Agent-Based Modeling

ACTIVE LIVING RESEARCH CONFERENCE WORKSHOP

SAN DIEGO, 9 MARCH 2014

Overview of Agent-Based Models

"Generative" model
- Simulate individual agents
- Study global, system-wide behavior

Goals:
- Test hypotheses about various mechanisms
- Understand the dynamics underlying global processes
- Predict patterns and outcomes

Each model is characterized by
- Spatial configuration
- Agents
- Updates

Example 1: Location Selection

Mechanism
- People self-select into neighborhoods whose infrastructure matches their walking preference
- People prefer to move less distance to more

Hypotheses
- This mechanism produces “spatial segregation”

Additional Questions
- Interaction between distance effect and selection effect
- Robustness of spatial segregation

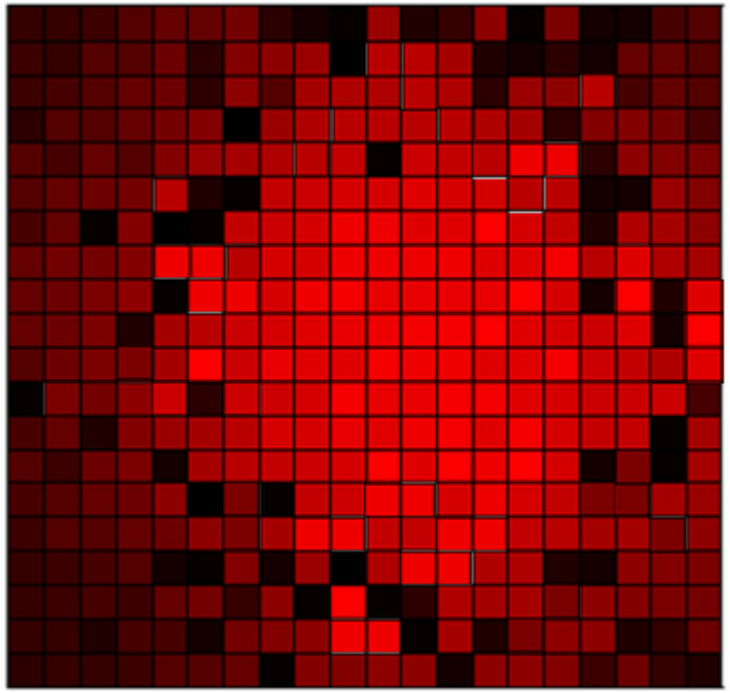
Example 1: Location Selection

SPATIAL CONFIGURATION:

Grid

“Walkability”

Walkability Map



Not Walkable — Very Walkable

Example 1: Location Selection

SPATIAL CONFIGURATION:

Grid

“Walkability”

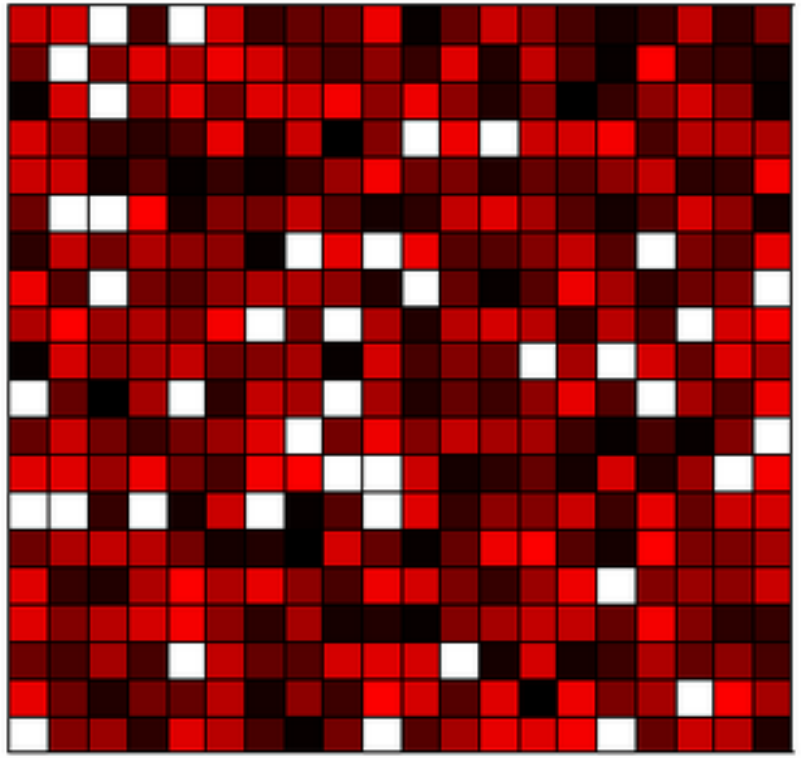
AGENTS:

