Lecture 2: Schelling's Finite Automata Model, Homophily and Segregation

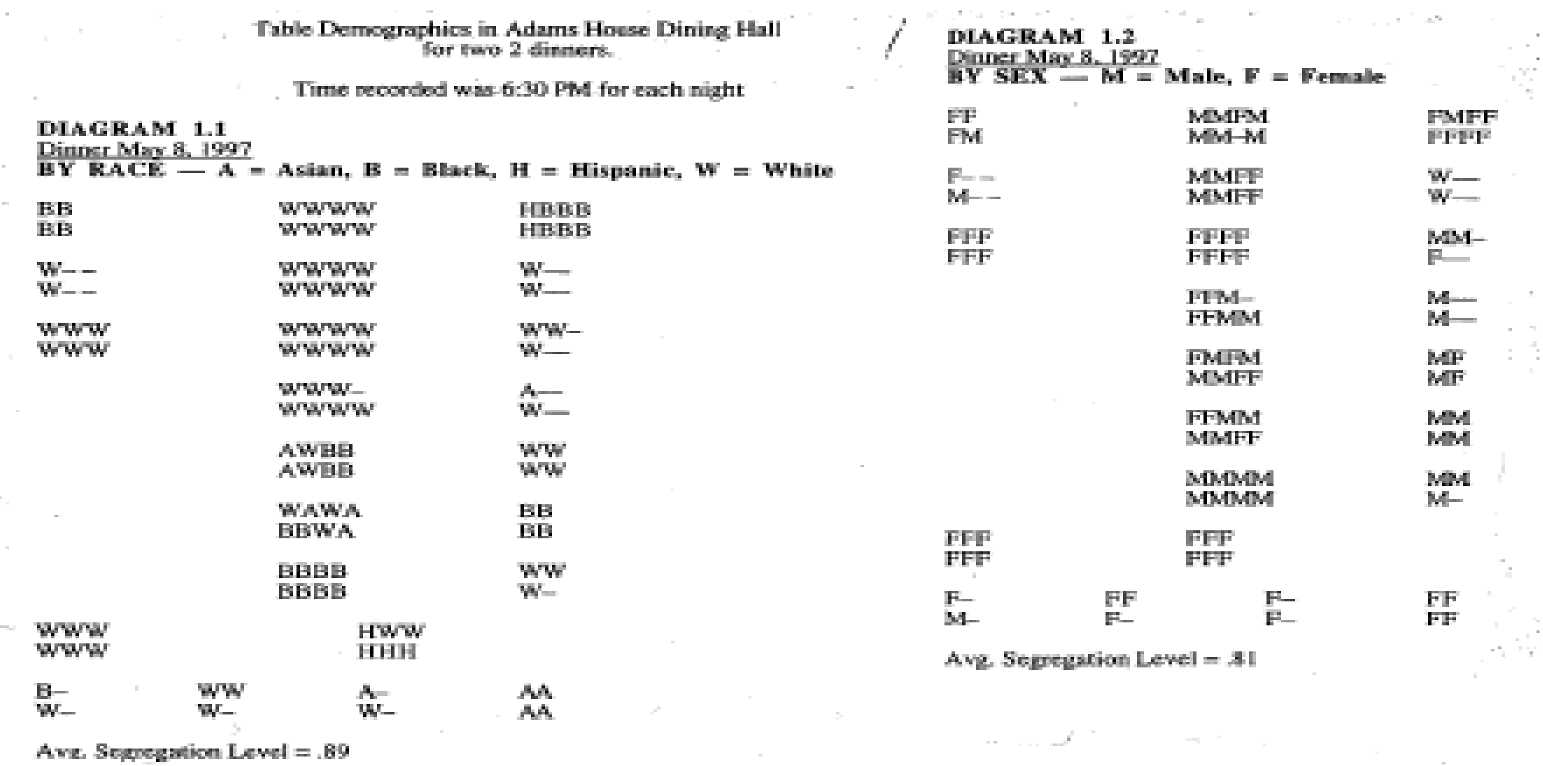
Ex 1.People of similar ethnicity do science together. Freeman and Huang studyof 1.5 million US-addresseds ci papers

