Introduction to Agent-Based Modeling

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Outline

(1) Example: birds flocking (Reynolds, 1987)

(2) Key features of agent-based models

(3) Example: Residential segregation (Schelling, 1969)

(4) Example: Neighborhood social networks (Neal & Neal, 2014)

(5) Example: Building public spaces (Neal & Lawlor, 2015)

– Feel free to interrupt with questions

– You can follow along using the online versions of these example models at the web addresses on the handout

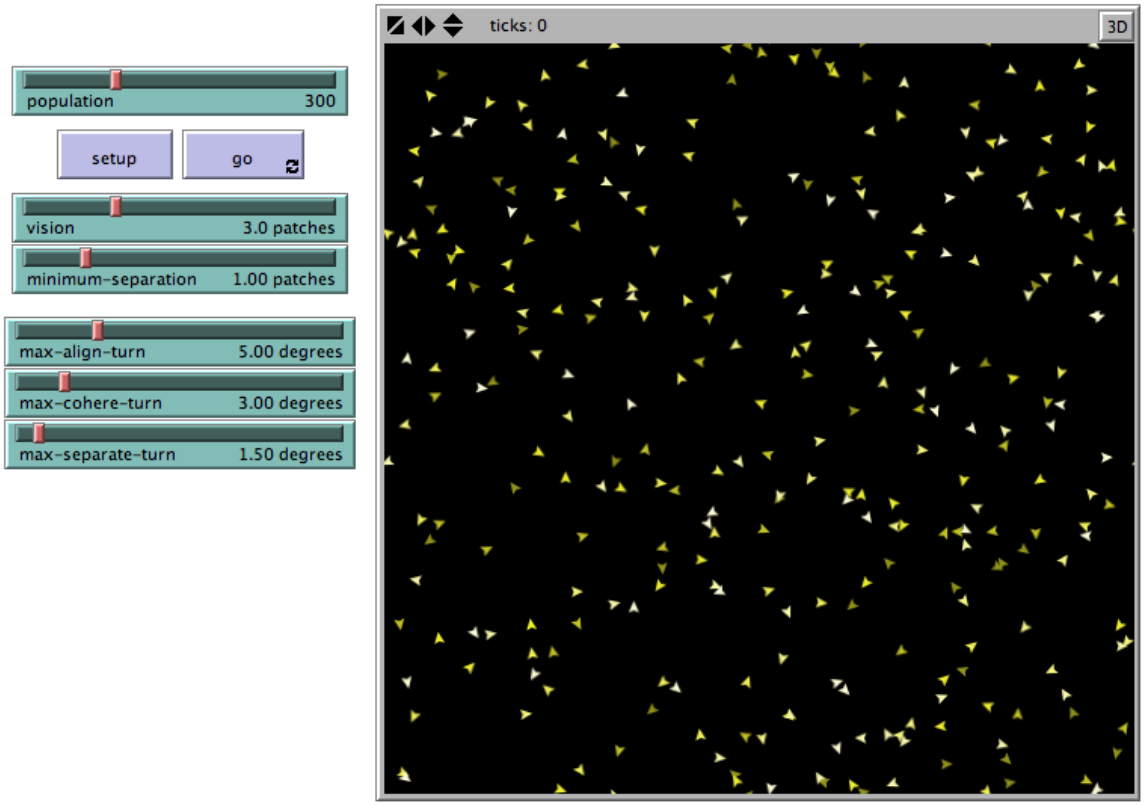
What are agent-based models?

Models designed to:

"Situate an initial population of autonomous heterogeneous agents in a relevant spatial environment; allow them to interact according to simple local rules, and thereby generate – or 'grow' – the macroscopic regularity from the bottom up." (Epstein 1999:42)

What are agent-based models?

Flocking Model
(Reynolds, 1987)



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What are agent-based models?

Definition

"Situate an initial population of autonomous heterogeneous agents…

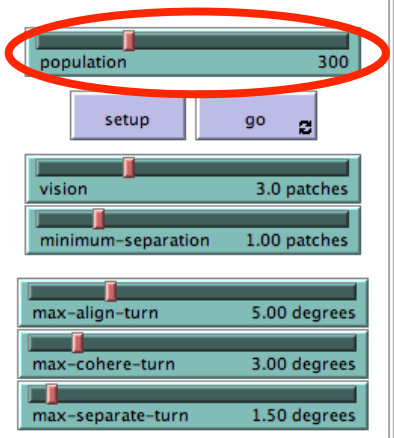
Example

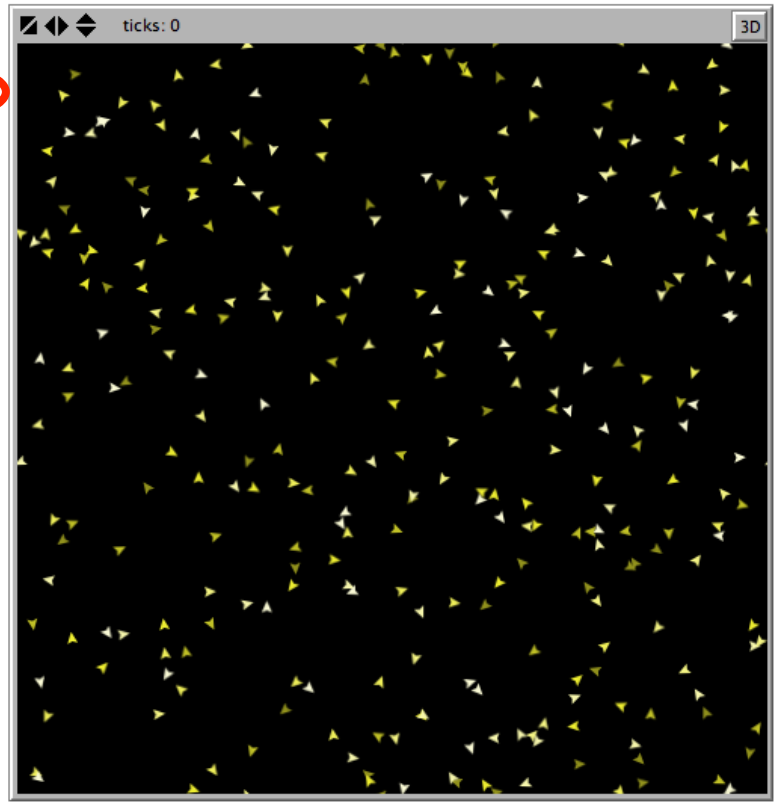
Agents – Birds

Autonomous – Each bird is independent, there is no bird dictator

Heterogeneous – Each bird has its own location and heading

Flocking Model (Reynolds, 1987)





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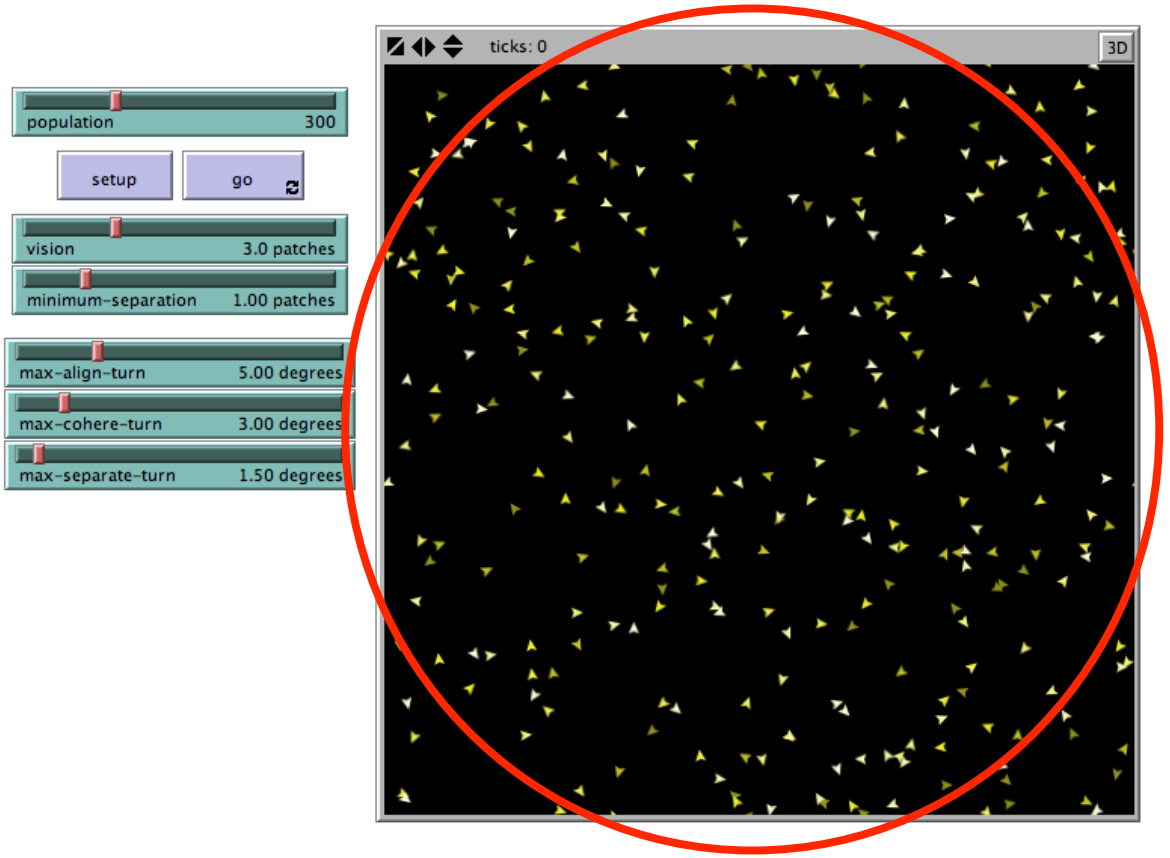
What are agent-based models?

Definition
…in a relevant spatial environment…

Example
The birds are located in a big, open space with no obstructions. The sky.

Flocking Model (Reynolds, 1987)



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What are agent-based models?

