Agent-Based Systems

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Slides credit: Ozalp Babaoglu

Agents

- An Autonomous Agent is an entity that interacts with its environment (including other agents)
  - without any central coordination
  - using local information only
  - without following any global plan
- Behavior may be
  - “Optimal” based on rational choices
  - Non-optimal (simple) and involve interacting with (and changing) the environment
- Some global outcome may result (often surprisingly) from simple local interactions

Simple Models

- Termites
- Langton's Ants
- Schelling’s Segregation Model
- Flocking Vee formation
- Fireflies

Termites

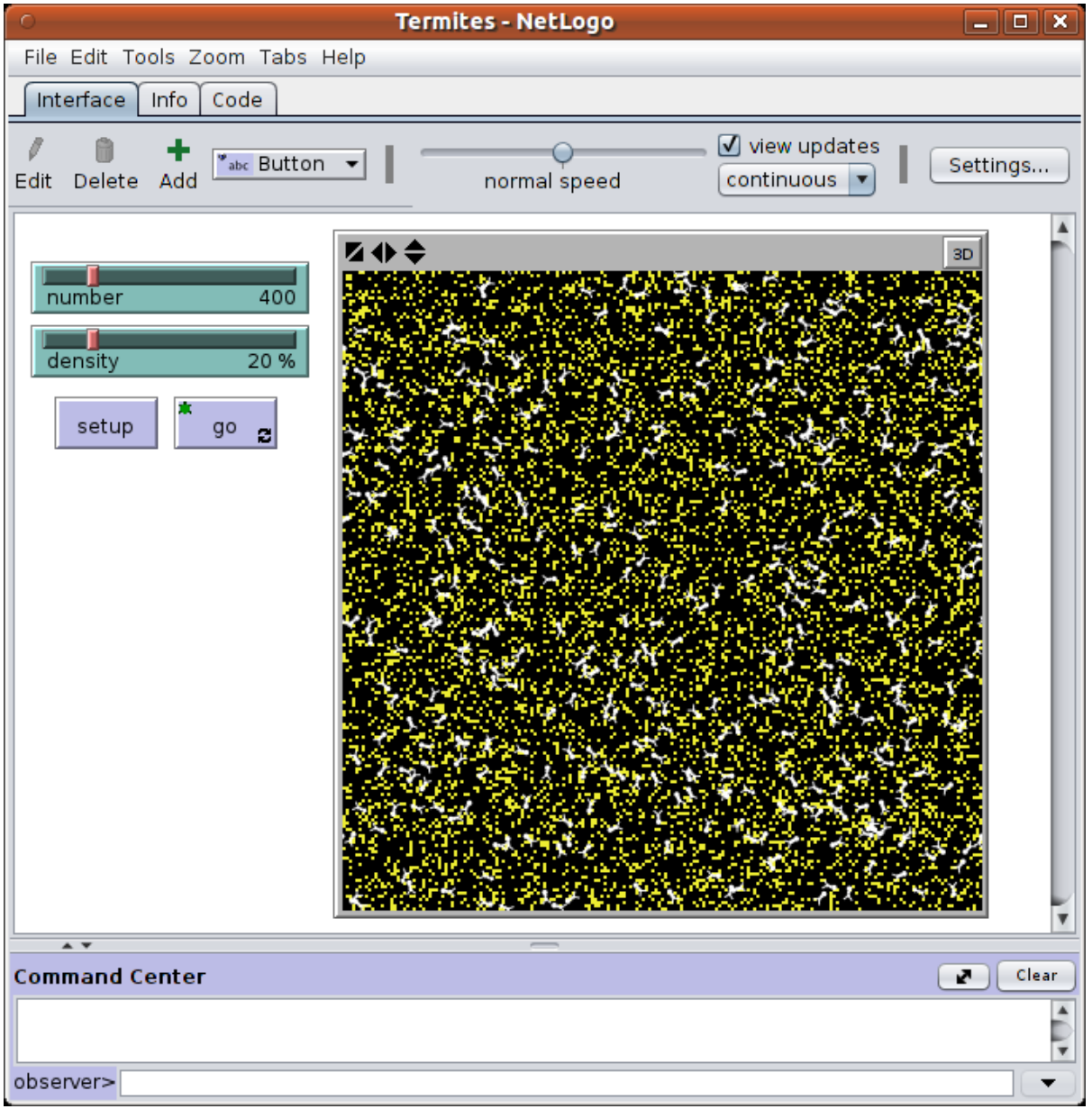
Termites

- Wood chips distributed over a 2-Dimensional space
- Rules for termites:
  - Wander randomly until the termite bumps into a wood chip
  - If the termite is carrying a wood chip, it drops the chip and continues to wander
  - If the termite is not carrying a wood chip, it picks up the one that it bumped into and continues to wander
- The rules above are so simple that nothing useful could possibly come out
  - ...or can it?

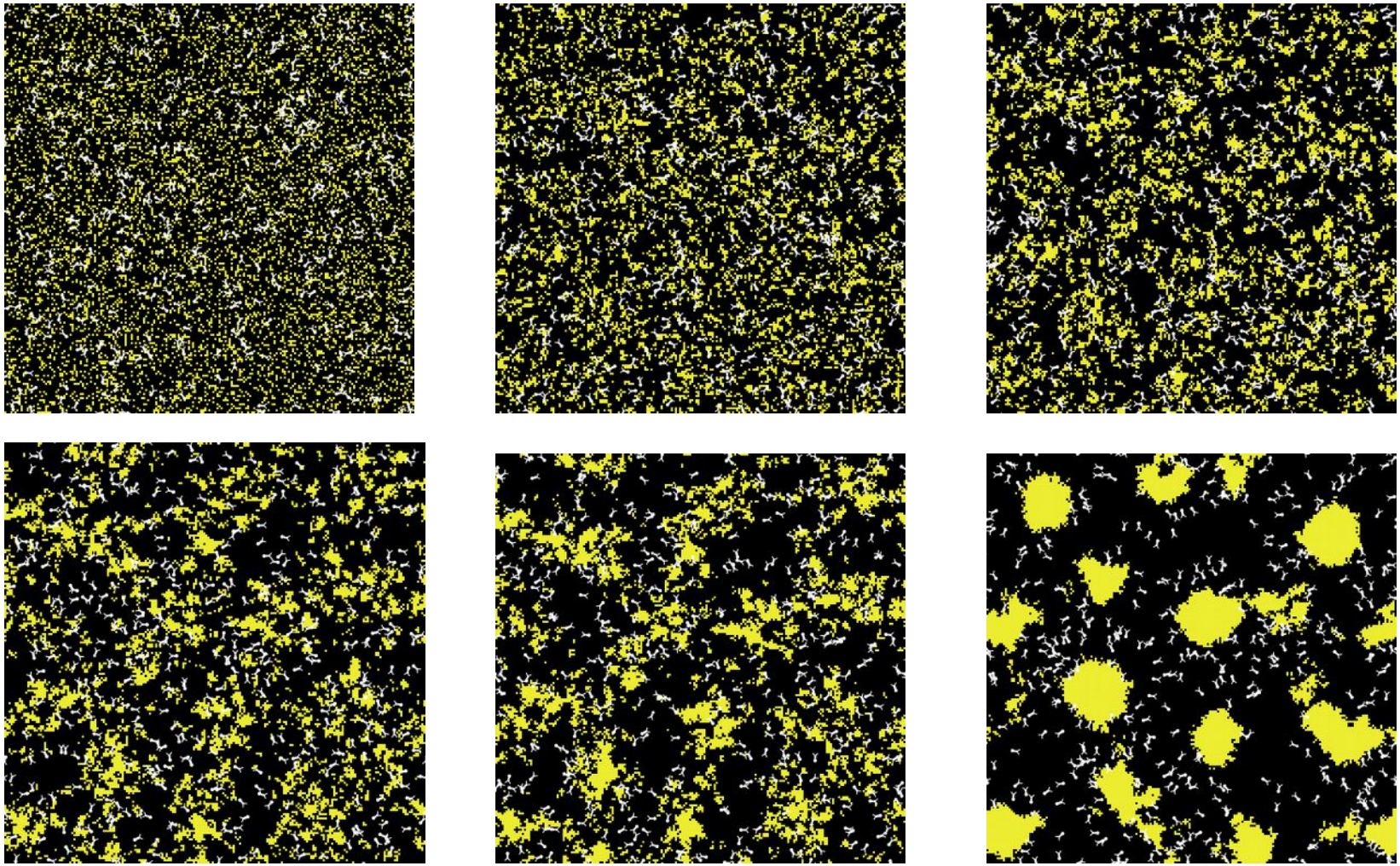
Mitchel Resnick
(MIT)