Ethnicity	(1) Authors' ethnicity distribution by position (%) First	(2) Second	(3) Third	(4) Fourth	(5) Probability of all authors same ethnicity (%) Random	(6) Realized	(7) Difference (6) - (5)	(8) Ratio (6)/(5)
Panel A: Two-author paper								
CHN	16.6	9.15			1.522	4.157	2.636	2.73
ENG	49.8	60.2			29.99	33.56	3.57	1.12
EUR	12.8	14.7			1.870	2.274	0.404	1.22
HIN	7.71	6.53			0.504	1.605	1.102	3.19
HIS	4.57	3.76			0.172	0.429	0.257	2.50
JAP	2.24	1.31			0.029	0.270	0.241	9.23
KOR	2.39	1.02			0.024	0.135	0.111	5.58
RUS	3.55	3.15			0.112	0.397	0.285	3.55
VNM	0.35	0.23			0.001	0.009	0.008	11.1

The random is what would happen if first and second authors chosen by distribution in column (1)

Similar homophily by gender but doubtful by age due to PI receipt of grants and control of instruments/lab space etc.
Why homophily along "non-scientific" dimensions? Preferences per se? Connections? Gender difference in non-scientific topics – men into pro wrestling and sports etc; women into theater, fashion, etc? Homophily in groups?

Ex 1: Harvard students in dining halls: Who did you sit next to at your dining hall yesterday. People like yourself? Or people different from you? Here are results rom 1977 men, women, ethnic groups sit together in Adams house.
John Mogg noticed, men were seated with men, women with women, blacks with blacks, whites with whites, Asians with Asians, Hispanics with Hispanics. He define average segregation as the mean percentage in the majority at all tables.



To find out if people wanted much segregation, Mogg distributed surveys to Adams House diners: "You have come to a dining hall that has only two tables and are looking for a place to sit down and eat. Both tables have only one seat left ... You must choose a seat now." He specified the ratios of groups in the two tables, then derived utility functions, and found that whites preferred tables 75% white, blacks preferred 50% black, men and women preferred 50% of other group. **But the observed segregation exceeded the preferred amount!!**