Definition

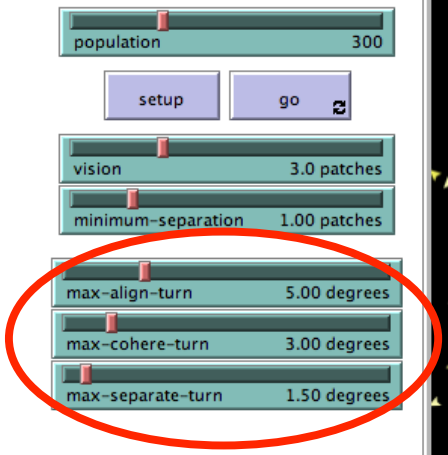
…allow them to interact according to simple local rules…

Example

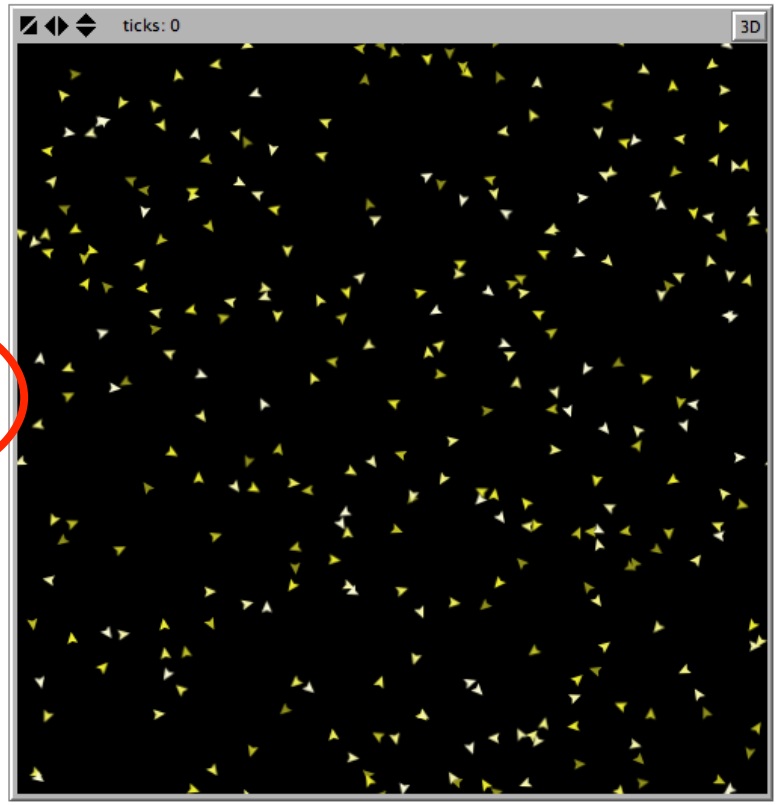
Align: Match direction of other birds

Cohere: Fly toward other birds

Separate: Don't get too close to other birds



Flocking Model (Reynolds, 1987)



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What are agent-based models?

Definition

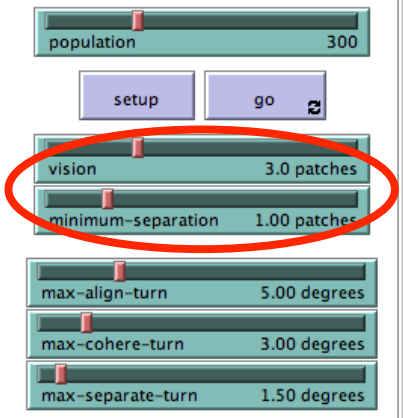
…allow them to interact according to simple **LOCAL** rules…

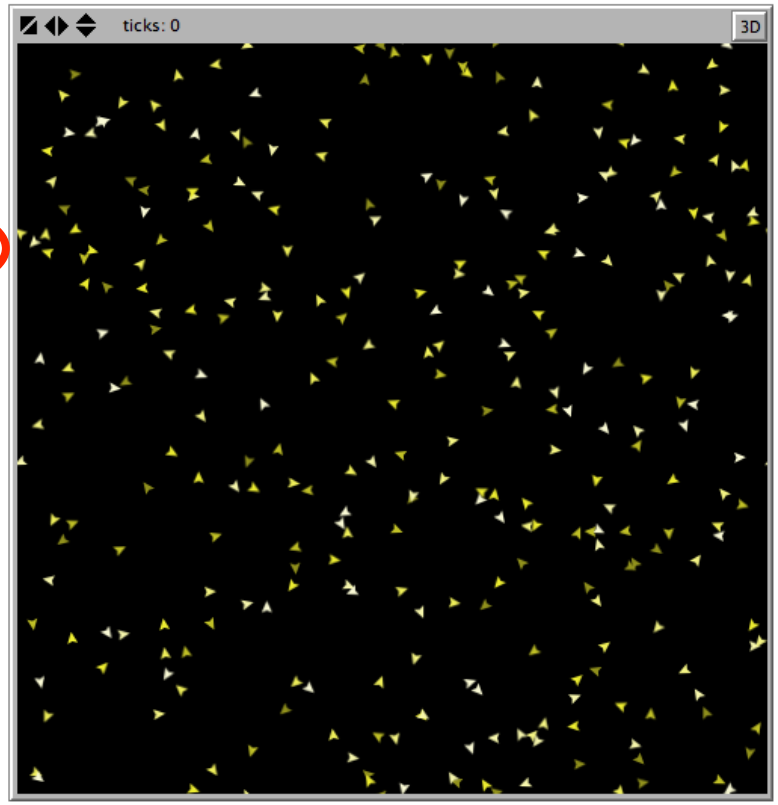
Example

For the rules, who counts as "other birds"?

How much of the environment can each bird see?

Flocking Model (Reynolds, 1987)





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What are agent-based models?

Definition

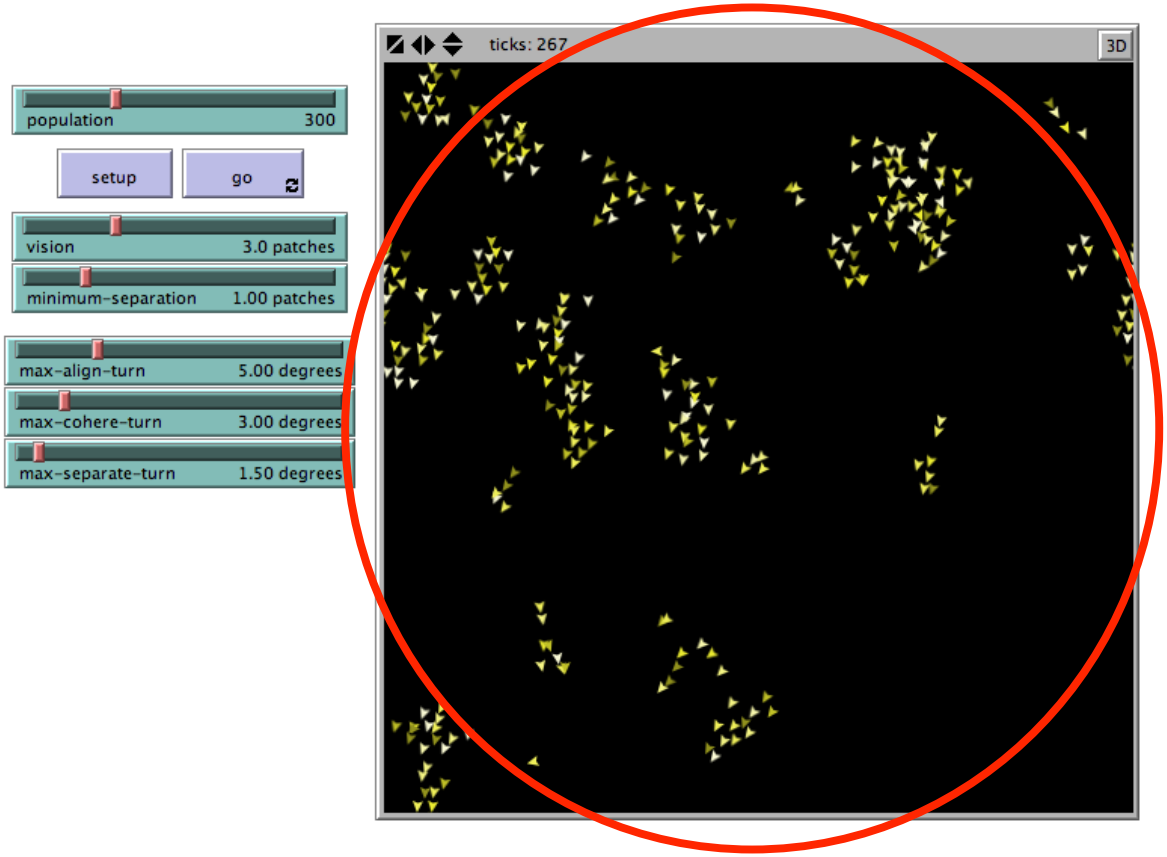
…and thereby generate the macroscopic regularity from the bottom up."

Example

The pattern that emerges is what we call "flocking."

But no bird decided to, or tried to, form a flock.

Flocking Model (Reynolds, 1987)



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Key features of ABMs

The building blocks

(1) Agents –

- Entities that follow rules and interact with each other
- Can be nearly anything (people, animals, cells, cars)
- Autonomy: Each one acts on its own
- Interdependence: They can affect one another
- Heterogeneous: They can have attributes (race, wealth)
- What are the agents in your system?

Key features of ABMs

The building blocks

(1) Agents

(2) Behavioral rules –

- Specify how agents interact with each other
- Simple: Agents aren't supercomputers
- Local: Agents aren't omniscient
- What kinds of rules do agents follow in your system?

Key features of ABMs

The epistemology

Most agent-based models are rooted in a philosophical perspective called Methodological Individualism.

- All phenomena are the result of interactions among agents at a lower scale

- A complete explanation of a phenomenon must be made in terms of individual agents' actions

Many explanations of social phenomena are incomplete:

~~**CULTURE**~~ ~~**POLICY**~~ ~~**RELIGION**~~

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Key features of ABMs

The purpose

To understand how:

the interactions of individual agents at one scale	→	generate	→	an observed phenomenon at a higher scale.