Termites NetLogo model

Sample Models → Biology → Termites



Termites

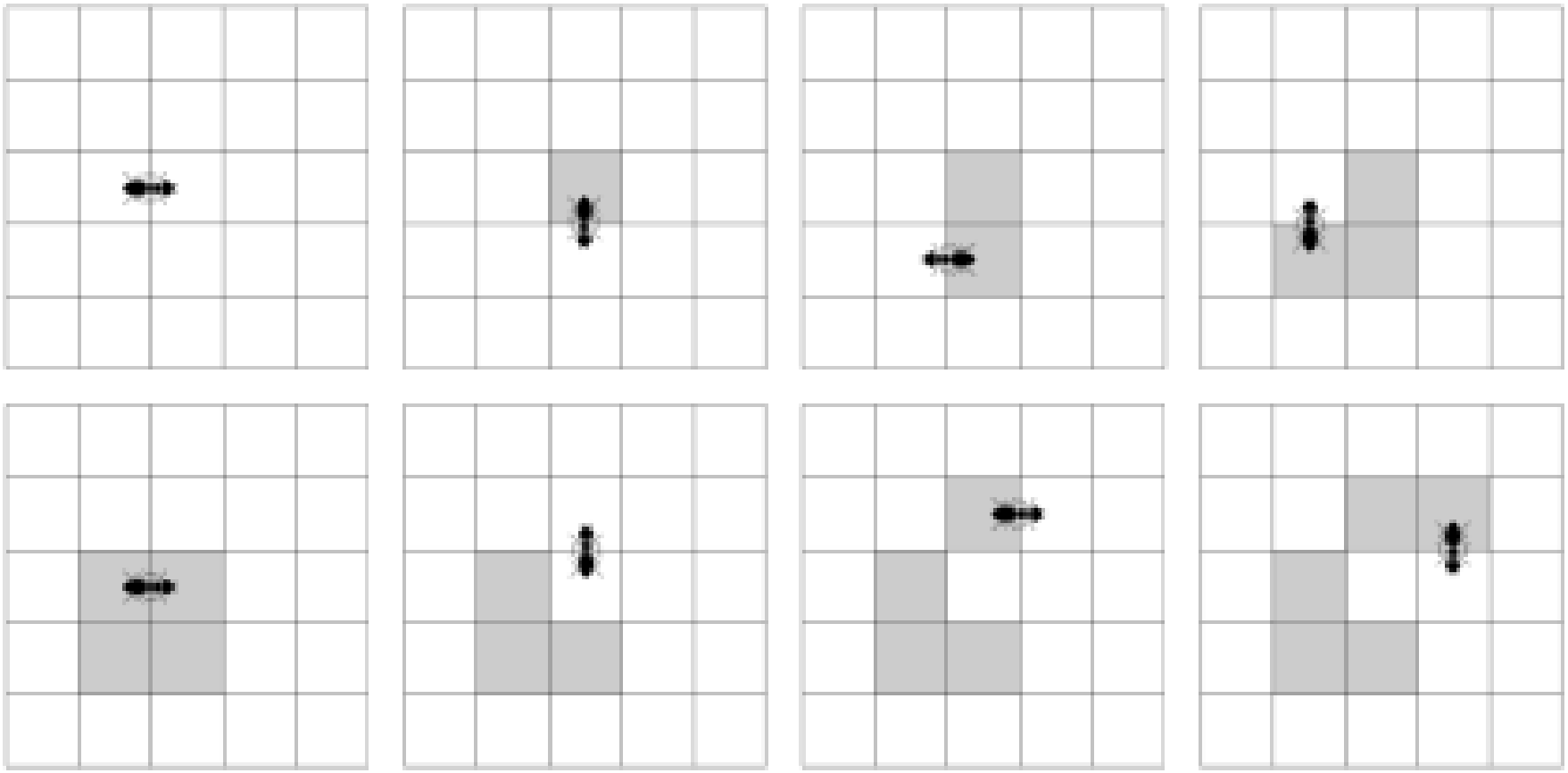


Langton's Ant

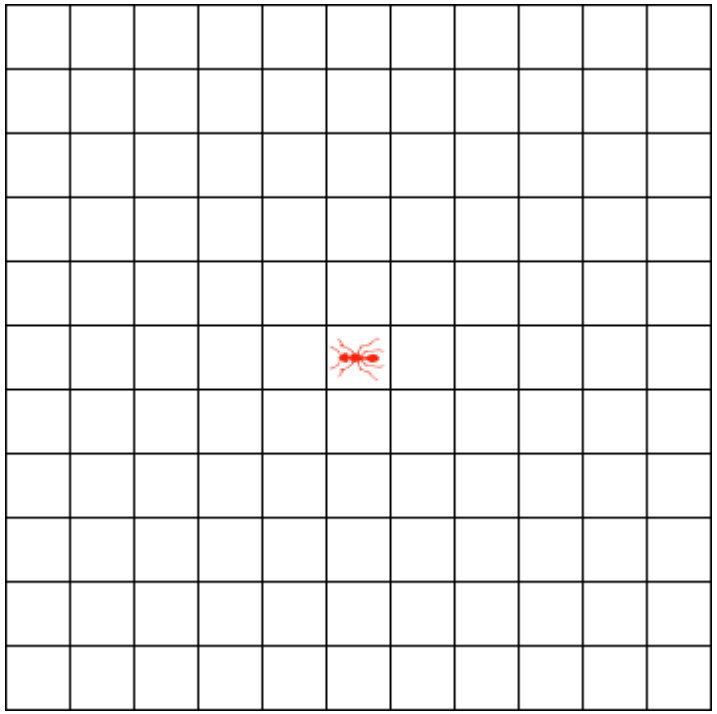
Langton's Ant

- 2D grid, each square can be black or white
- Ants have a direction and can turn right or left, move one square in the current direction, flip color of square they are on
- Rules:
  - If current square "white"
    - Flip the color of square
    - Turn 90° right
    - Move forward one unit
  - If current square "black"
    - Flip the color of square
    - Turn 90° left
    - Move forward one unit