People

Occupy one cell

“Walking Preference”

Agents on the grid



Prefers Walking — Prefers Driving

Example 1: Location Selection

SPATIAL CONFIGURATION:

Grid

“Walkability”

AGENTS:

People

Occupy one cell

“Walking Preference”

UPDATES:

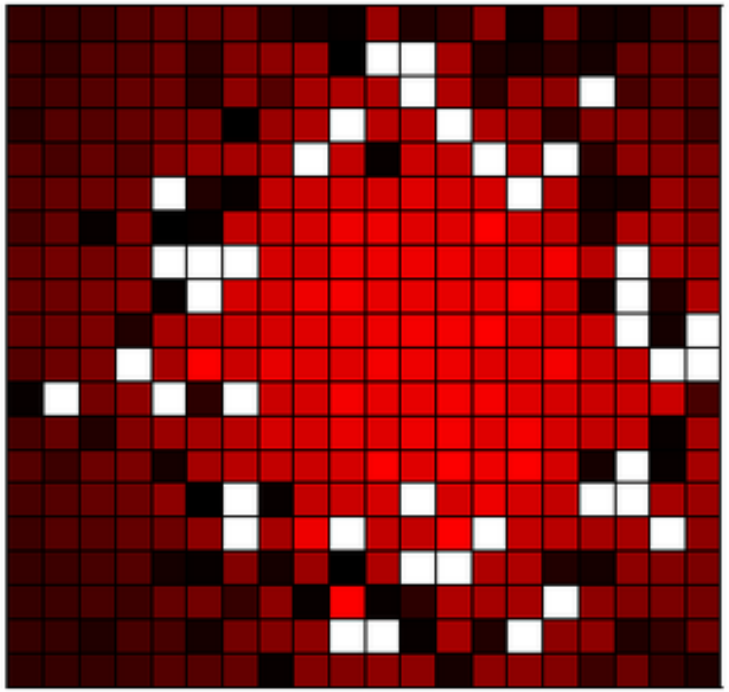
Sequential update events

At each step:

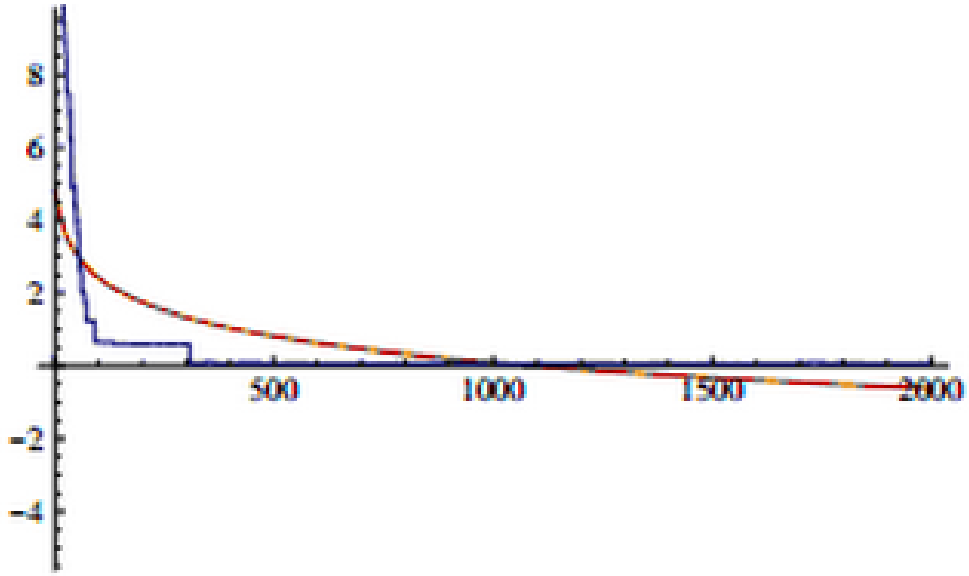
- Randomly select an agent
- Agent relocates to a cell on the grid randomly
- Probability of moving to each cell depends on
  - its distance from agent’s location
  - the difference between the agent’s “walking preference” and the cell’s “walkability”