In the flocking model: How do individual birds' decisions about where to fly generate what we call "flocking"?

In your context:

What macro-scale phenomena are important?

What micro-scale interactions might cause it?

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Key features of ABMs

The applied use

After a working model is built that generates the phenomenon of interest, it can be used to:

- Test potential interventions
  - What if we gave the birds glasses to see farther away?
  - What interventions on your phenomenon might be worth testing?
- Anticipate consequences of shocks to the system
  - What if half the birds suddenly died?
  - What sudden shocks might occur in your system?
- Guide plans for data collection in the field
  - How many birds would we need to track to study flocking behavior?
  - Have you struggled to know what (or how much) data to collect?

Example: Segregation (Schelling, 1969)

Purpose

Understand how patterns of residential segregation are generated by the behaviors of individual households.

What kinds of individual behaviors will generate residential segregation even without any external forces like housing policy or lending practices?

Example: Segregation (Schelling, 1969)

The agents – Households, with a type & preference

There are two types of households: **RED** and **GREEN**

- The types represent a social characteristic
- Could be race, income, religion, etc.

All households prefer at least X% of their immediate neighbors to be the same type as themselves.

- If X = 75, households prefer living in an area where at least 75% of their neighbors are them same as themselves (i.e. they want to be in the majority)

Example: Segregation (Schelling, 1969)

The behavioral rules

(1) If the composition of your immediate neighborhood satisfies your preference, do nothing.

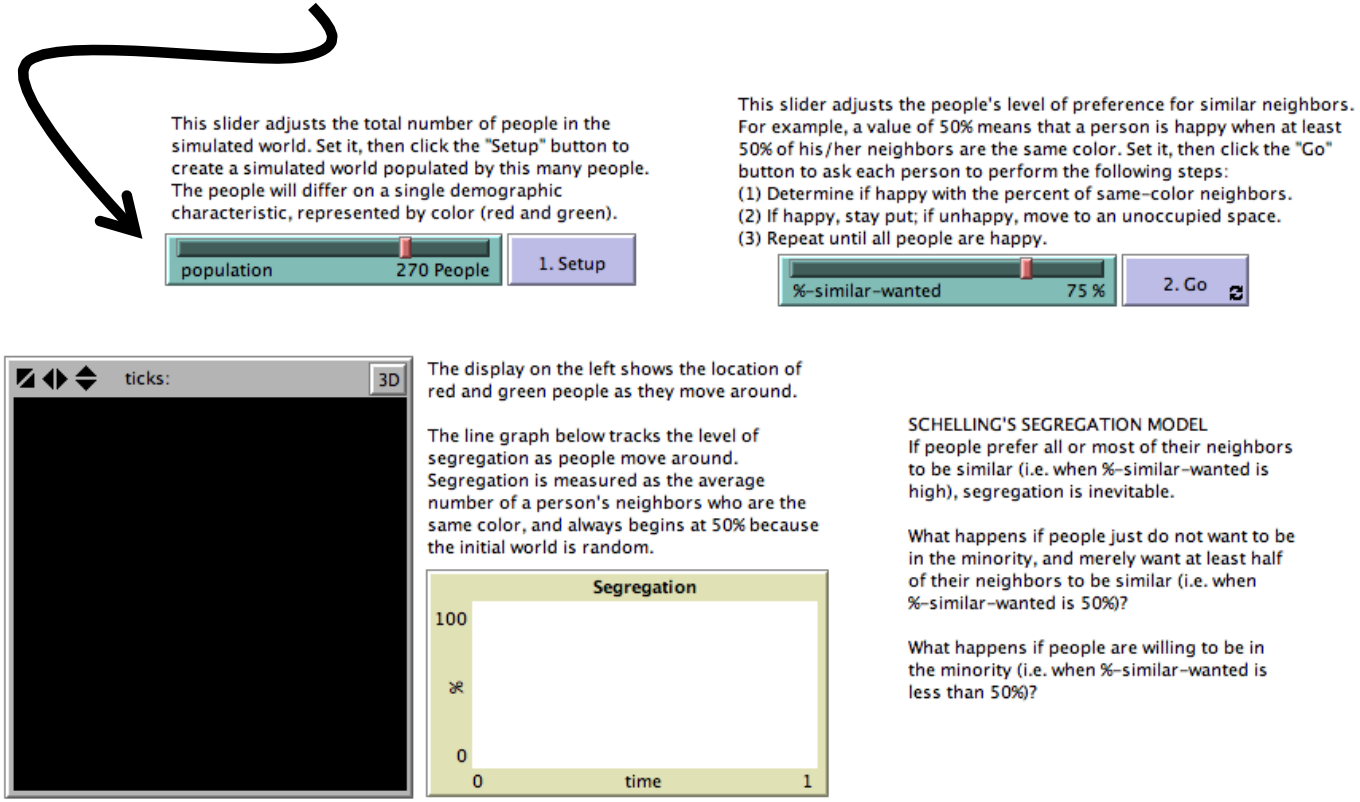
(2) If the composition of your immediate neighborhood does not satisfy your preference, move.

– Simple: Look around and decide "should I stay or should I go"
– Local: Only look at your immediate neighborhood

Example: Segregation (Schelling, 1969)

How the model works

(1) Set the population size of the neighborhood (270 households)



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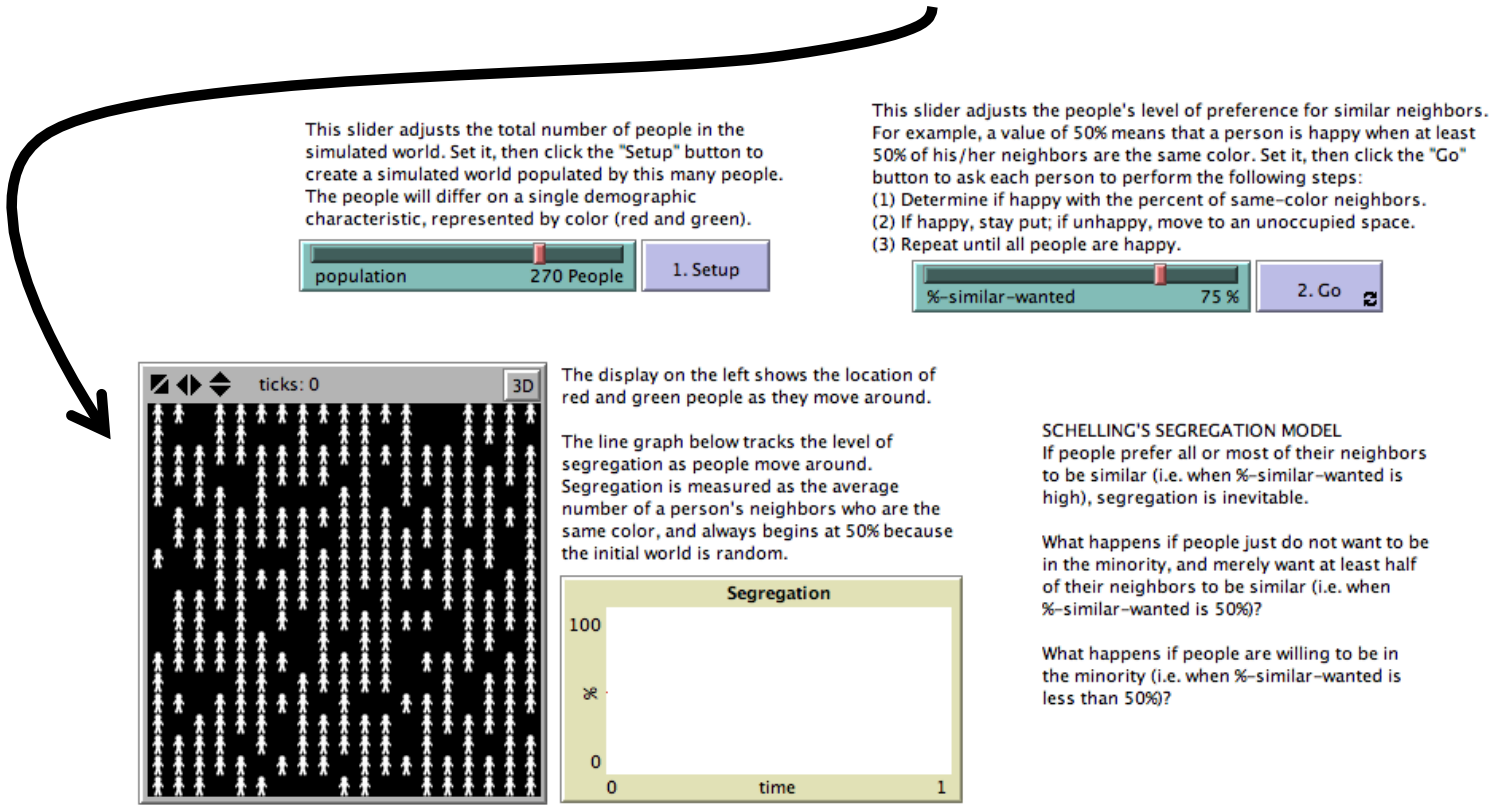
Example: Segregation (Schelling, 1969)

How the model works

(2) Click [1. Setup] to arrange 270 households on a grid.



