craig Reynolds published "Flocks, herds and schools: A distributed behavioral model," which describes an agent-based model of herd behavior.

Agents in this models are called "boids," which is both a contraction of "bird-oid" and an accented pronunciation of "bird"

Can you give the behaviors that should be coded within each boid?

Conway's Game of Life

1. Any live cell with fewer than two live neighbours dies, as if by underpopulation.
2. Any live cell with two or three live neighbours lives on to the next generation.
3. Any live cell with more than three live neighbours dies, as if by overpopulation.
4. Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction.

Conway's Game of Life

It is a **computationally universal system**. This means, given enough space and time, it could theoretically **run any program** that a modern computer can.

2 Case Studies

Schelling segregation

Leadership in animal groups

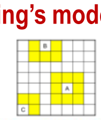
Schelling's model of segregation

From: http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/

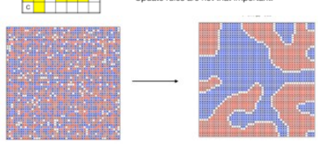
"Racial segregation has always been a pernicious social problem in the United States. Many factors have contributed to segregation including prejudice, zoning laws, housing discrimination, and loan discrimination. Although much effort has been extended to desegregate our schools, churches, and neighborhoods, the [US continues to remain segregated] by race and economic lines.

In 1971, the American economist [Thomas Schelling] created an agent-based model that suggested inadvertent behavior might also contribute to segregation. His *model of segregation* showed that even when individuals (or "agents") didn't mind being surrounded or living by agents of a different race or economic background, they would still *choose* to segregate themselves from other agents over time."

Schelling's model of segregation



- Agents live on a lattice. Not all spaces are filled.
- There are two types of agents, say red and blue.
- If the agent has too many dissimilar neighbors they move to a random open spot.
- Update rules are not that important.



http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/

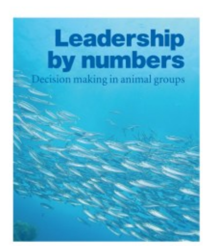
Leadership in animal groups

Effective leadership and decision-making in animal groups on the move

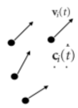
Iain D. Couzin, Jens Krause, Nigel R. Franks & Simon A. Levin

NATURE | VOL 433 | 3 FEBRUARY 2005 |

- Animal group movement depends on interactions between the group members.
- Only some of the members have information about food source, danger, etc
- How is movement coordinated? Is signaling necessary? Do animals need to know who is informed, and who is not?



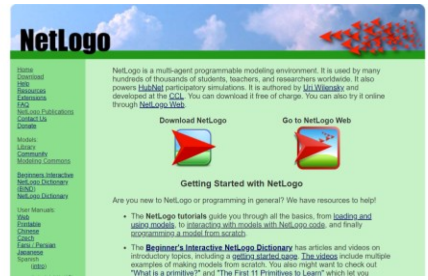
Leadership in animal groups



S_i: - speed
$\mathbf{v}_i(t)$ - direction
$\mathbf{c}_i(t)$ - position
$\mathbf{d}_i(t+\Delta t)$ - desired direction of travel

- We will update the position of each individual based on their current position, their direction and their speed
- The main rule is that individuals adjust their speed to avoid each other, but also follow the direction of the group
- The adjustment process is noisy, that is each agent chooses its direction with some noise.

Net-Logo



https://ccl.northwestern.edu/netlogo/index.shtml

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https://ojs.lib.uwo.ca/mase
https://doi.org/10.5206/mase/10876

DETERMINING THE EFFECTIVENESS OF PRACTICING NON-PHARMACEUTICAL INTERVENTIONS IN IMPROVING VIRUS CONTROL IN A PANDEMIC USING AGENT-BASED MODELLING

STEVEN KYLE D.C. VILLANUEVA AND CHRISTIAN ALVIN H. BUHAT

ABSTRACT. To determine the effectiveness of non-pharmaceutical interventions on an epidemic, we develop an agent-based model that simulates the spread of an infectious disease in a small community and its emerging phenomena. We vary parameters such as initial population, initial infected, infection rate, recovery rate, death rate, and asymptomatic rates, as inputs. Our simulations show that (i) random mass testing and quarantines decreases the number of deaths, infections, and time duration; (ii) social distancing lengthen outbreak period to an extent and helps flatten the epidemic curve; (iii) the most effective combination of NPIs to minimize death, infection, and duration is no mass testing, no social distancing, and a total lockdown but is not ethical; and (iv) the most feasible intervention is to implement an enhanced community quarantine while doing random testing on a maximum of 100 individuals. Results of this study can aid policymakers in determining interventions for their communities during a pandemic.

Home > Modeling Earth Systems and Environment > Article

Spatiotemporal modeling of parasite aggregation among fish hosts in a lentic ecosystem

Original Article | Published: 16 October 2020

Volume 7, pages 2179–2195, (2021) Cite this article

Christian Alvin H. Buhat, Jomar F. Rabajante & Vachel Gay V. Paller

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Community Transmission of Respiratory Infectious Diseases using Agent-based and Compartmental Models

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```
to setup
  clear-all
  create-turtles 10 [
    set shape "butterfly"
  ]

  reset-ticks
end


to setup-patches
  ask patches [set pcolor green]
end
```

```
to go
  ask turtles [
    fd 1
    rt random 10
    lt random 10
  ]

  tick
end


to eat-patch
  ask turtles [
    if pcolor = green [
      set pcolor brown
    ]
  ]
end
```