Langton's Ant



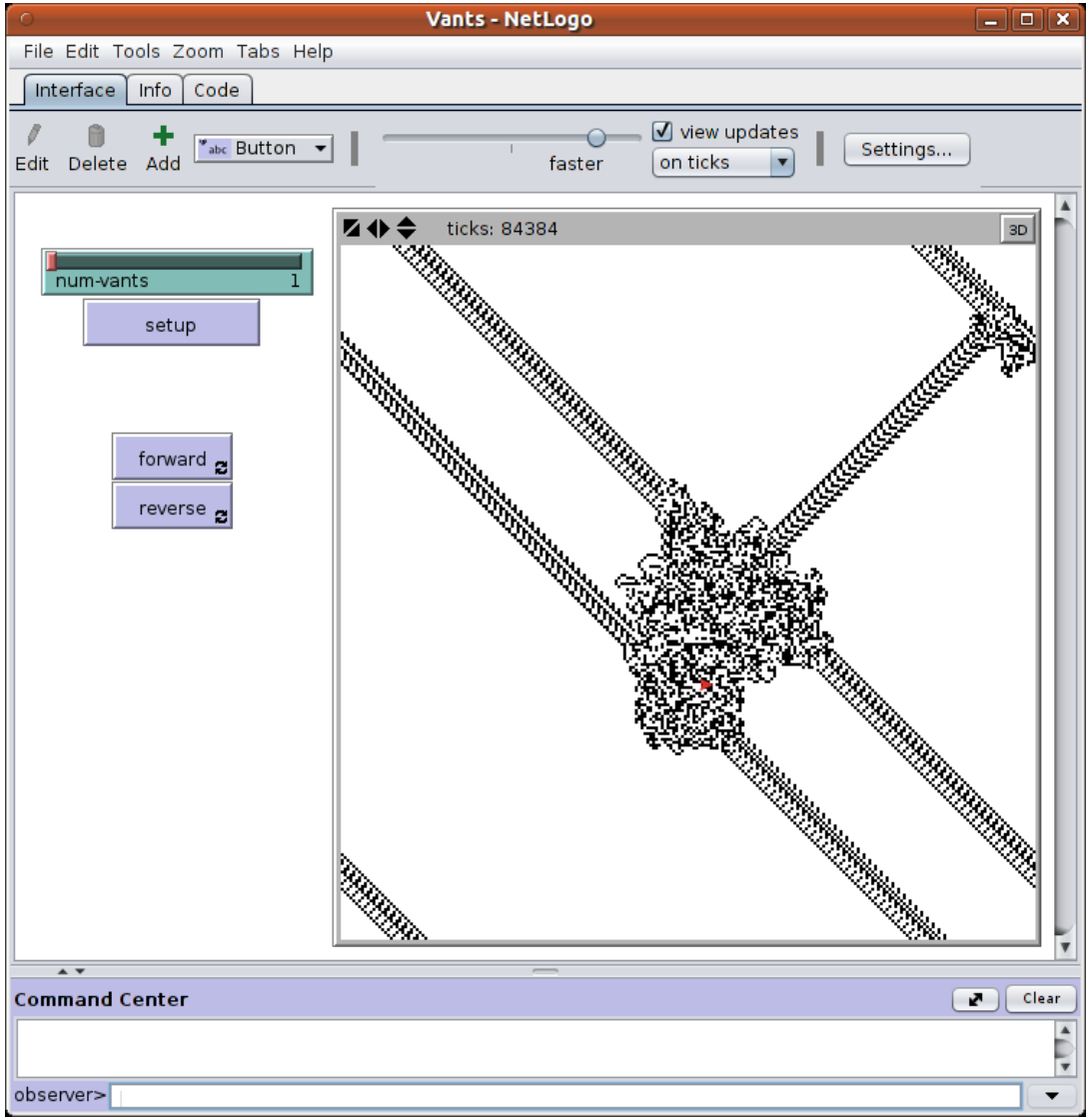
Langton's Ant



Source: https://en.wikipedia.org/wiki/Langton%27s_ant

Langton's Ant

Sample Models → Computer Science → Vants



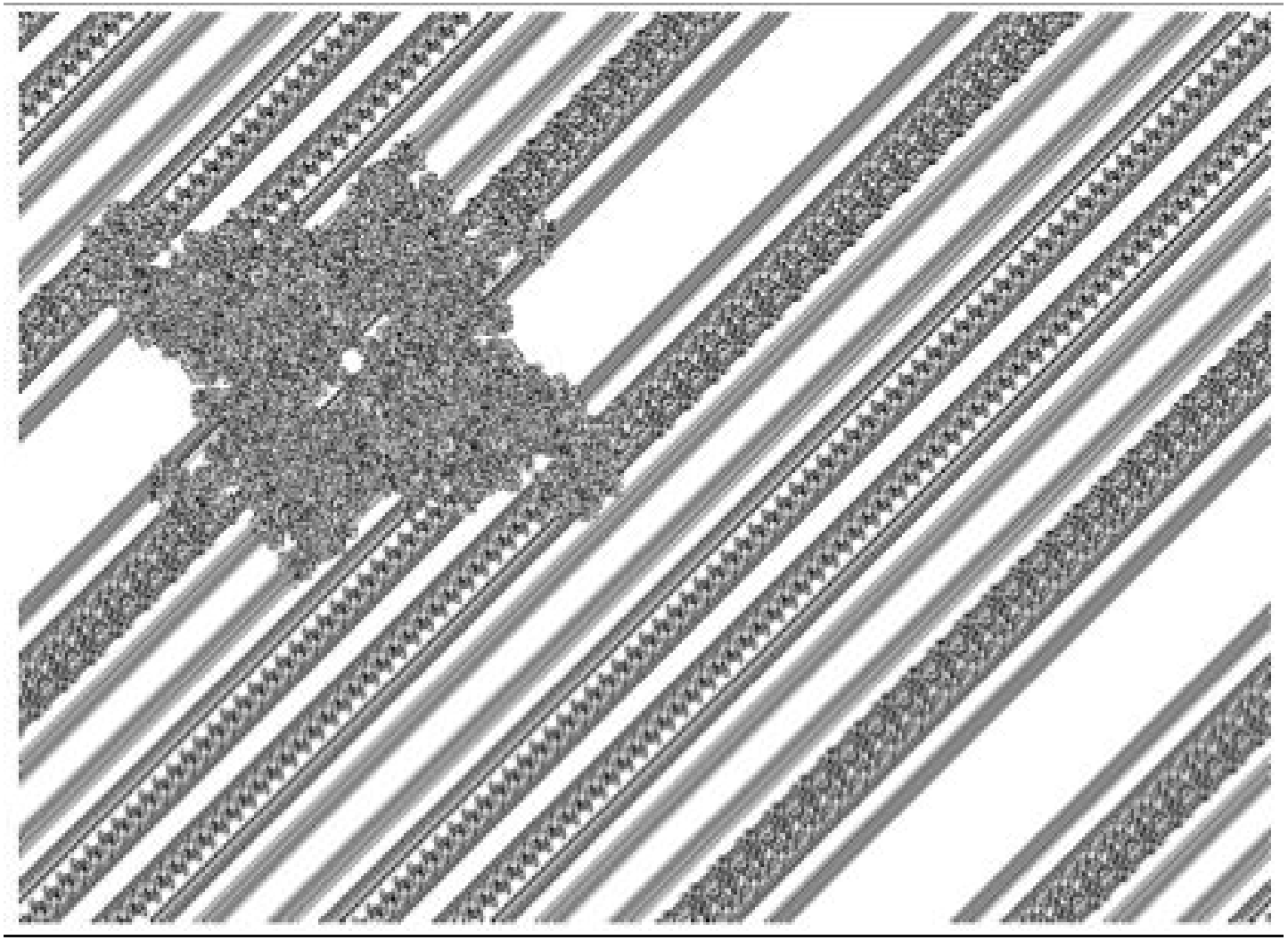
Langton's Ant

- Simplicity
  - During the first few hundred moves, the ant creates very simple symmetric patterns

- Chaos
  - After a few hundred moves, an irregular pattern of black and white squares appears. The ant traces a pseudo-random path until around 10,000 steps

- Emergent order
  - The ant starts building a recurrent "highway" pattern of 104 steps that repeat indefinitely.
  - All tested finite initial configurations eventually converge to the same repetitive pattern, suggesting that the "highway" is an attractor of Langton's ant (
  - The ant's trajectory is always unbounded regardless of the initial configuration (Cohen-Kung theorem)

Multiple Virtual Ants



Langton's Ant

- The rules are time-reversible
  - For each “current” configuration of the ant, there is exactly one “previous” configuration
  - The “arrow of time” can be reversed by simply reversing the direction of the ant(s)
- Langton's Ant is universal
  - An ant can simulate any boolean circuit
  - Gajardo, A.; A. Moreira, E. Goles (15 March 2002). "*Complexity of Langton's ant*". Discrete Applied Mathematics 117 (1-3): 41–50. doi:10.1016/S0166-218X(00)00334-6.

Segregation Model

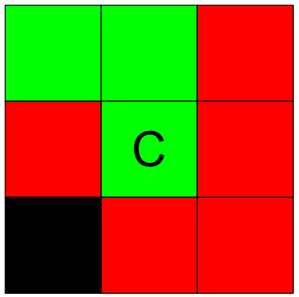
Schelling's Segregation Model

- Rectangular board with green turtles, red turtles and empty patches
- A turtle with less than a fraction *X* of neighbors of its color jumps to a randomly chosen empty patch
  - possibly triggering other turtles to jump
- Thomas C. Schelling. Dynamic Models of Segregation, Journal of Mathematical Sociology, 1(2), pp. 143–186, 1971

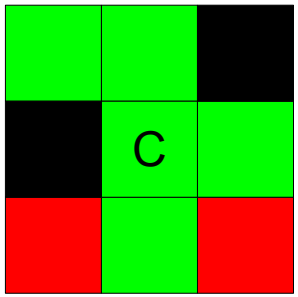
Thomas Crombie Schelling (1921--)

Agent-based model

- Rectangular grid of cells
  - Each cell either empty or occupied by red / green turtle
- Each red / green turtle prefers to have *at least* a fraction X of neighbors of its color
  - Moore Neighborhood
- Example: $X = 0.4$