Example 1: Location Selection

“SPATIAL SEGREGATION”



RAPID CONVERGENCE



Example 2: Route Selection

Mechanism

- Seeing others walk down a path encourages people to keep on that path
- Slow moving encourages people to take a different path

Hypotheses

- This mechanism produces “path convergence”
- Agents will cluster along paths that are shared by others with similar walking speed

Additional Questions

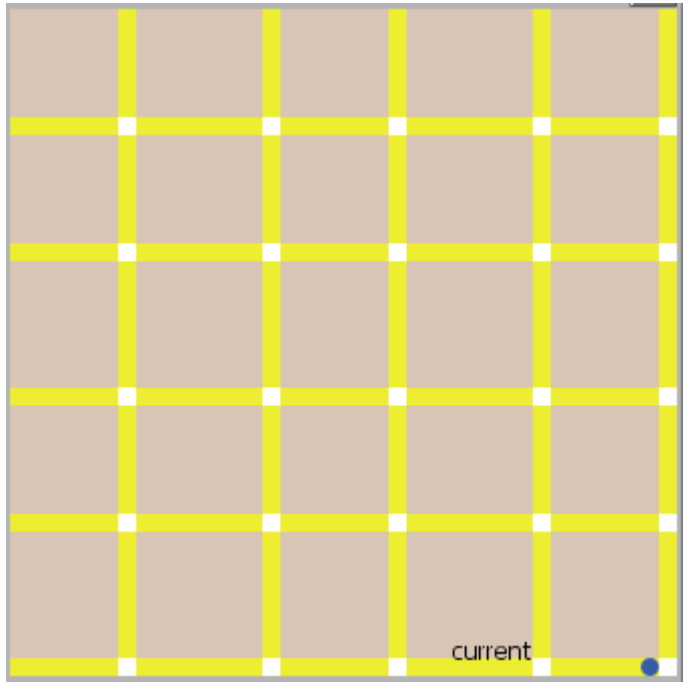
- Interaction between norm effect and traffic effect
- Robustness of path convergence

Example 2: Route Selection

SPATIAL CONFIGURATION:

Network

“Traffic”, “Travel Speed”



Example 2: Route Selection

SPATIAL CONFIGURATION:

Network

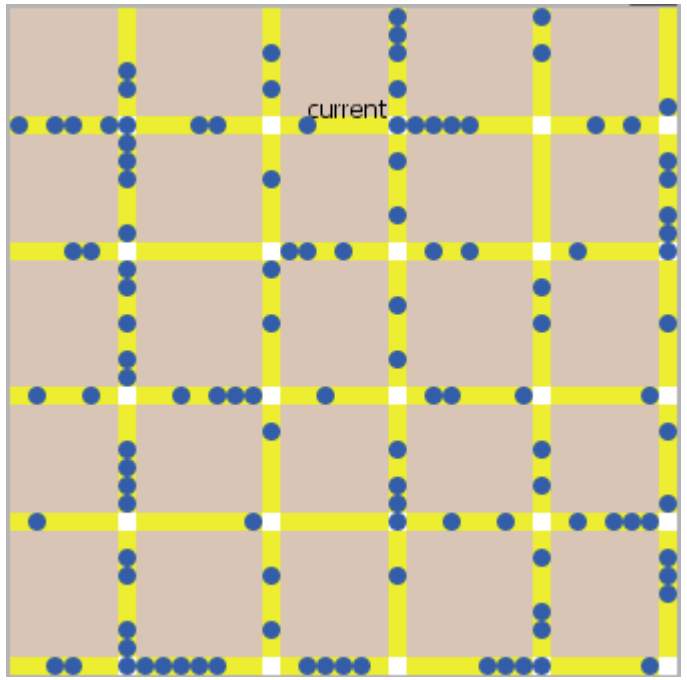
“Traffic”, “Travel Speed”