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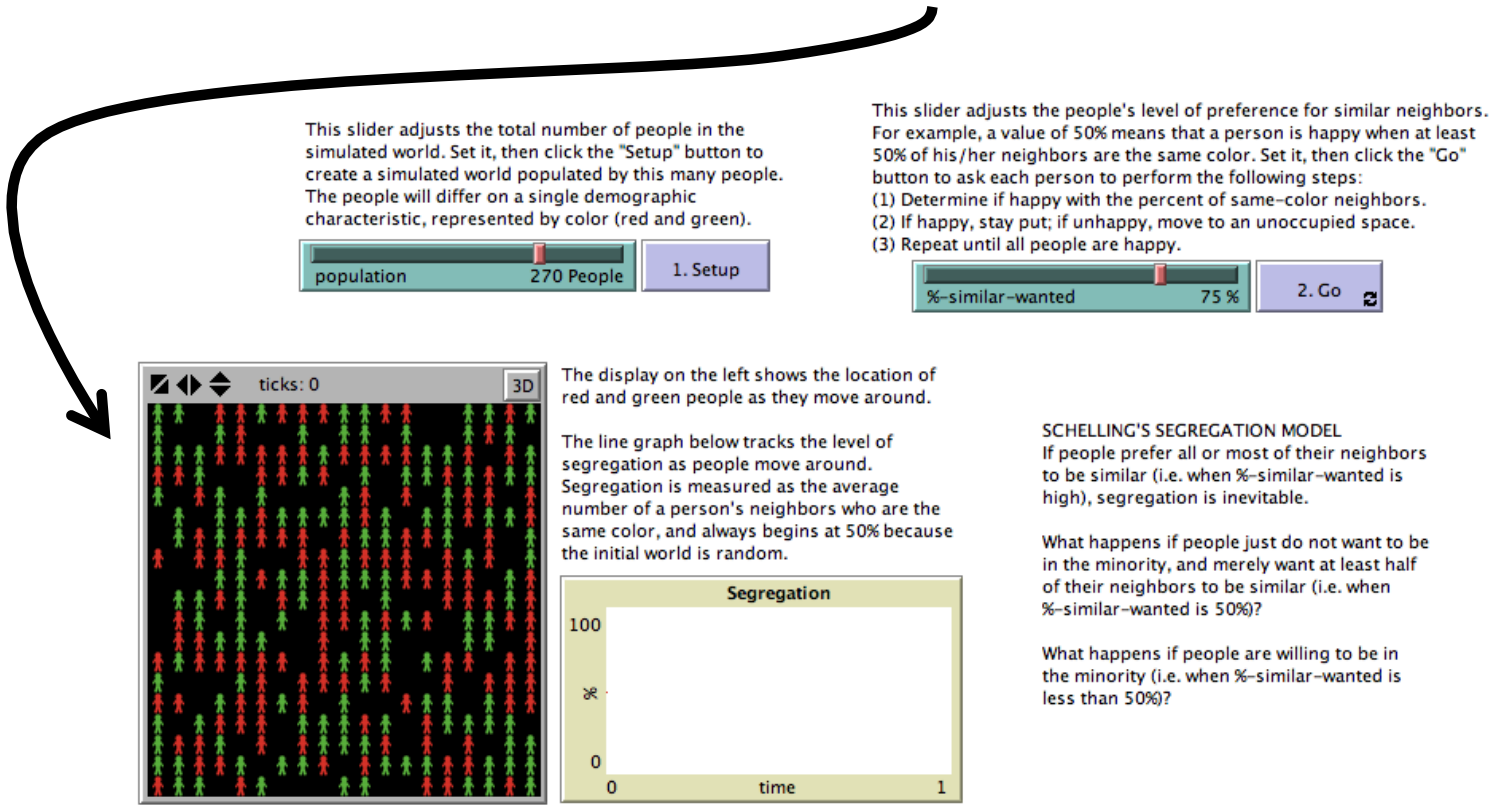
Example: Segregation (Schelling, 1969)

How the model works

(3) Randomly make half **RED** and half **GREEN**. (this is automatic)



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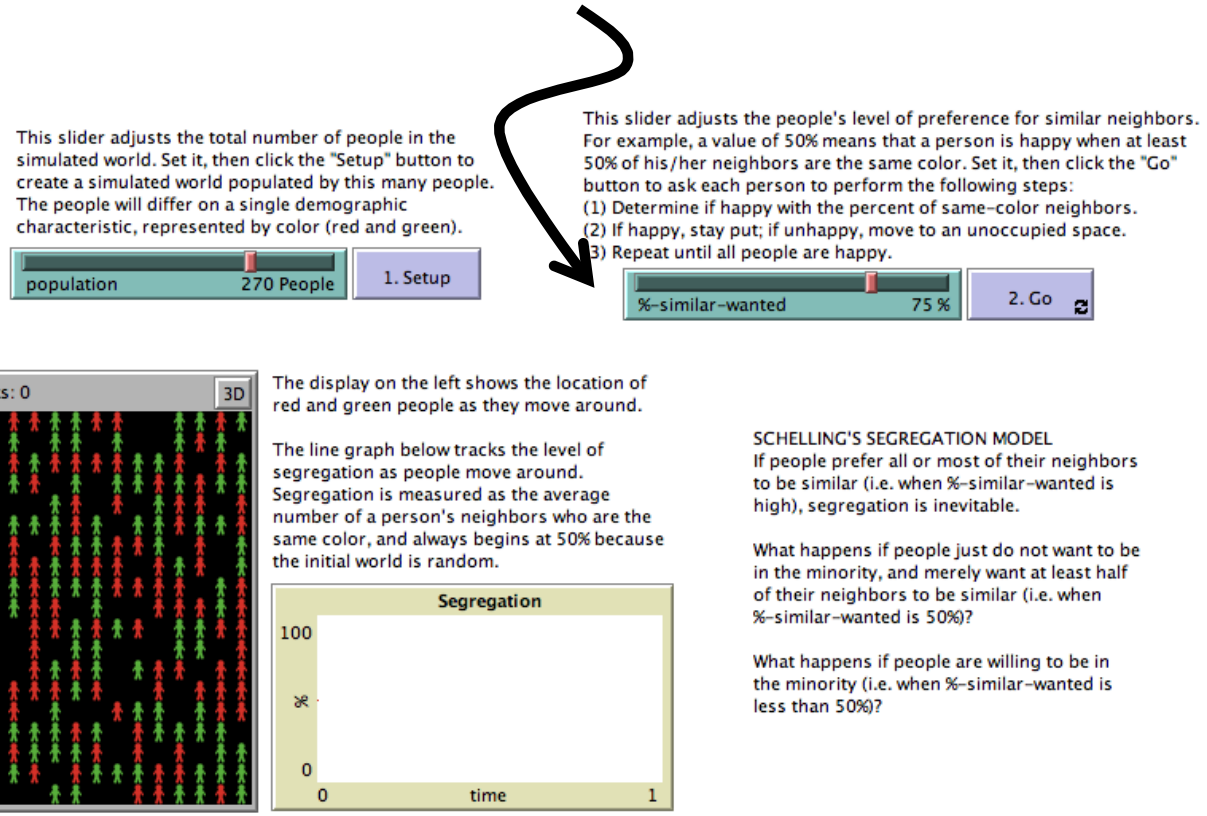
Example: Segregation (Schelling, 1969)

How the model works

(4) Set households' level of preference for similar neighbors. (75)



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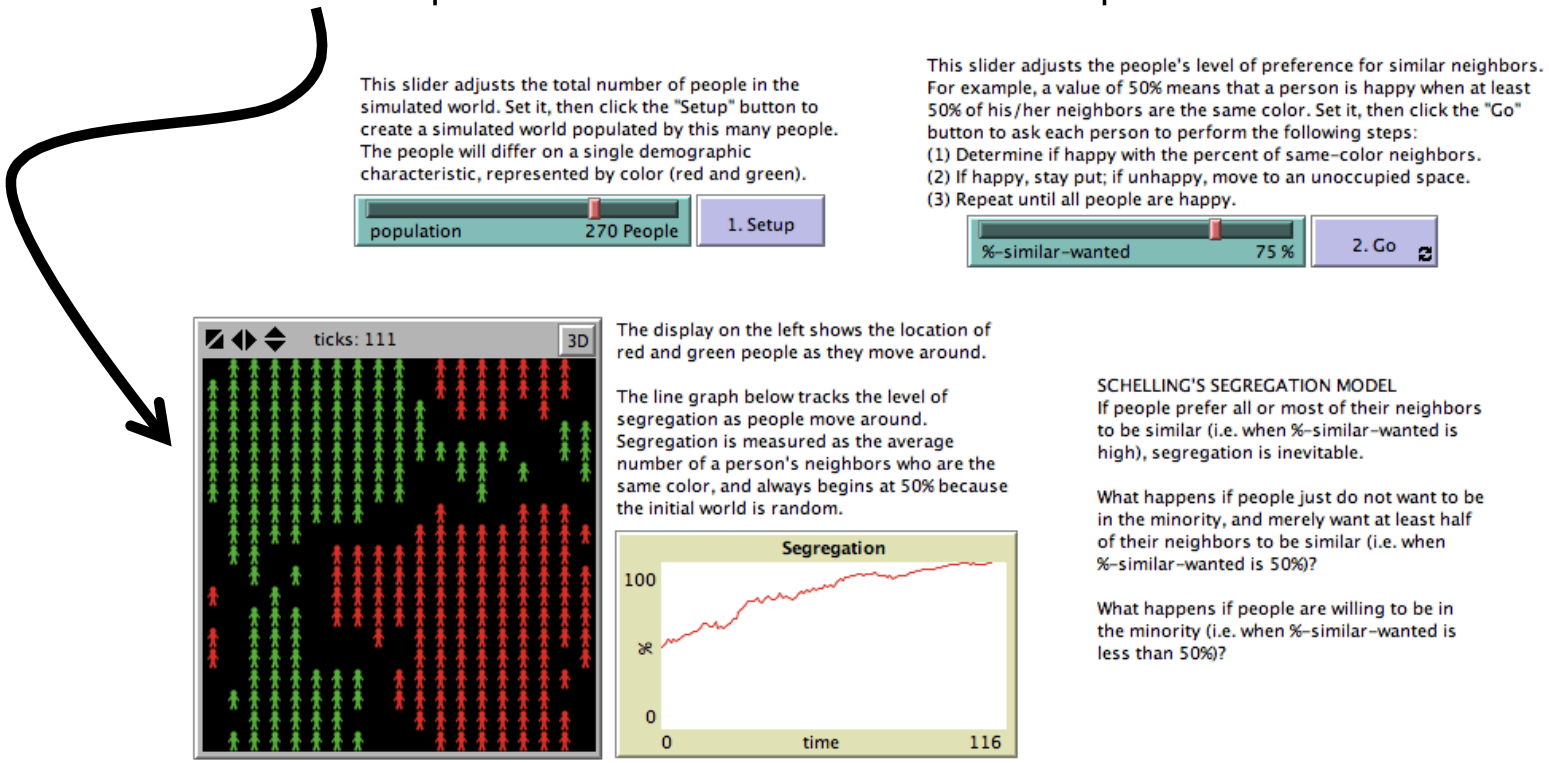
Example: Segregation (Schelling, 1969)

How the model works

(5) Click [2. Go] to allow each household to take a turn following the rule. This repeats until all households' preference is satisfied.