3.Housing by ethnicity:Chicago and Sydney Australia

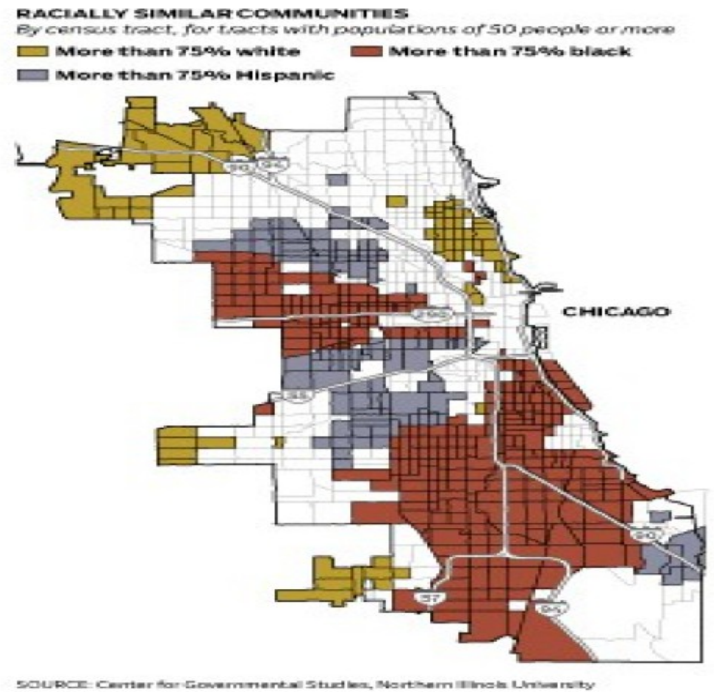
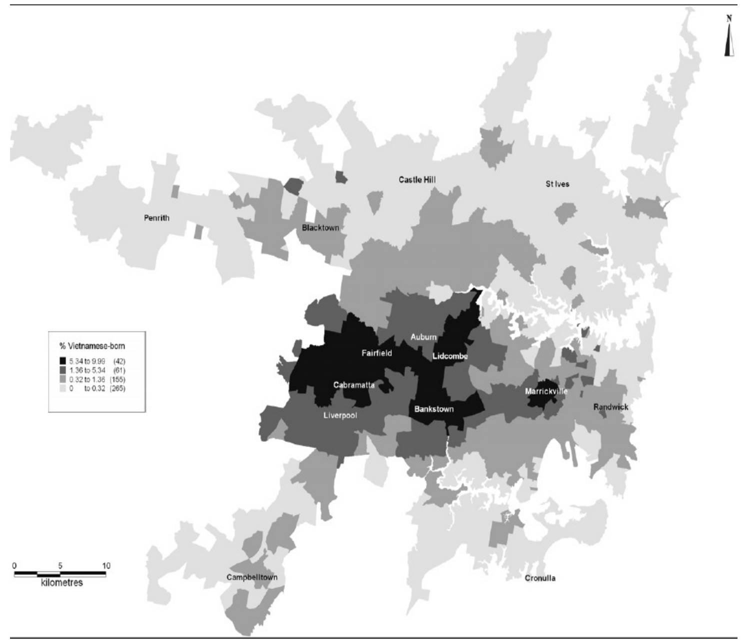
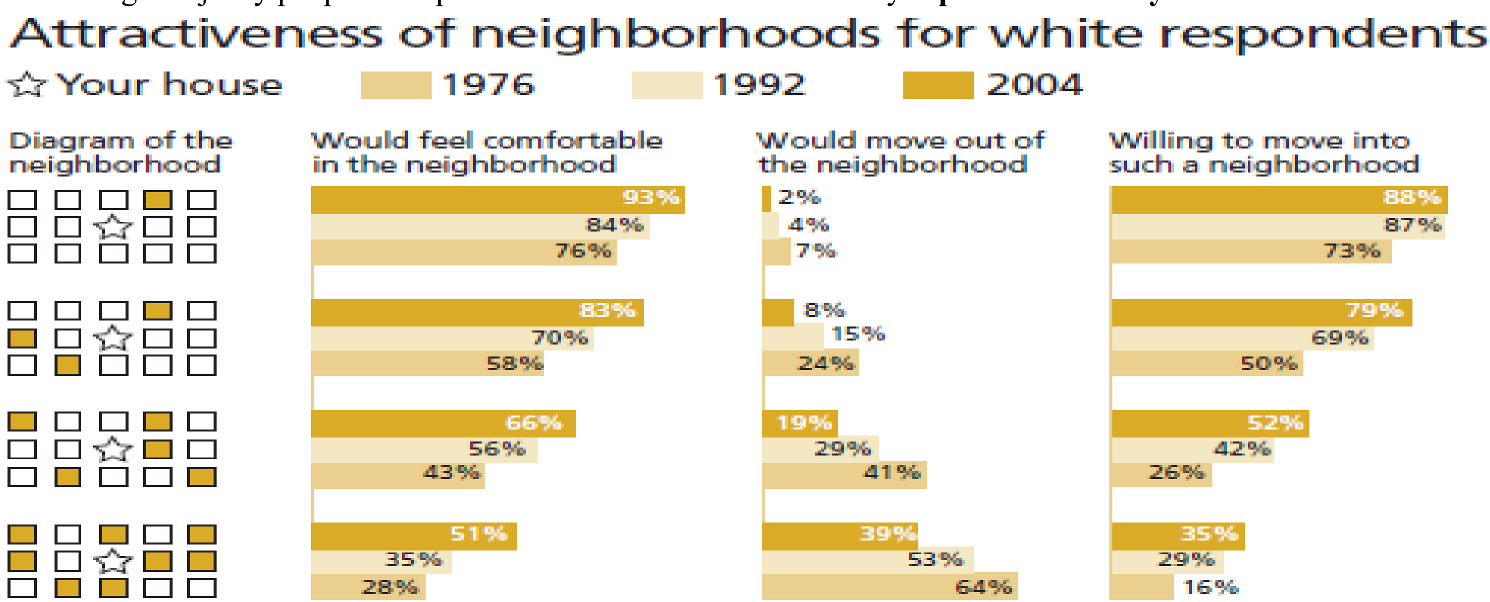


Figure 1. Percentage of the population born in Vietnam, in Sydney suburbs, 2001.



Source: Australian Bureau of Statistics (ABS), 2002.

