Lecture 3

The Occupation of Modeling: Simulating with Cells

Geog 490/590
Spatial Modeling
Spring 2015
what are models?
who are modelers?
Simulation models are used to emulate how a particular process takes place over time.
spatial simulation models are used to emulate how a particular process takes place over space and time
space
Discrete Space
raster grid or lattice
of cells or pixels
neighborhoods

von Neumann

Moore

Euclidean
neighborhoods

von Neumann

\[ N_V(c_{x,y}) = \left\{ \begin{array}{ccc} c_{x-1,y} & c_{x,y+1} & c_{x+1,y} \\ c_{x,y-1} & \end{array} \right\} \]

\[ N_V(c_{x,y}) = \{c_{i,j} : |i - x| + |j - y| \leq 1\} \]
Moore neighborhoods

\[ N_M(c_{x,y}) = \begin{pmatrix} c_{x-1,y+1} & c_{x,y+1} & c_{x+1,y+1} \\ c_{x-1,y} & c_{x,y} & c_{x+1,y} \\ c_{x-1,y-1} & c_{x,y-1} & c_{x+1,y-1} \end{pmatrix} \]

\[ N_M(c_{x,y}) = \{ c_{i,j} : \max(|i-x|, |j-y|) \leq 1 \} \]
neighborhoods

Euclidean

\[ N_r(c_{x,y}) = \left\{ c_{i,j} : \sqrt{(i-x)^2 + (j-y)^2} \leq r \right\} \]
Euclidean neighborhood
Euclidean neighborhood
Continuous Space

points, lines and polygons

models 6.5
spatial extent of study site

1. Finite
2. Infinitely extensible
3. Toroidal

models 6.6 and 1.1
time
Updating Time

synchronous vs asynchronous

1. Synchronous update
2. Random asynchronous without replacement
3. Random asynchronous with replacement
4. Systematic Asynchronous

models 6.1 & 6.2
1. Discrete
2. Event-driven
3. Continuous

representing time
Cellular Automata
$Z_i$
$Z_i$
majority rules

von Neumann

\[ z_i(t+1) = \begin{cases} 
1 & \text{if } (z_i(t) = 0 \text{ and } \sum z_j > 2) \text{ or } (z_i(t) = 1 \text{ and } \sum z_j \geq 2) \\
0 & \text{otherwise}
\end{cases} \]

Moore

\[ z_i(t+1) = \begin{cases} 
1 & \text{if } (z_i(t) = 0 \text{ and } \sum z_j > 4) \text{ or } (z_i(t) = 1 \text{ and } \sum z_j \geq 4) \\
0 & \text{otherwise}
\end{cases} \]
life-like rules

\[ \beta_1 \quad \text{birth rate} \quad \beta_2 \]

\[ \delta_1 \quad \text{death rate} \quad \delta_2 \]
interacting particle systems

If the site is occupied, then with some probability $p$ the particle dies.

If the site is vacant, then a new particle is born with a probability given by the proportion of neighboring sites that are currently occupied.
cyclical relationships between states

If the states $z_i = z_j$, then nothing happens

If the neighboring site dominates the central site ($z_j > z_i$), then $z_i \rightarrow z_j$

Otherwise, if $z_i > z_j$, then $z_j \rightarrow z_i$
Shelling Models
1. Two types of individuals are located in cells in a two-dimensional grid.

2. A proportion of cells, $p_v$, must remain vacant to allow individuals to reorganize themselves.

3. Individuals tolerate individuals of opposite type in their neighborhood, BUT desire to be in locations with some mimim proportion of neighboring individuals $p_{\text{like}}$ of the same type as themselves.

4. Any individuals dissatisfied with their current location move to the nearest available locational which their requirements are satisfied.
individual preferences = micro-motives

aggregate outcome = emergent patterns