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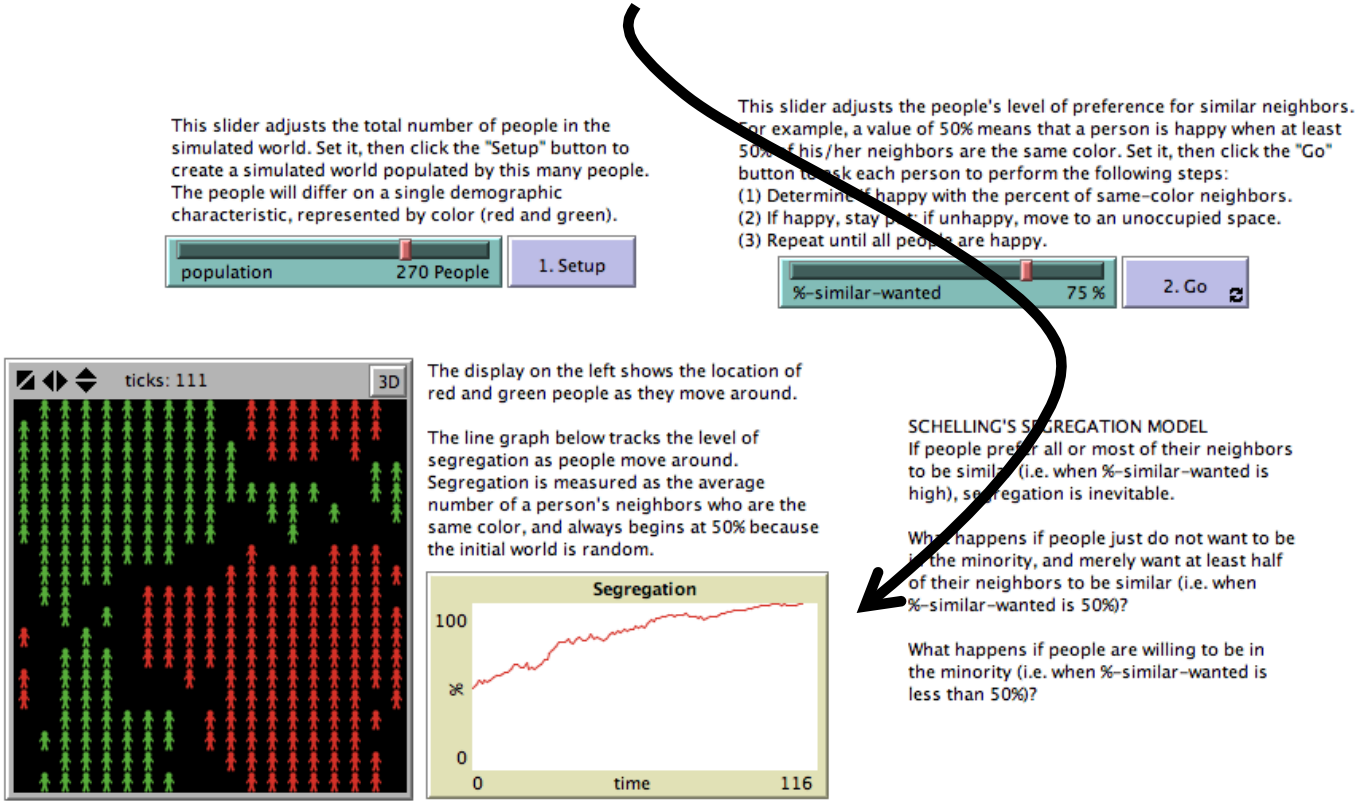
Example: Segregation (Schelling, 1969)

How the model works

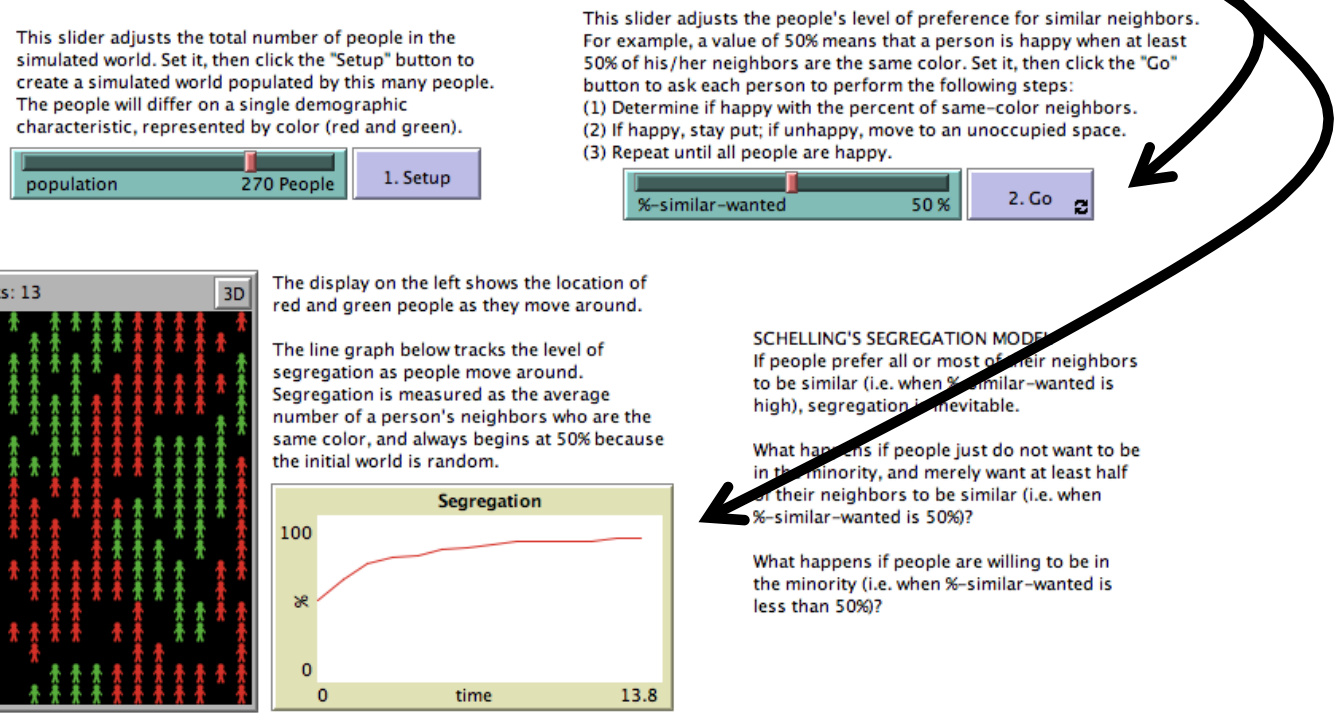
(6) Look at the resulting level of segregation. (almost 100%)



Example: Segregation (Schelling, 1969)

How the model works

(7) Repeat with a different level of preference (50) and compare the resulting level of segregation (almost 90%).



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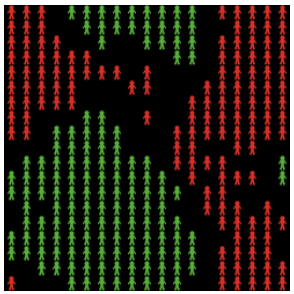
Example: Segregation (Schelling, 1969)

What can we learn?

A preference that most of your neighbors are like you (X = 75) can lead to segregation. ➔



A preference that at least half your neighbors are like you (X = 50) can lead to segregation. ➔

A preference that at least one-third of your neighbors are like you (X = 33) can lead to segregation. ➔

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Example: Segregation (Schelling, 1969)

What can we learn?

A preference that most of your neighbors are like you (X = 75) can lead to segregation.

A preference that at least half of your neighbors are like you (X = 50) can lead to segregation.

A preference that at least one-third of your neighbors are like you (X = 33) can lead to segregation.

Residential segregation can emerge even when no one prefers living in a segregated neighborhood.

Example: Segregation & Cohesion

(Neal & Neal, 2014)

Purpose

Multiple empirical studies by Robert Putnam and others have suggested that diverse and integrated neighborhoods tend to be less cohesive. Why?

What kinds of social relationship-forming behaviors would lead segregated neighborhoods to be cohesive, but integrated neighborhoods to be fragmented?

Example: Segregation & Cohesion

(Neal & Neal, 2014)

The agents

Like Schelling, two types of households: **GREEN** and WHITE

- All households have a preference (called homophily) for forming social ties with households that are the same color.
- All households have a preference (called proximity) for forming social ties with households that are nearby.
- The researcher can set these preferences to be stronger or weaker.

Example: Segregation & Cohesion

(Neal & Neal, 2014)

The behavioral rule

Based on your preferences for homophily and proximity, form social ties with other households in your neighborhood.

For example:

– If a **GREEN** household has a preference for homophily, it will be more likely to form ties with other **GREEN** households, than with WHITE households.

– If a household has a preference for proximity, it will be more likely to form ties with nearby households, than with households located further away.