AGENTS:

People

Travel along one Edge

“Walking Speed”



Example 2: Route Selection

SPATIAL CONFIGURATION:

Network

"Traffic", "Travel Speed"

AGENTS:

People

Travel along one Edge

"Walking Speed"

UPDATES:

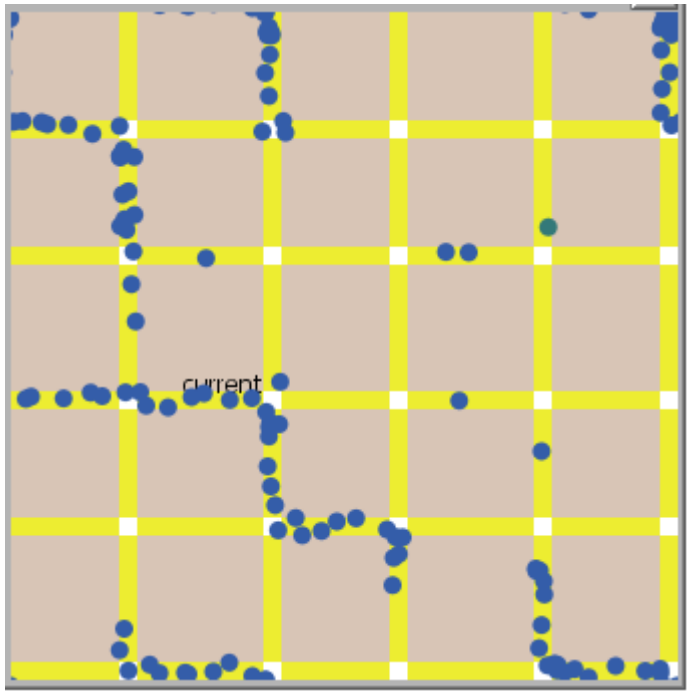
Discrete update events

At each step:

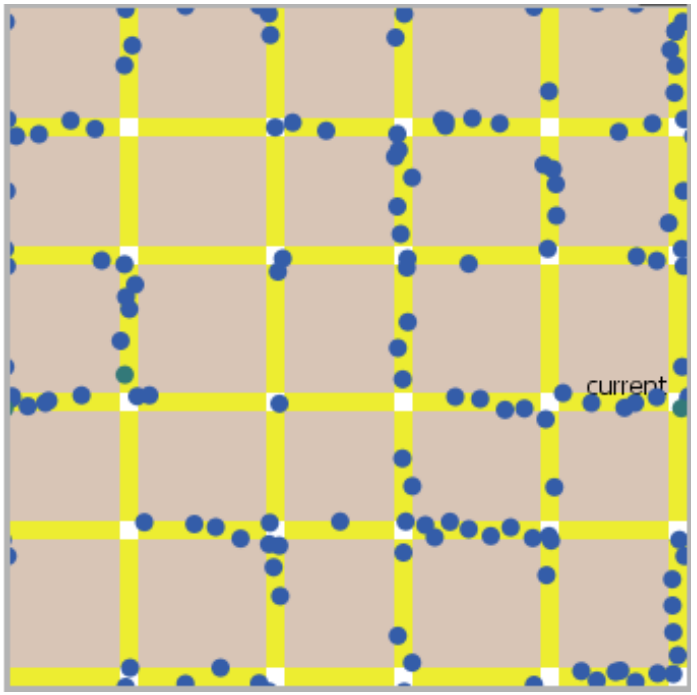
- Move each agent towards the destination
- Agent chooses which path to take randomly
- Probability of choosing each path depends on
  - its "encounters" (i.e., number of agents who travel)
  - the difference between its "travel speed" and the agent's "walking speed"