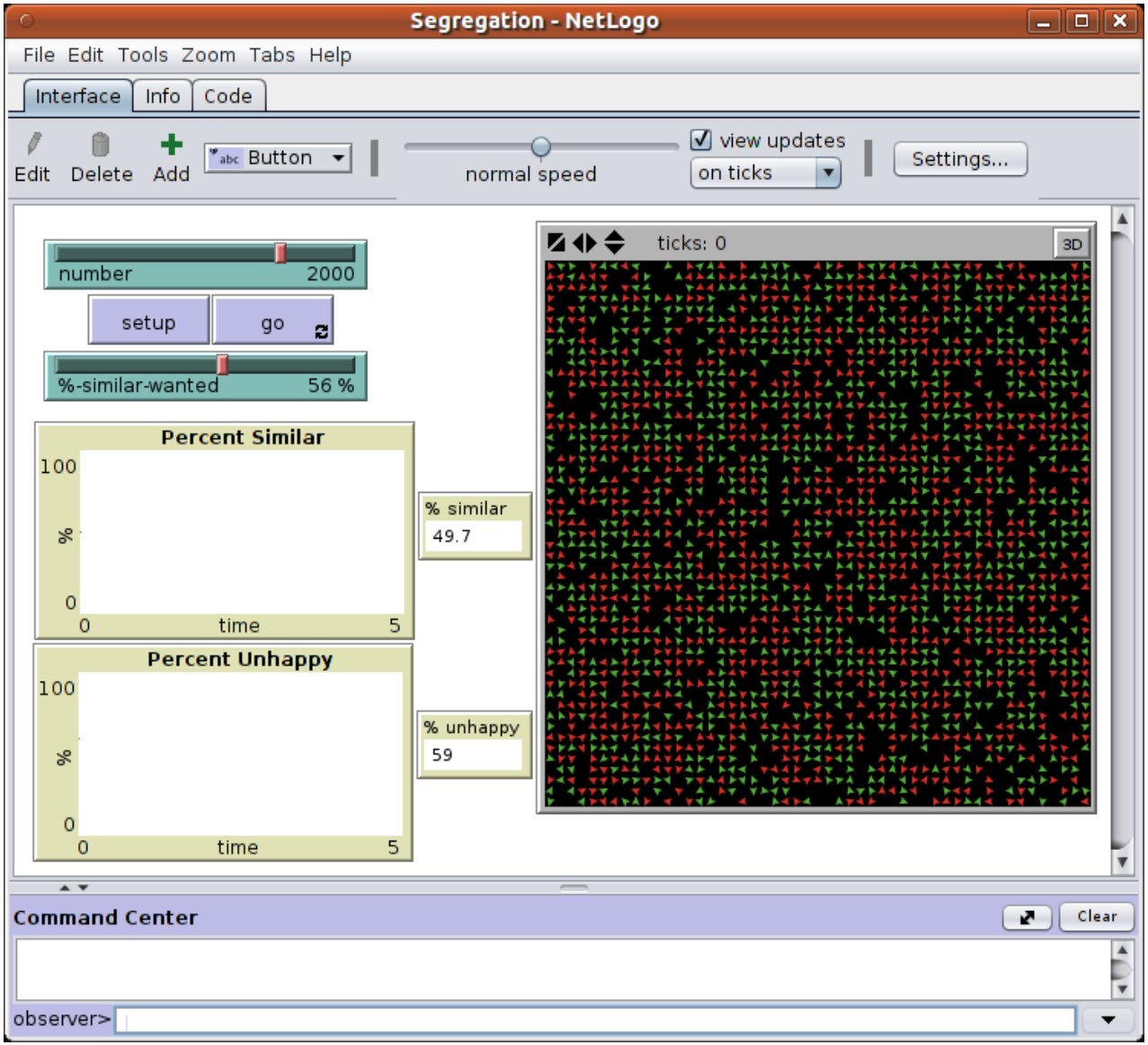
C jumps to a new position



C stays in the current position

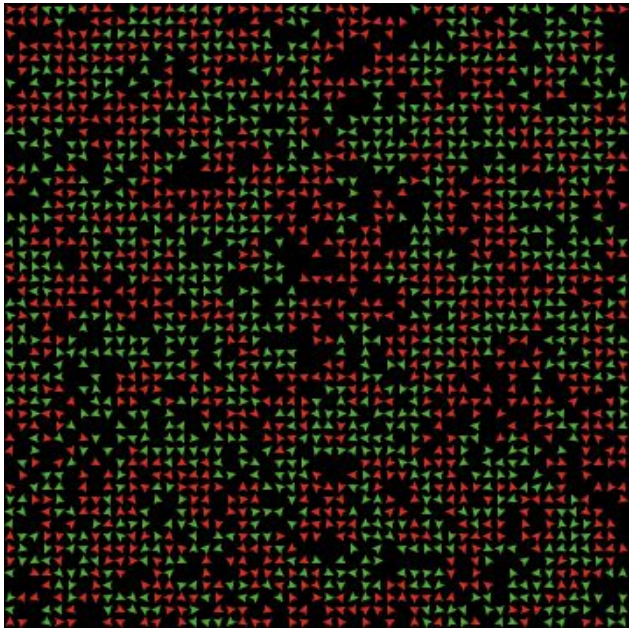
Segregation Model

Sample Models → Social Science → Segregation

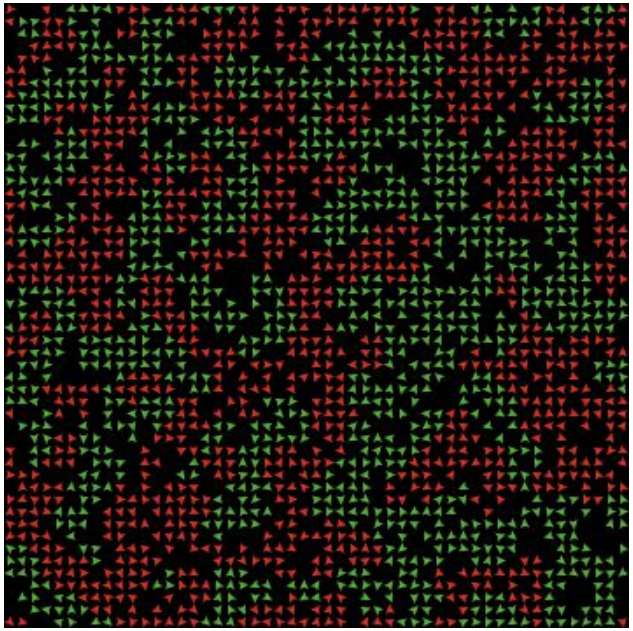


NetLogo segregation model results

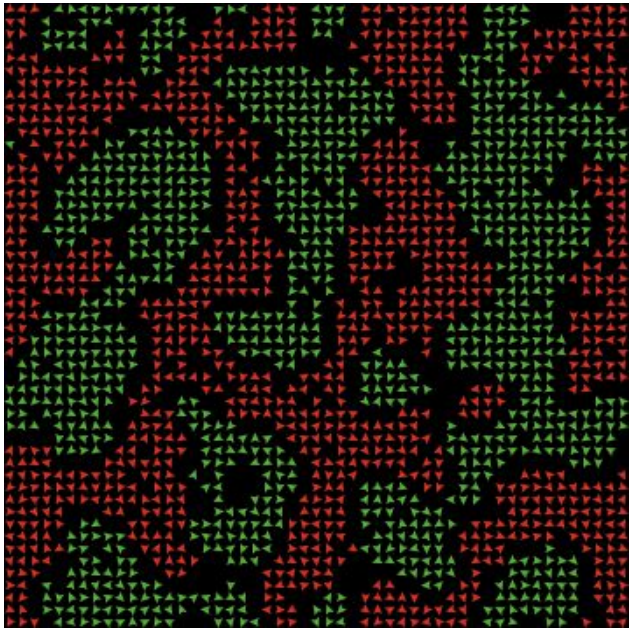
25% neighbors same color



40% neighbors same color

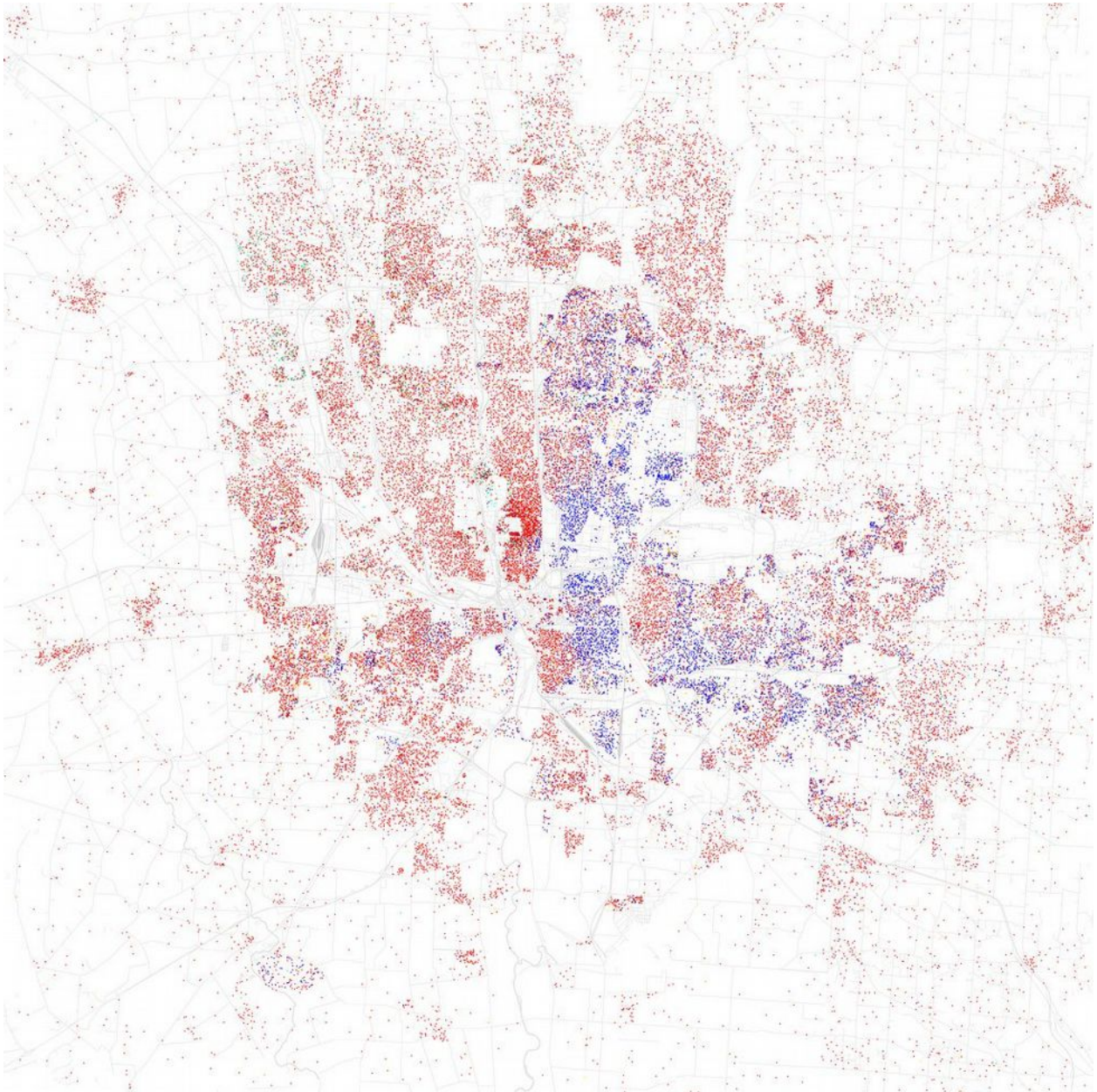


65% neighbors same color



Schelling's Segregation Model in the real world

http://www.businessinsider.com/most-segregated-cities-census-maps-2013-4?op=1#ixzz2Rx64bVpr



COLUMBUS, Ohio — African Americans (blue dots) cluster in the inner city.

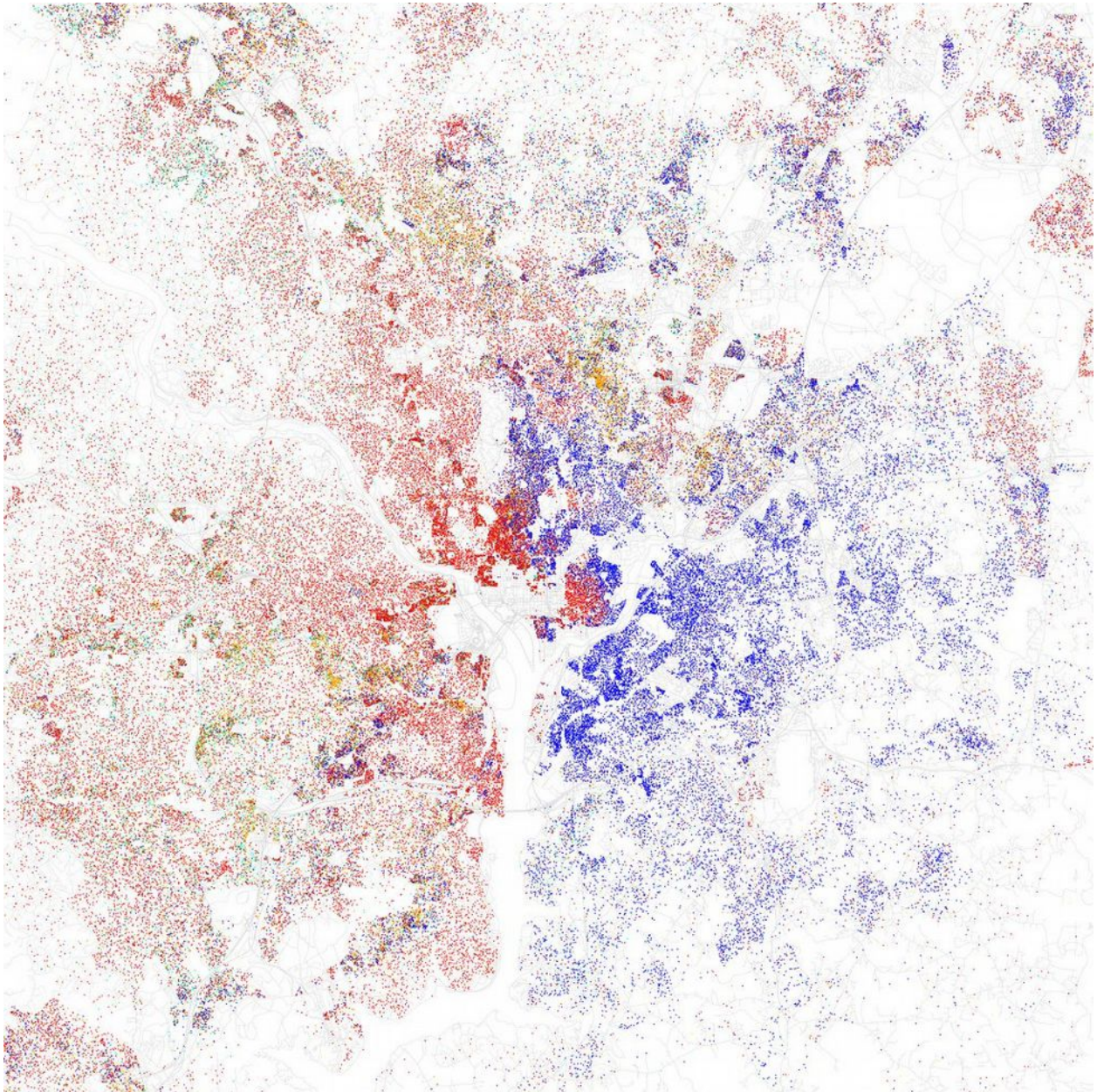
Schelling's Segregation Model in the real world

http://www.businessinsider.com/most-segregated-cities-census-maps-2013-4?op=1#ixzz2Rx64bVpr

HOUSTON, Texas — African Americans, Hispanics (orange dots), and Caucasians (red dots) fan out in separate communities.

Schelling's Segregation Model in the real world

http://www.businessinsider.com/most-segregated-cities-census-maps-2013-4?op=1#ixzz2Rx64bVpr



WASHINGTON, D.C. — White people have gentrified much of downtown D.C., pushing black people to outer Southeast, Northeast, Anacostia, and the Maryland suburbs.