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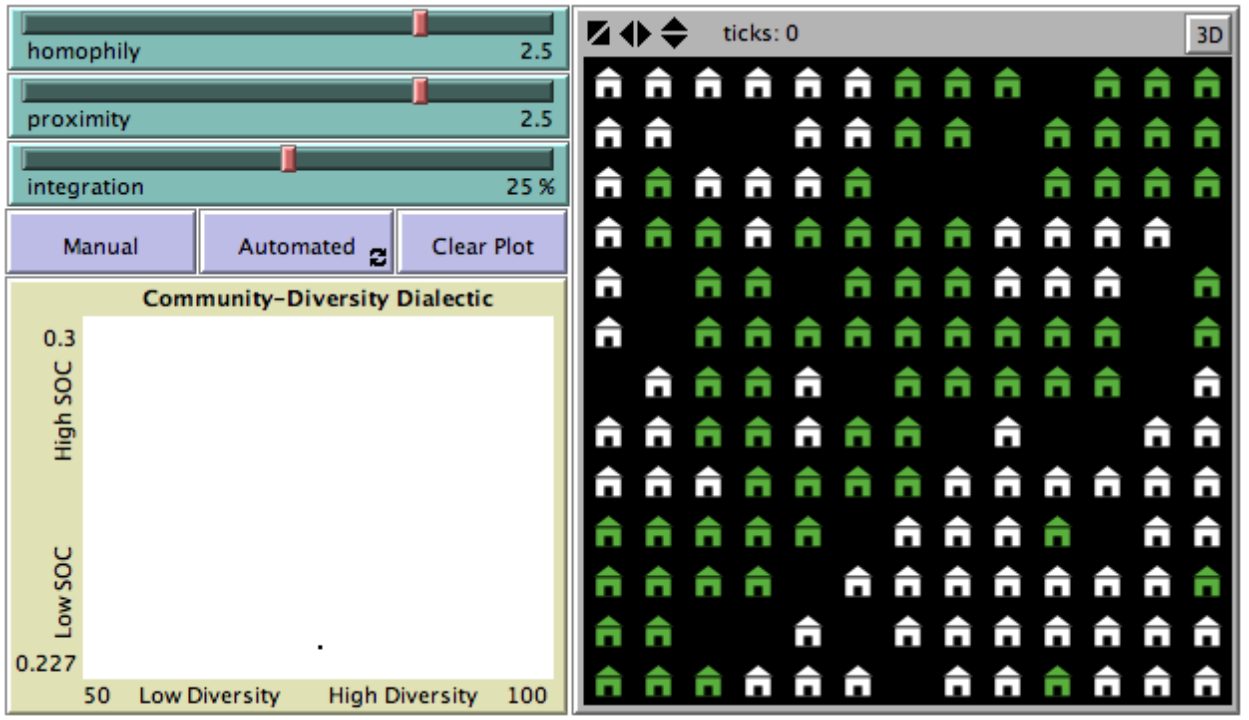
Example: Segregation & Cohesion

(Neal & Neal, 2014)

How the model works

(1) Create a neighborhood with a specified level of residential integration. (Note: This step uses Schelling's model)



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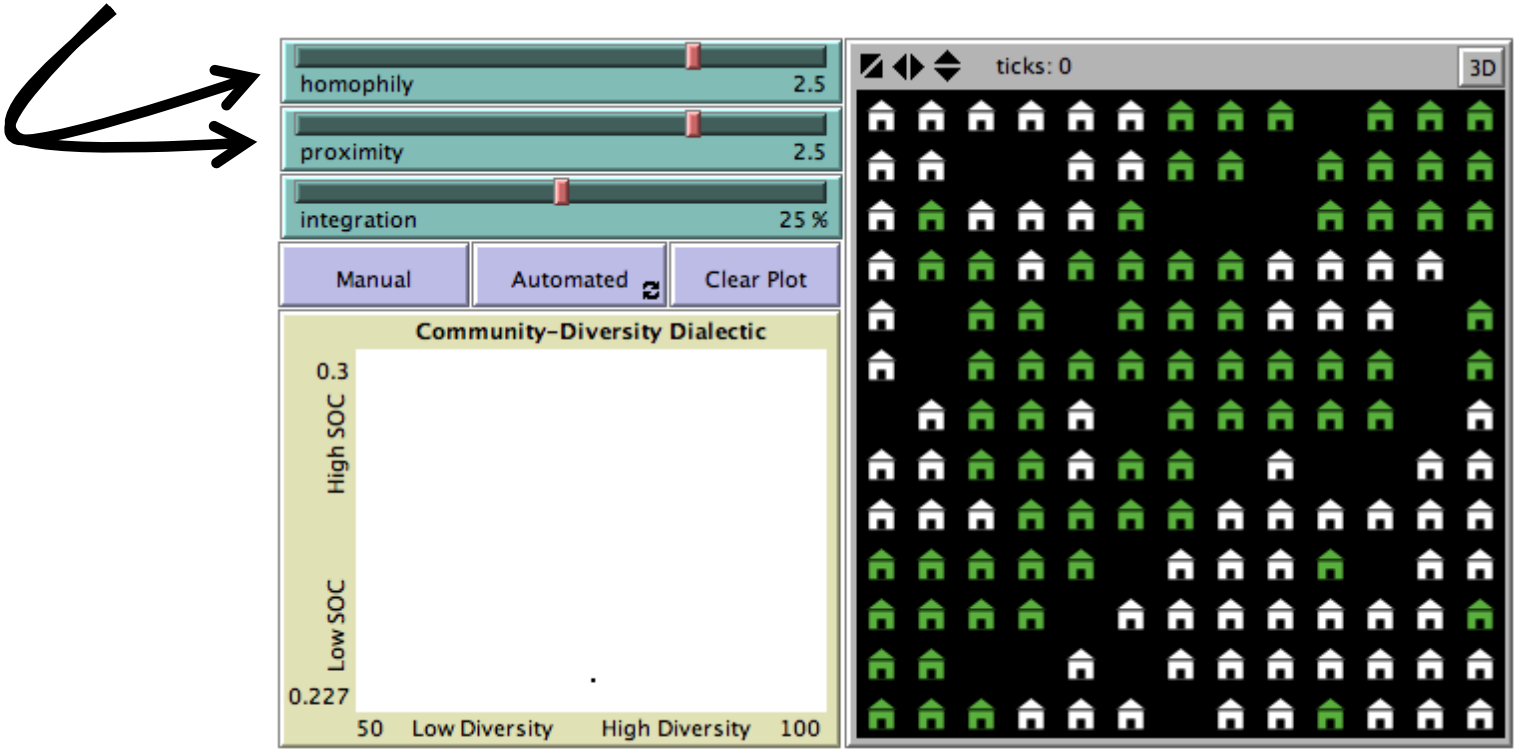
Example: Segregation & Cohesion

(Neal & Neal, 2014)

How the model works

(2) Set households' preferences for homophily and proximity in their social networks.



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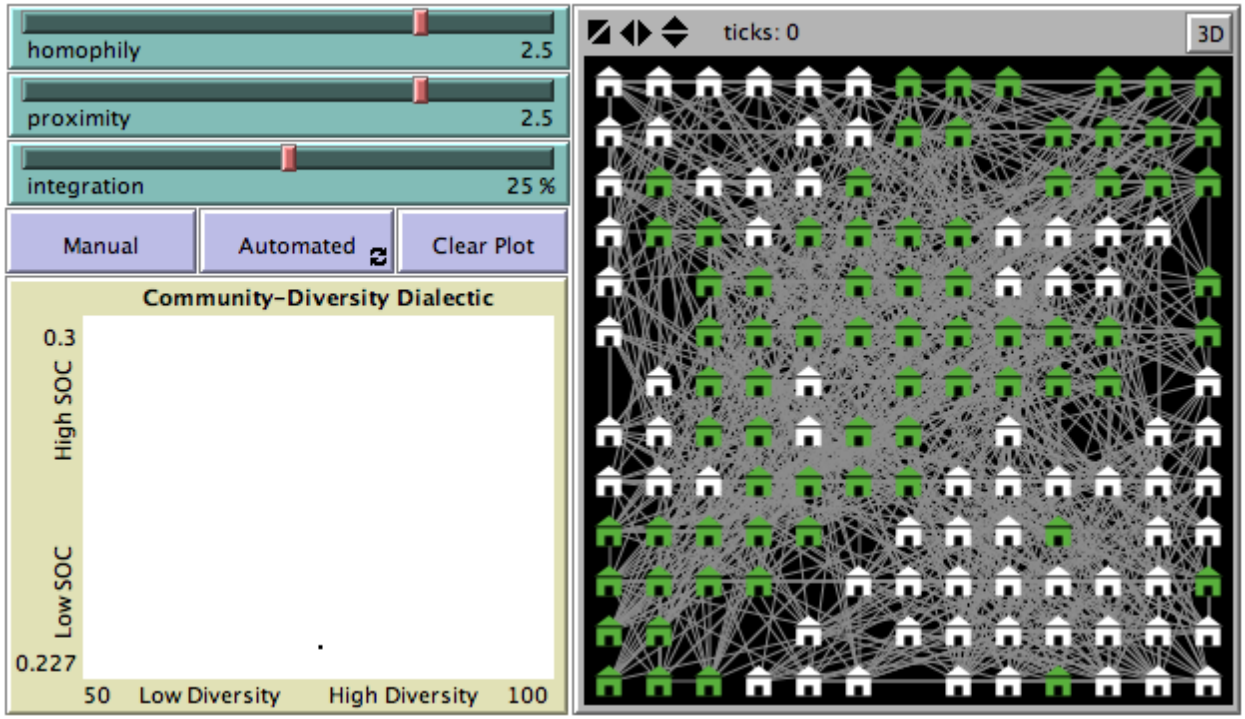
Example: Segregation & Cohesion

(Neal & Neal, 2014)

How the model works

(3) Allow households' to form social ties with other households given their preferences for homophily and proximity.