Example 2: Route Selection

PATH CONVERGENCE



PARAMETER INTERACTION



Understanding Underlying Dynamics

Mechanism
- Change in variables over time
- Interaction of collaborating and competing effects

Robustness
- Parameter changes
- Behavior supported by the mechanism

Emergence
- Coordinated individual-level action creates global outcome
- System-wide effect is greater than agent behavior

Understanding Underlying Dynamics

Self-Organization

Criticality

Self-Similarity

Adaptiveness

Convergence and Cooperation

Understanding Underlying Dynamics

Self-Organization
- Initially disorganized system converges to an ordered final state using only local interactions

Criticality

Self-Similarity

Adaptiveness

Convergence and Cooperation

Understanding Underlying Dynamics

Self-Organization

Criticality

- Rapid change in system behavior over a relatively small change in parameter
- “Self-organized criticality”

Self-Similarity

Adaptiveness

Convergence and Cooperation

Understanding Underlying Dynamics

Self-Organization

Criticality

Self-Similarity

- Whole system has the same distribution as part of the system, in some parameter
- Power law

Adaptiveness

Convergence and Cooperation

Understanding Underlying Dynamics

Self-Organization

Criticality

Self-Similarity

Adaptiveness

- Agents are “reactive” to changes in environment
- Not all model features are generative

Convergence and Cooperation

Understanding Underlying Dynamics

Self-Organization

Criticality

Self-Similarity

Adaptiveness

Cooperation

- Non-punitive incentive to follow the rules

Understanding Underlying Dynamics

Self-Organization

Criticality

Self-Similarity

Adaptiveness

Convergence and Cooperation

Apply existing models to new phenomena

- Percolation
- Ferromagnetic spin (Ising)

Adding spatial features to existing models

- Segregation (Schelling)
- Civil Disobedience (Epstein)
- Ethnocentrism (Axelrod, Hammond)

Creating feedback loops between space and agents

Adding Realism

Simplistic	**Realistic**
Clear dynamics	Predictions
Explain patterns	Data integration
Track interactions	Examine a larger number of phenomena
Widely applicable	Test specific scenarios
Robust results	

Adding Realism

Simplistic → **Realistic**

Ising Model
(Ising, 1925)

Grid with global environment parameter

Each agent has 2 states and fixed location

Agents change states based on the environment and state of its neighbors

Parameters are set without data.

Modeling Walking Behavior
(Yang et al., 2011)

Different types of locations with roads connecting them

Each agent moves between locations, either walking to driving, based on activity plan

Agents choose their transport mode based on preference, safety, and distance. Preference is updated based on social network and trip quality.

Some parameters are calibrated from the data; others are set without data.

Microsimulation of Walking
(de Nazelle et al., 2009)

Same as Yang et al., but with more realistic spatial configuration and trip plans.

All parameters are set directly from the data

Adding Realism

Simplistic → **Realistic**

Ising Model
(Ising, 1925)

Criticality: Behavior spreads rapidly when the environmental parameter is above a threshold

Not sensitive to initial conditions

Modeling Walking Behavior
(Yang et al., 2011)

Distribution of locations and safety levels is strongly related to levels of walking.

Individuals who live in safer areas tend to walk more.

Microsimulation of Walking
(de Nazelle et al., 2009)

The most active individuals (top 5%) receive the recommended amount of physical activity at most 25% of the days.

Half the days, there is no day-to-day variation in physical activity due to built environment change; the other days are split evenly between increased and decreased activity levels

Testing Hypotheses

Intervention effectiveness
- Safety Levels
- Social Norms
- Road Configuration
  - Jin and White, 2012
- School Placement
  - Yang and Diez-Roux, 2013

Conceptual models of behavior
- Self Selection
- Route Choice

Validation with Data
- Calibration vs. Direct use of features
- Regression to estimate parameters for simulated individuals
- Model and feature selection
- Integration of Multiple Data Sources
  - GIS
  - Behavioral Survey Data