Schelling's Segregation Model in the real world

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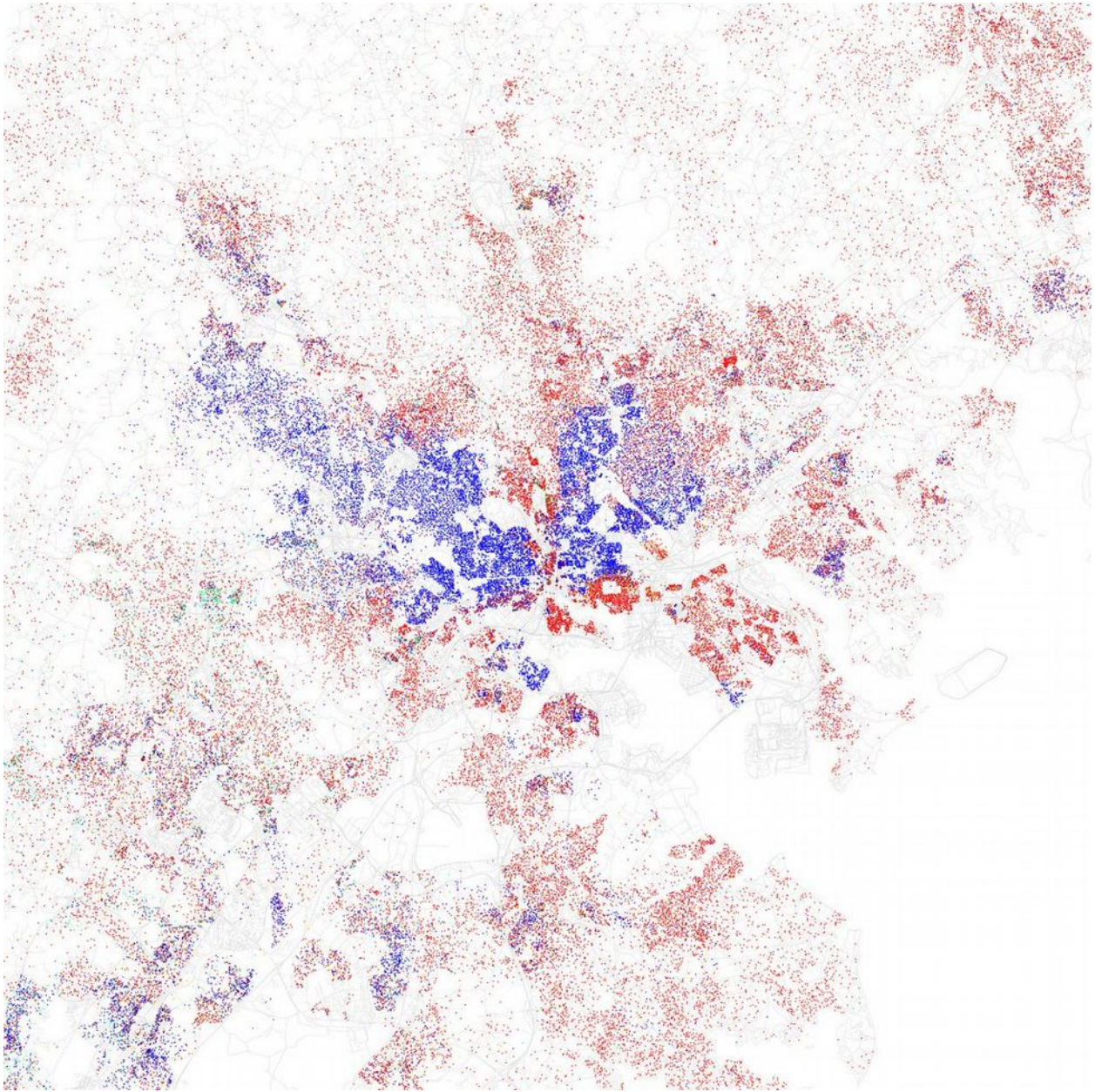
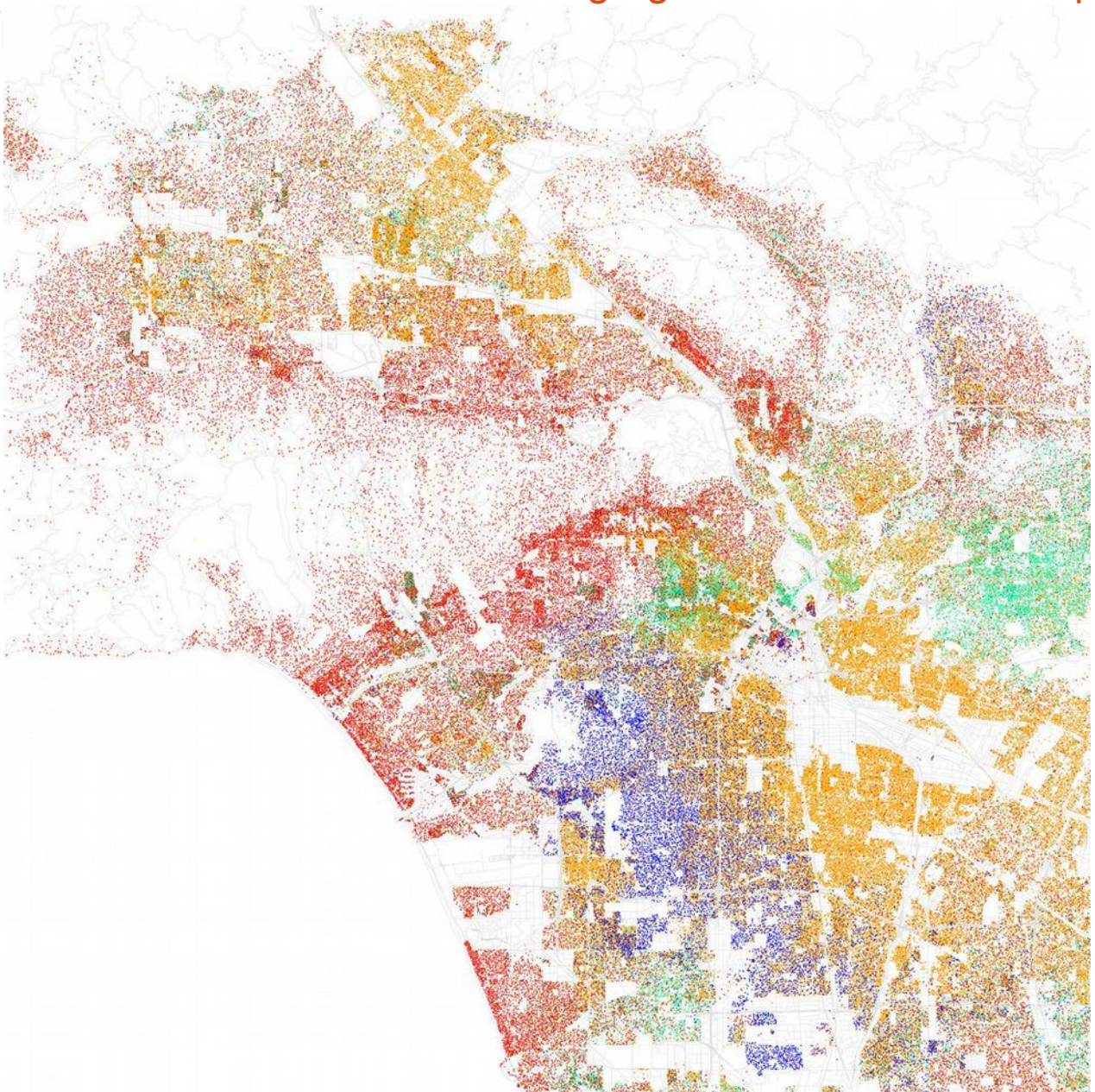


BALTIMORE, Md. — Black people live mostly in the inner city and in the western suburbs.

Schelling's Segregation Model in the real world

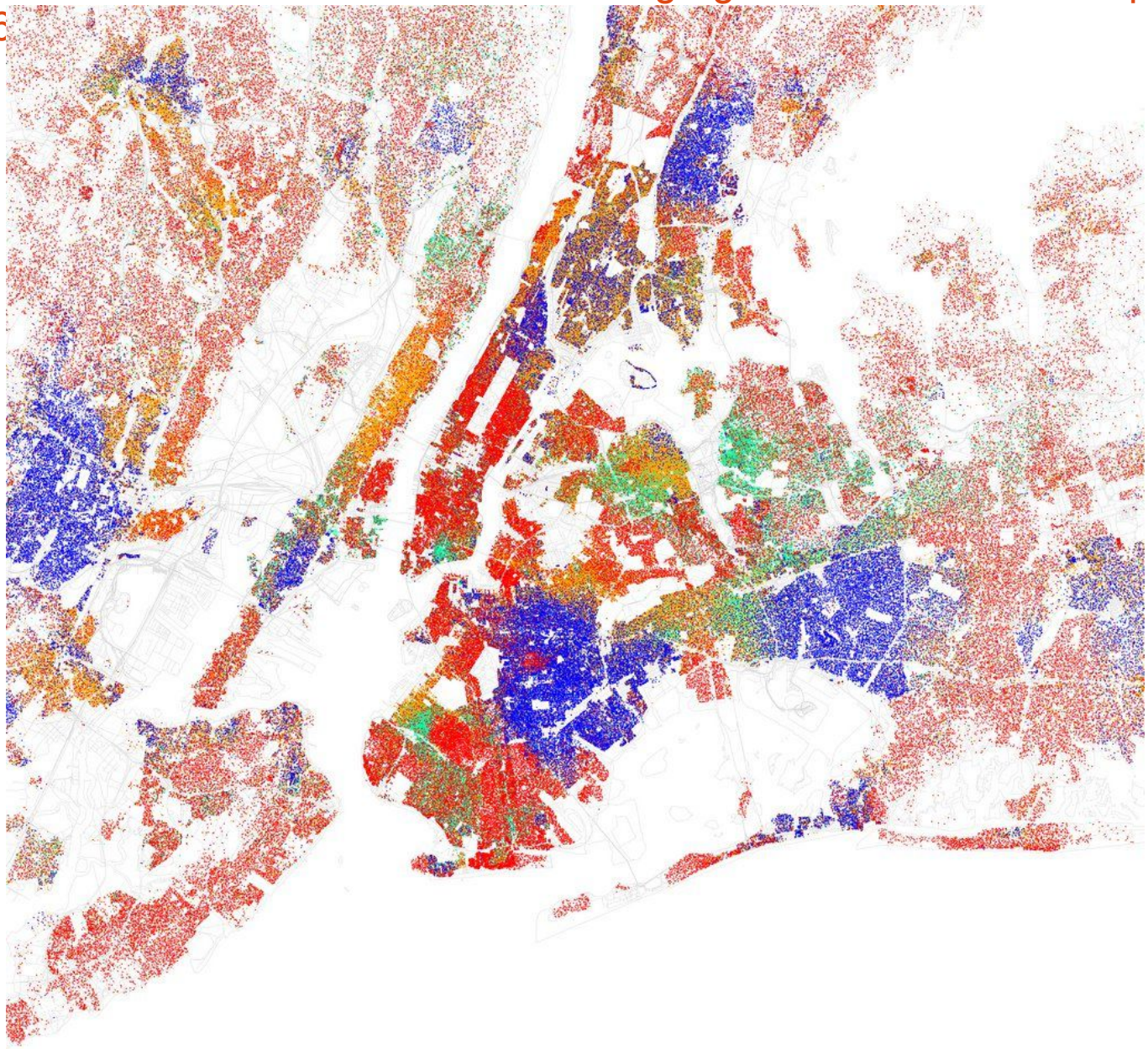
http://www.businessinsider.com/most-segregated-cities-census-maps-2013-4?op=1#ixzz2Rx64bV



LOS ANGELES, Calif. — White people cling to the coast around Santa Monica and Brentwood, and the north side of the city beginning with the Hollywood Hills.