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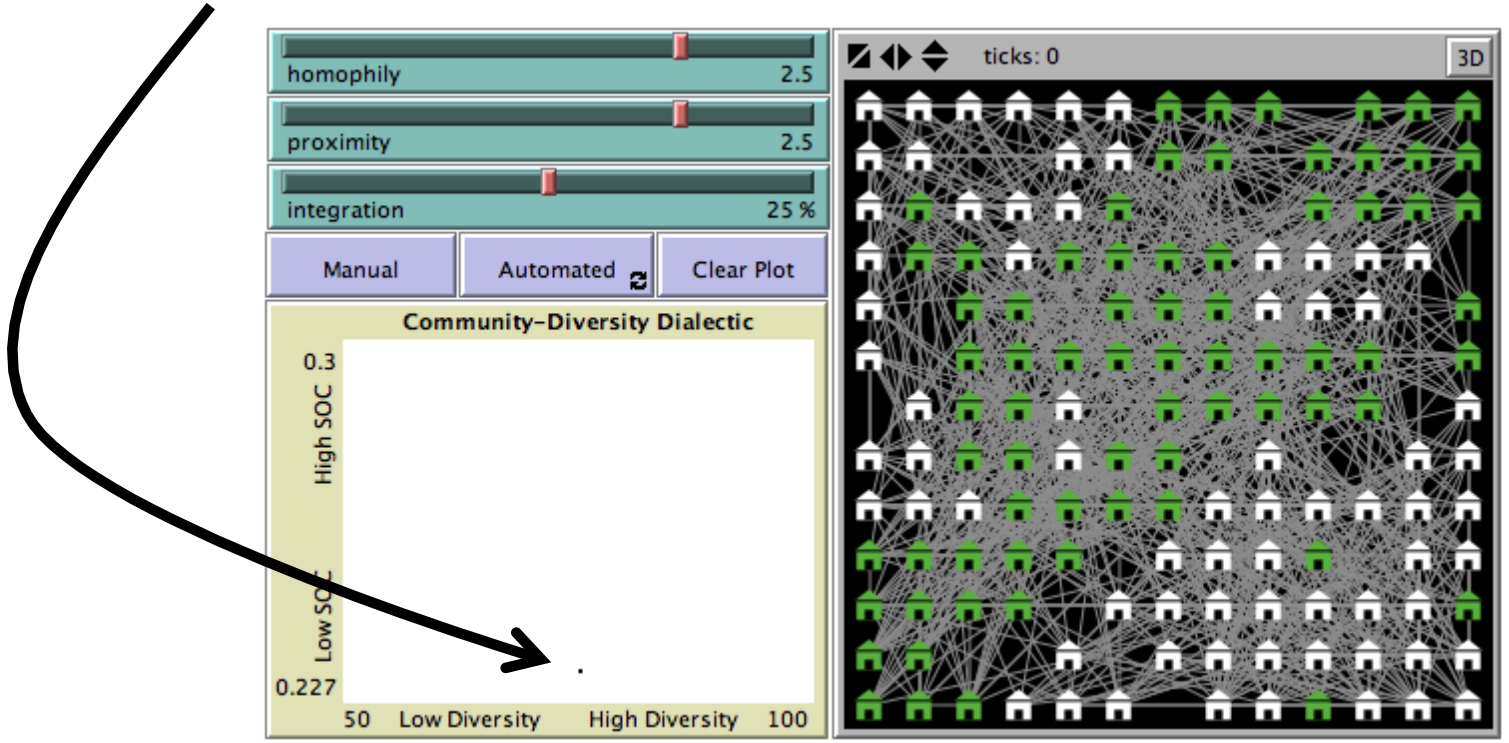
Example: Segregation & Cohesion

(Neal & Neal, 2014)

How the model works

(4) Record the level of integration in the neighborhood, and the amount of cohesion in the social network.



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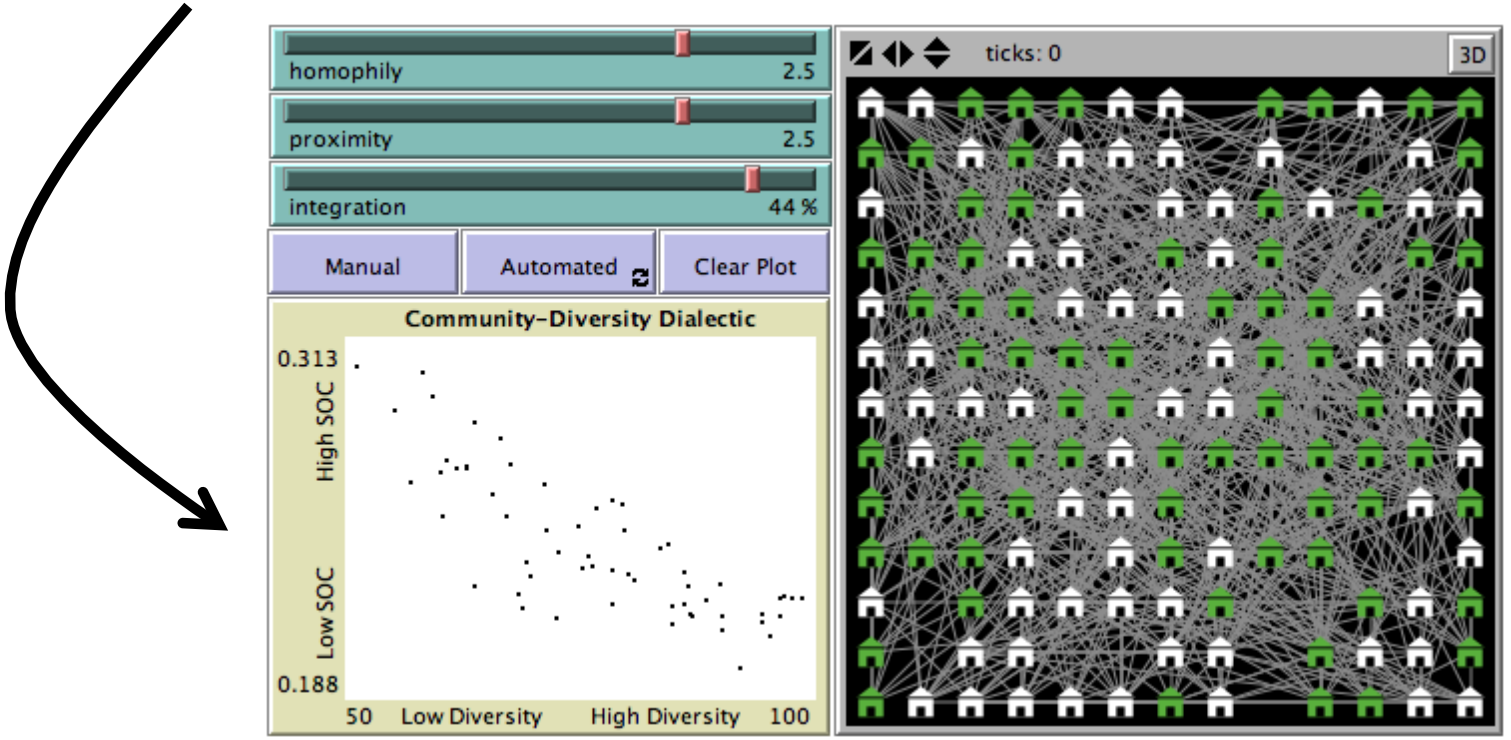
Example: Segregation & Cohesion

(Neal & Neal, 2014)

How the model works

(5) Repeat in neighborhoods with different levels of integration, and look at the relationship between integration & cohesion.



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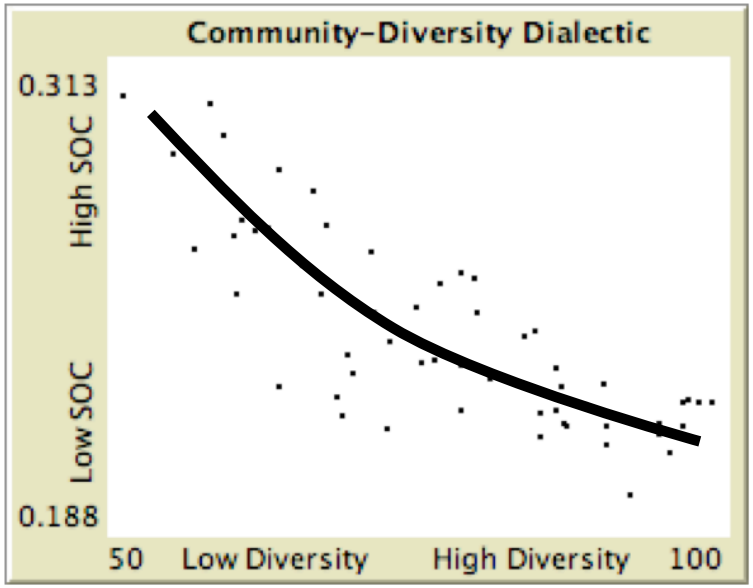
Example: Segregation & Cohesion

(Neal & Neal, 2014)

What can we learn?

The macro-level phenomenon –
The frequently observed pattern that segregated neighborhoods are more cohesive than integrated neighborhoods…

The micro-level behavior –
…is generated because the formation of social relationships is guided by residents' preferences for homophily (similar friends) and proximity (nearby friends).



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Example: Building public spaces

(Neal & Lawlor, 2015)

Purpose

We know that residentially integrated neighborhoods tend to be less cohesive. Can this tendency be mitigated by building public spaces that provide residents with opportunities for social mixing?

Taking Neal & Neal's (2014) model of segregation and cohesion as a starting point, what happens if we build some parks?

Example: Building public spaces

(Neal & Lawlor, 2015)

The agents

Same as Neal & Neal (2014)

But, all households also have a preference (called place homophily) for forming social ties with households that us the same community public space.

The behavioral rule

Same as Neal & Neal (2014), but residents also take public spaces into account when deciding when to form social ties with other households.