Schelling's Segregation Model in the real world

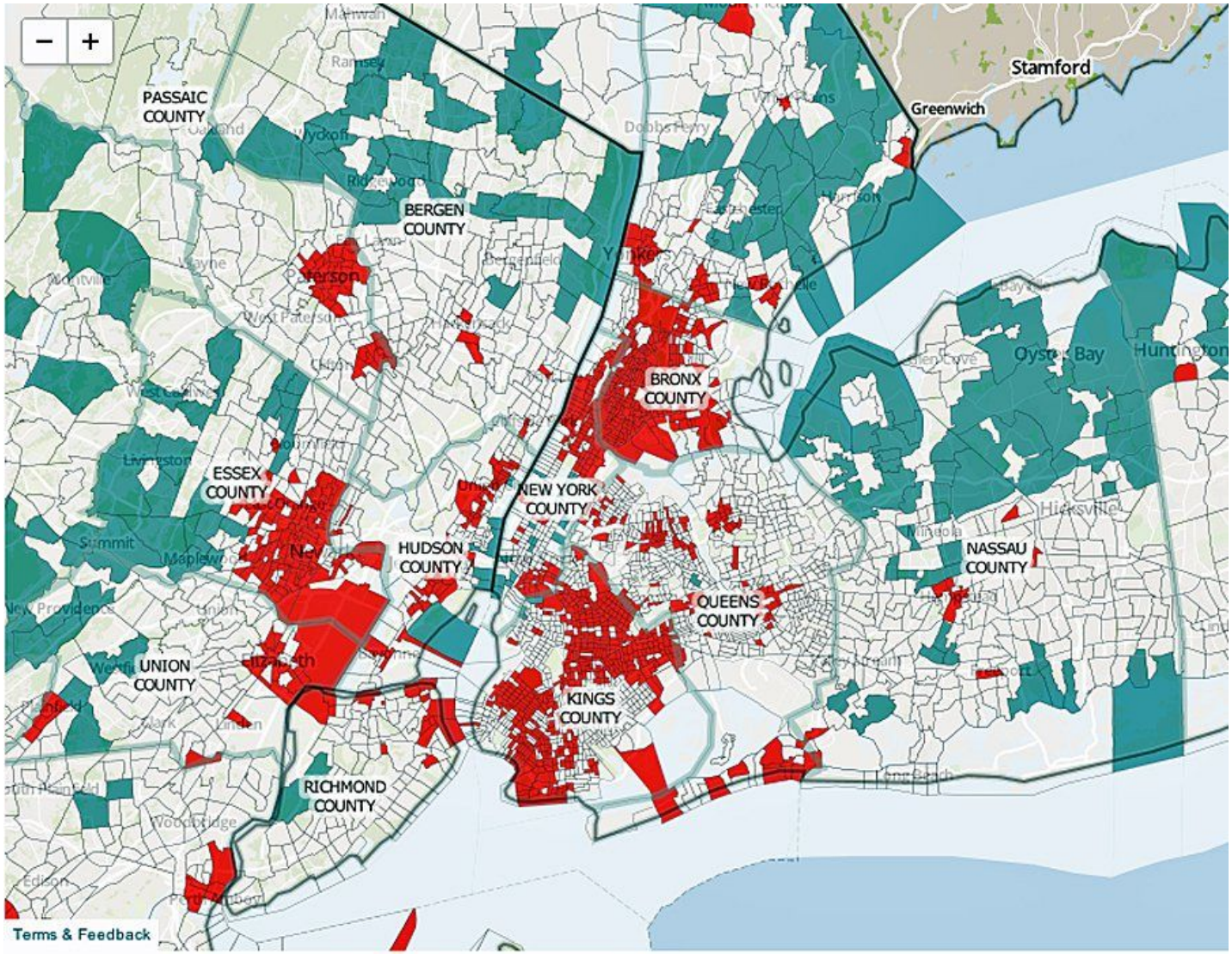
http://www.businessinsider.com/most-segregated-cities-census-maps-2013-4?op=1#ixzz2Rx6



NEW YORK, N.Y. — Most of Manhattan is white south of 125th Street, with the exception of Chinatown. South Brooklyn is mostly white, with pockets of Asians and Hispanics, and Northeast Brooklyn going into Queens is heavily black. Queens and the Bronx are highly diverse.

Schelling's Segregation Model in the real world

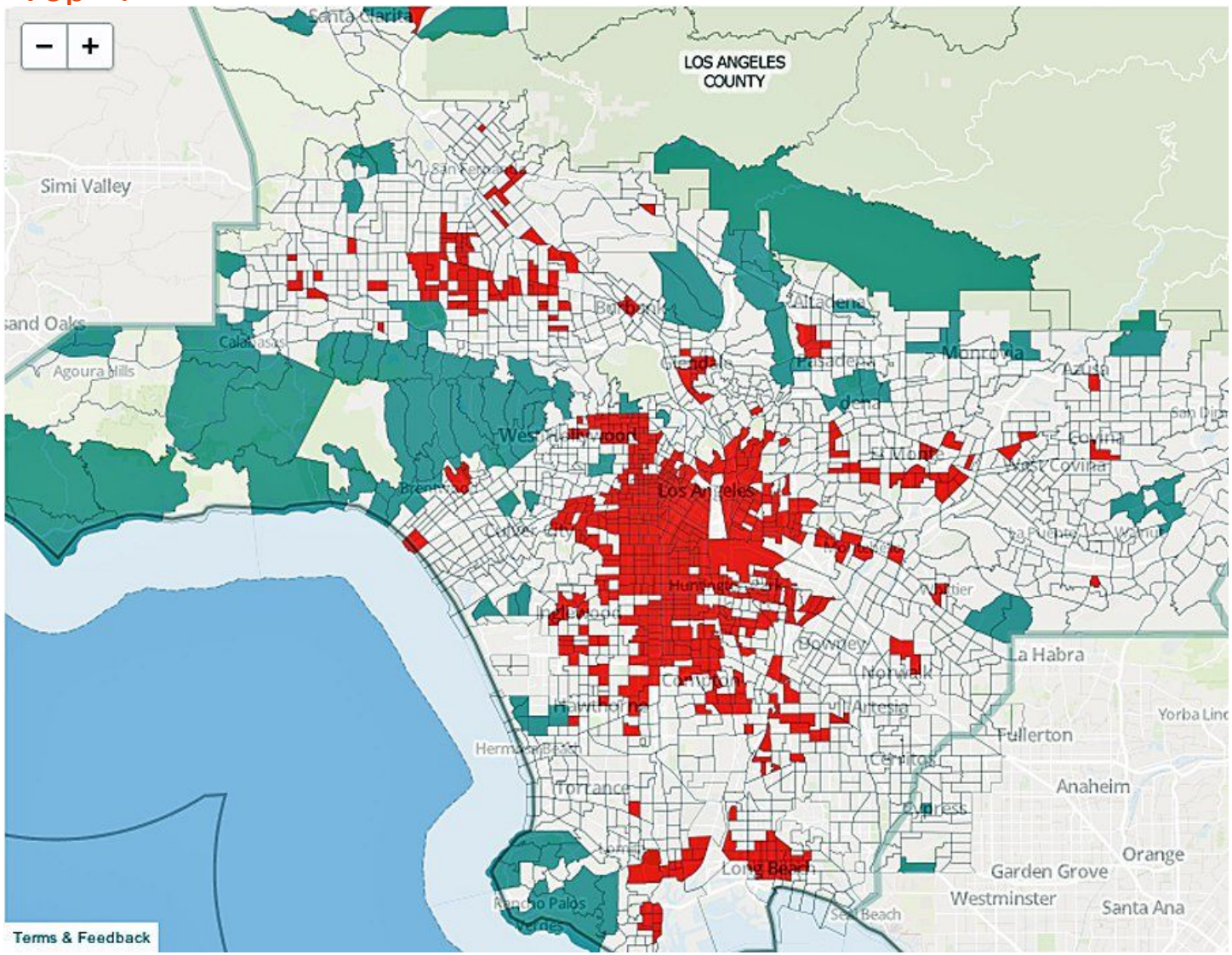
http://www.businessinsider.com/maps-of-extreme-income-segregation-in-us-cities-2012-8?op=1



New York is far more economically segregated than the average Northeast metro area. Its overall segregation score jumped nine points since 1980. [Red is low income. Blue is high income.]

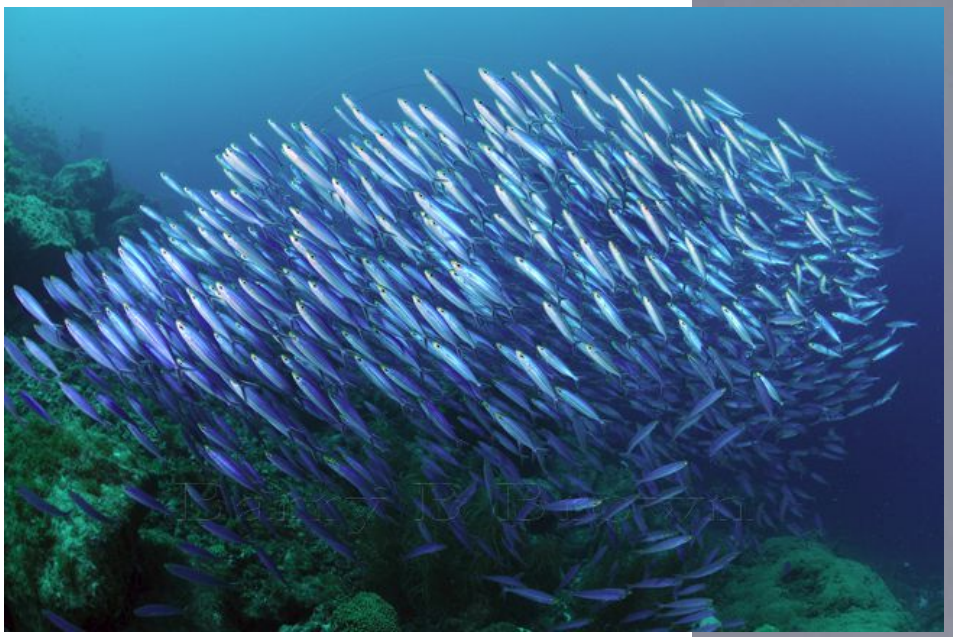
Schelling's Segregation Model in the real world

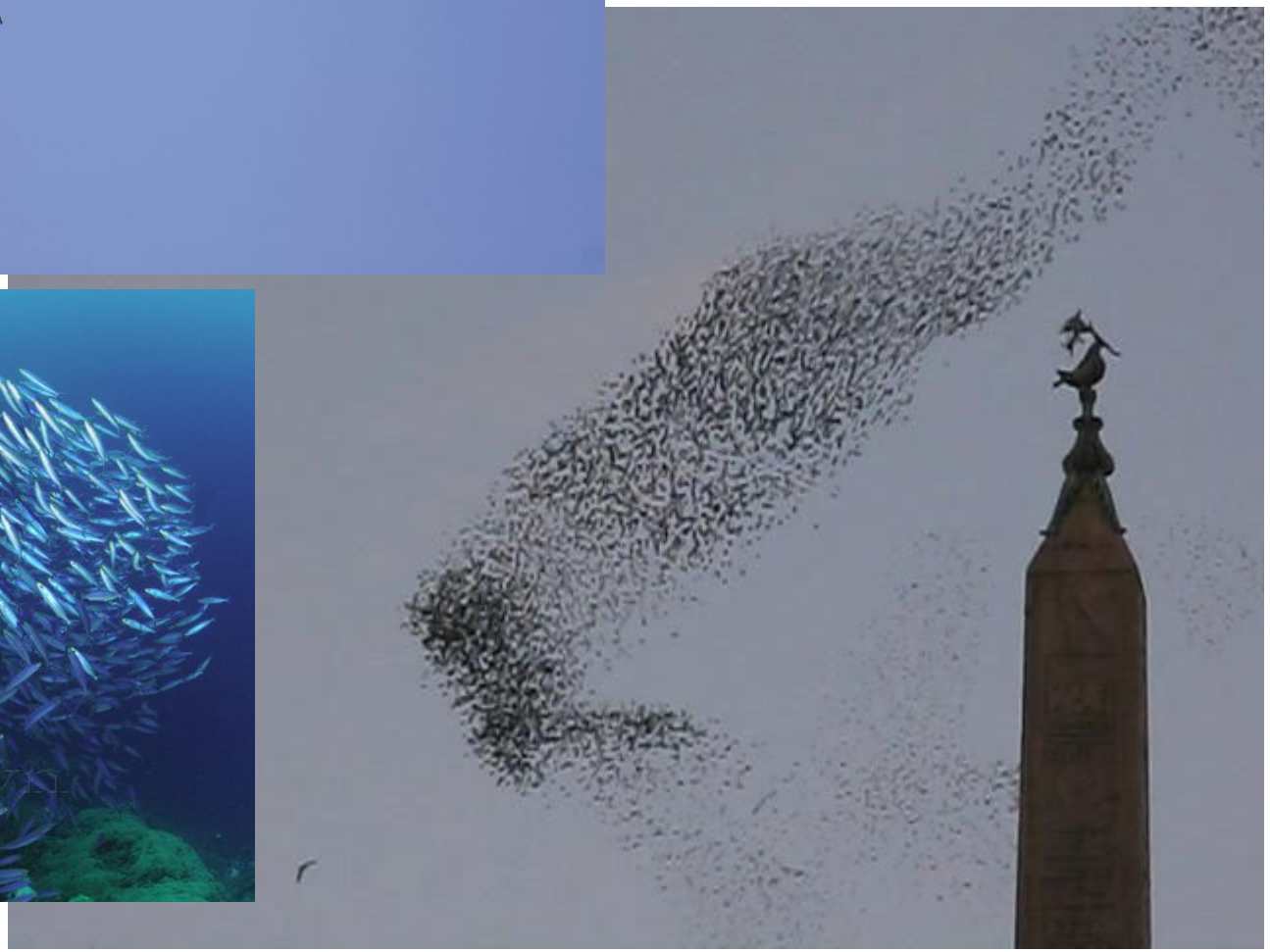
http://www.businessinsider.com/maps-of-extreme-income-segregation-in-us-cities-2012-8?op=1



Since 1980, L.A.'s segregation score increased by only four points, but it's still 19 points higher than the average for Western cities. [Red is low income. Blue is high income.]

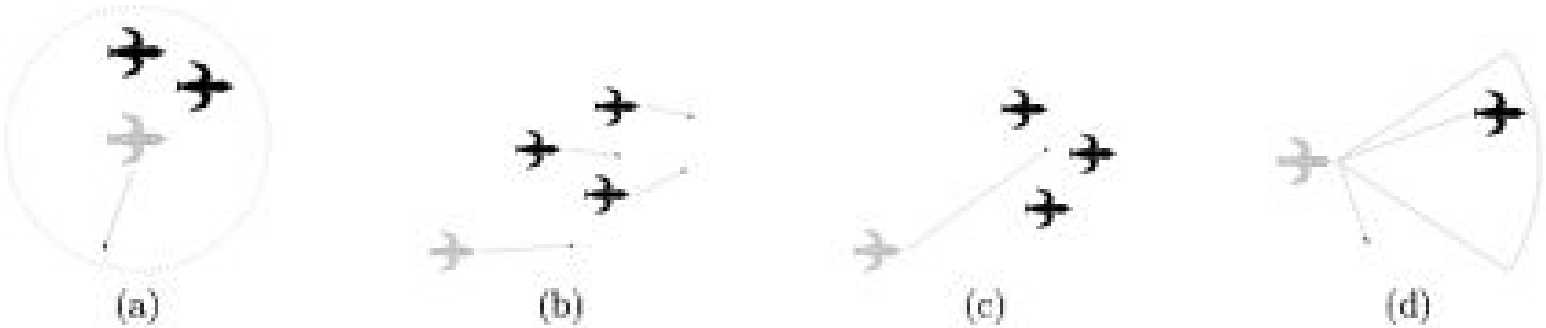
Flocking Vee Formation





Birds and Fish

- Craig Reynolds proposed in 1987 a model to describe the motion of animals, called *boids*
- Each boid in the flock is an independent agent, obeying a simple set of rules



Avoid flying too close to others

Copy near neighbors

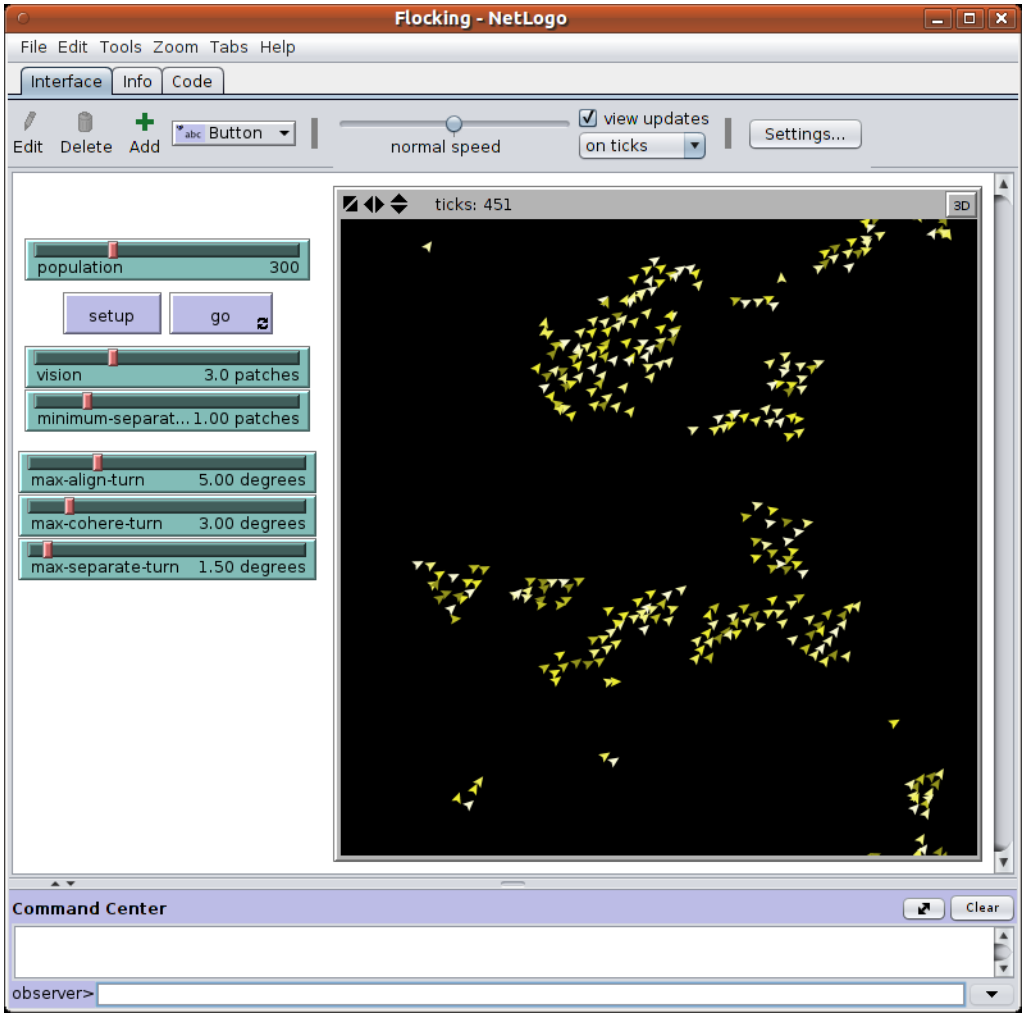
Move towards center of perceived neighbors