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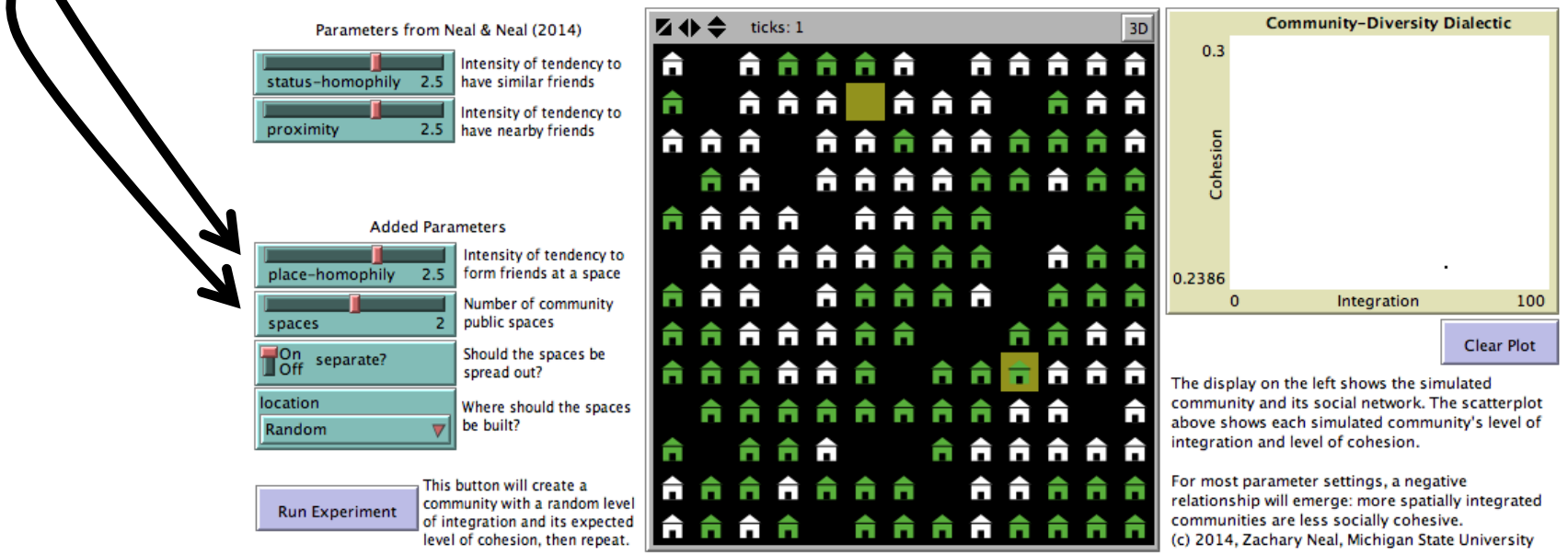
Example: Building public spaces

(Neal & Lawlor, 2015)

How the model works

(1) Setup is the same as Neal & Neal (2014), except the researcher also sets:

- households' preferences for "space homophily"
- the number of public spaces in the community (yellow squares)



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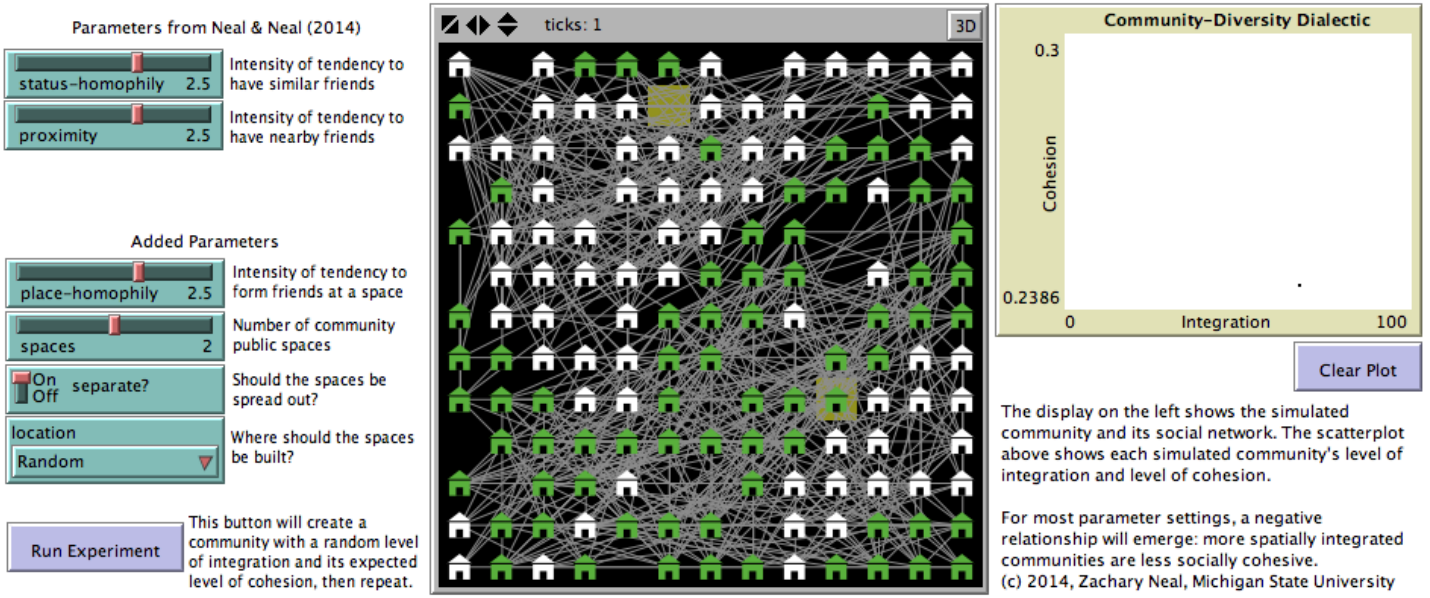
Example: Building public spaces

(Neal & Lawlor, 2015)

How the model works

(2) Running is the same as Neal & Neal (2014), except that households also consider public spaces when forming ties.



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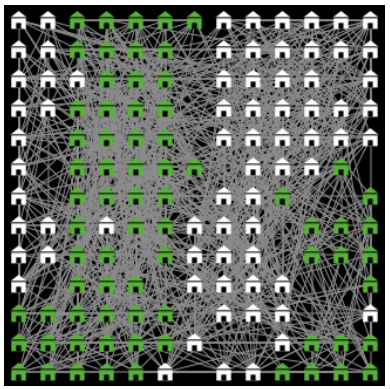
Example: Building public spaces

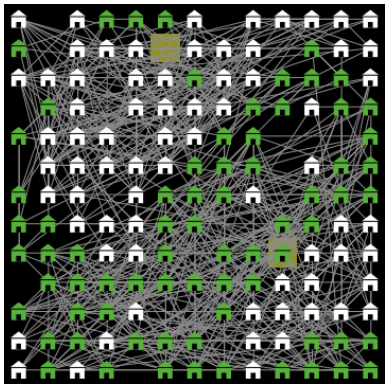
(Neal & Lawlor, 2015)

What can we learn?

When there are no public spaces, like in Neal & Neal's (2014) original model, relationships are clustered within segregated parts of the neighborhood. ➔



When public spaces are added, relationships cluster around these spaces and bridge across the segregated parts of the neighborhood. ➔



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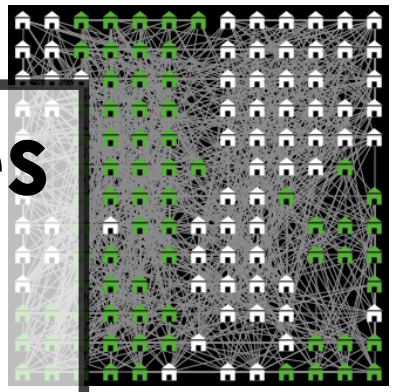
Example: Building public spaces

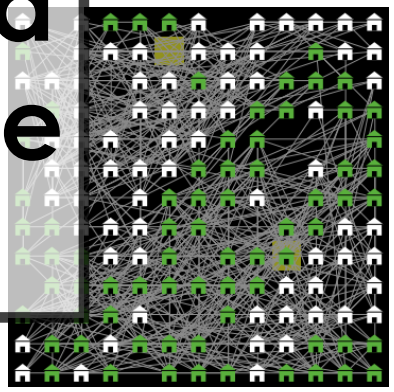
(Neal & Lawlor, 2015)

What can we learn?

When there are no public spaces like in Neal & Neal's (2014) original model, relationships are clustered within segregated pods of the neighborhood. →



When public spaces are added, relationships cluster around these spaces and bridge across the segregated pods of the neighborhood. →



Building public spaces in communities may be one way to help diverse and integrated neighborhoods also be socially cohesive.

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Take-away points about ABM

– Highly flexible method for understanding how big-picture phenomena emerges from small-picture behaviors.

– Useful for testing interventions, anticipating unanticipated consequences, and guiding data collection

– Models can be built by adapting and extending earlier models: Schelling → Neal & Neal → Neal & Lawlor

Questions?

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Introduction to Agent-Based Modeling

AGENT-BASED MODEL EXAMPLES

Reynolds' (1987) flocking model –

- **Learn more:** Reynolds, C. W. (1987) Flocks, Herds, and Schools: A Distributed Behavioral Model. *Computer Graphics, 21,* 25-34.
- **Follow along**: http://ccl.northwestern.edu/netlogo/models/run.cgi?Flocking.783.569

Schelling's (1969) segregation model –

- **Learn more:** Schelling, T. (1969). Models of segregation. *American Economic Review, 59*, 488-493.
- **Follow along:** https://www.msu.edu/~zpneal/communityabm/segregation.html

Neal & Neal's (2014) neighborhood social network model –

- **Learn more:** Neal, Z., & Neal, J. (2014). The (in)compatibility of diversity and sense of community. *American Journal of Community Psychology, 53*, 1-12.
- **Follow along:** https://www.msu.edu/~zpneal/research/nhoodnet.html

Neal & Lawlor's (2015) public space intervention model –

- **Learn more:** Neal, Z. & Lawlor, J. (2015). Agent-based models. In *Handbook of methodological approaches to community-based research: Qualitative, quantitative, and mixed methods*, edited by Jason, L. A., & Glenwick, D. S. New York, NY: Oxford University Press.
- **Follow along:** https://www.msu.edu/~zpneal/communityabm/publicspace.html

SOME USEFUL RESOURCES

Introductory textbook on using agent-based models –

- Railsback, S. F., & Grimm, V. (2011). *Agent-Based and Individual-Based Modeling: A Practical Introduction*. Princeton, NJ: Princeton University Press.

Free and user-friendly software for building and running agent-based models –

- Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

CONTACT INFORMATION

If you have any questions or would like to know more about agent-based modeling, please do not hesitate to contact me:

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