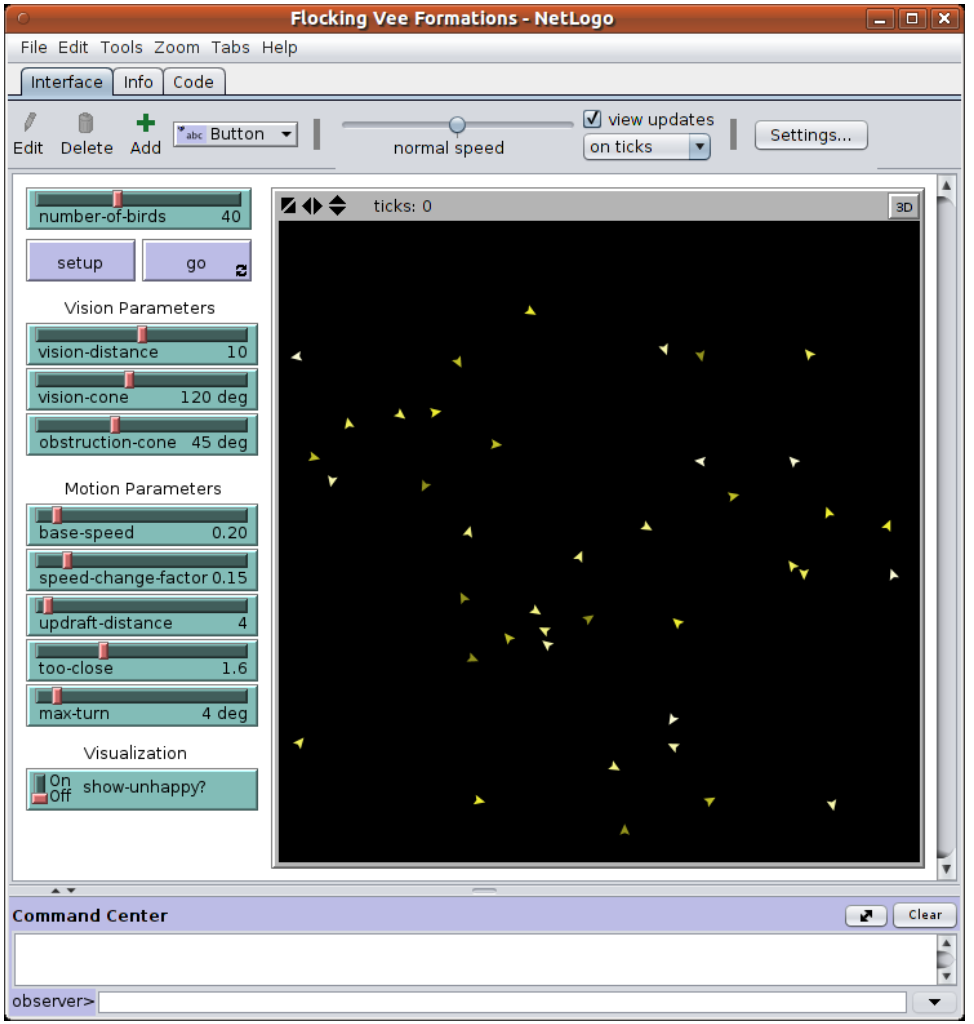
Attempt to maintain clear view

Flocking Vee

Sample Models → Biology → Flocking

Sample Models → Biology → Flocking Vee Formation





Fireflies

Fireflies

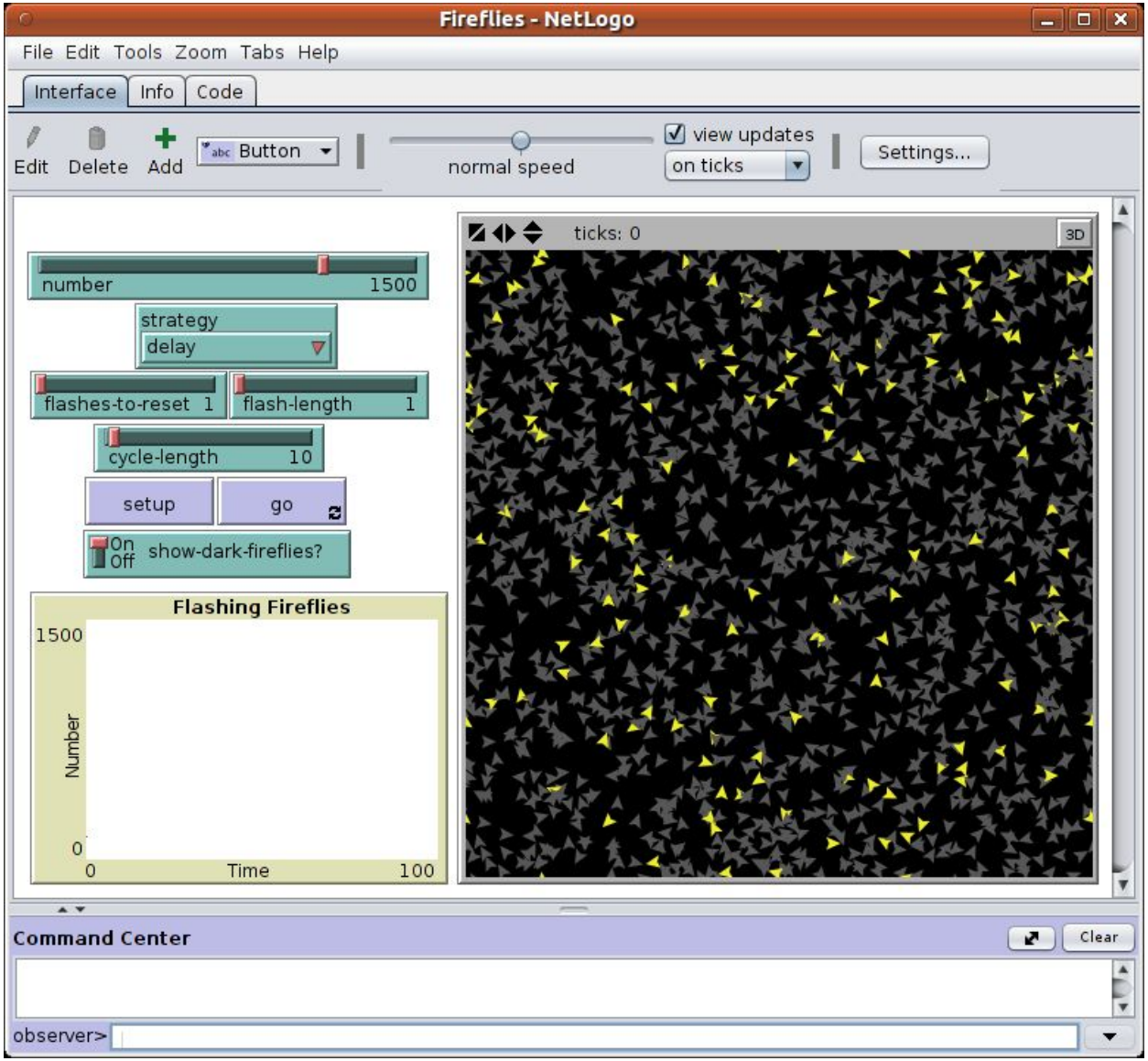
- Though most species of firefly do not generally synchronize in groups, there are some that have been observed to do so

Fireflies synchronization model

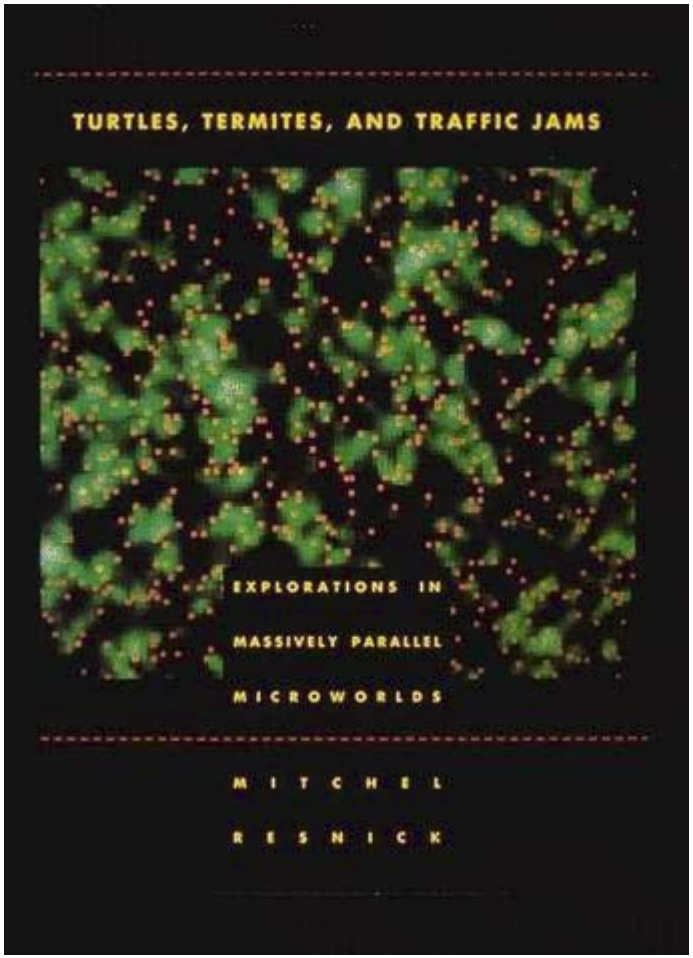
- Each firefly constantly cycles through its own clock, flashing at the beginning of each cycle and then resetting the clock to zero once it has reached the maximum
- At the start of each simulation all fireflies begin at a random point in their cycles (though they all have the same cycle lengths) and so flashing will occur erratically through the population
- As fireflies perceive other flashes around them they are able to use this information to reset their own clocks to try and synchronize with the other fireflies in their vicinity

Fireflies

Sample Models → Biology → Fireflies



Interesting read



Mitchel Resnick, *Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworlds*, MIT Press, January 1997, ISBN: 9780262680936