Studies of preferences for ethnic distribution of neighbors find that African Americans prefer to live in neighborhoods with half blacks or a slight black majority whereas whites favor neighborhoods with a minority of blacks. The overlap/ in preferences is small, implying that the most likely world will be one of racial separation, though it may be possible to find enough majority people with preferences consistent with minority **if preferences vary a lot**.



To explain observed segregation must also deal with evidence of explicit discrimination found in studies of paired testing of minority and majority home buyers that show differential treatment/information in the mortgage lending process. In table Y means blacks or Hispanicstreated worse than whites/Anglos by statistically significant amount

Adverse Treatment of African American and Hispanic Home buyers				
Treatment Categories	**Los Angeles**		**Chicago**	
	Blacks	**Hispanics**	**Blacks**	**Hispanics**
Information Requested	--	Y	Y	--
Loan amount and house price	--	--	--	Y
Number of products	--	Y	Y	Y

Coaching	Y	--	Y	Y
Follow-up contact	--	Y	Y	--
FHA encouraged	Y	--	--	--

4. Harvard Kuumba Singers https://en.wikipedia.org/wiki/The_Kuumba_Singers_of_Harvard_College **.** Once all-black group, then large influx of non-black students, leading Kirkie Masoswe (May 2004) to examine how low black proportion might go

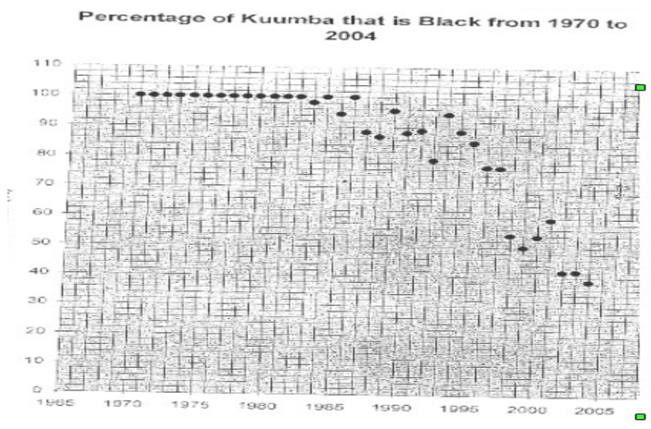
ısoswe, May 2004)

Kuumba in the early 1970s.

Kuumba today (2004).

Table 5: Percent of Black and Non-Black Respondents Whose Happiness is Maximized at a Given Percentage of Black People in Kuumba

% black to max. happiness	% of NB respondents	% of B respondents
0	0	0
10	0	0
20	0	0
25	2.78	0
30	5.56	0
40	5.56	15
50	47.22	25
55	5.56	0
60	16.67	0
70	13.89	15
75	2.78	15
80	0	15
90	0	5
99	0	5
100	0	5



Take-aways

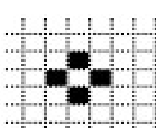
1.Responding optimally need not lead to best outcome for group. (seating in dining hall)
2. Homophily/Segregation CAN arise from preferences of one group, or both groups. Impossible to tell who prefers being with own group in 2-group setting; hard in 3+ groups. (papers)
3.Showing preferences **can** produce result does not disprove a regulation/non-market explanation. (housing))
4.Small changes in preferences of persons in group can produce discontinuous change (Kuumba)
5.Cannot extrapolate to see equilibrium: need to know structure and magnitude. (dynamic process)

2. The Schelling Model: a two-dimensional dynamic Cellular Automata

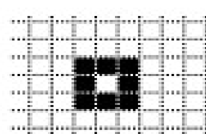
Schelling moved coins around on living room floor to see what happens if nickels prefer n-hood of nickels and dimes preferdimes. The key to the model is that every move changes the neighborhood for remaining neighbors --**an externality from the move**, which can induce the neighbors to change, with cascading effects. Say everyone wants ½ of their neighbors to be like them. Assume that initially everyone has ½ neighbors like them. This is an equilibrium. But one neighbor LIKEME moves, replaced by an OTHER. With less than ½ of my neighbors like me, I move, which changes the neighborhood for you, so you move. And so on. Feedbacks among local decision-makers CAN lead to bad outcome for the group. Moving to attain goal of having ½ of neighbors like them produces nearly perfect segregation.

The model has four elements:

1) **Definition of neighborhood**. In two dimensional space, people use two n-hoods, with 4 or 8 neighbors:



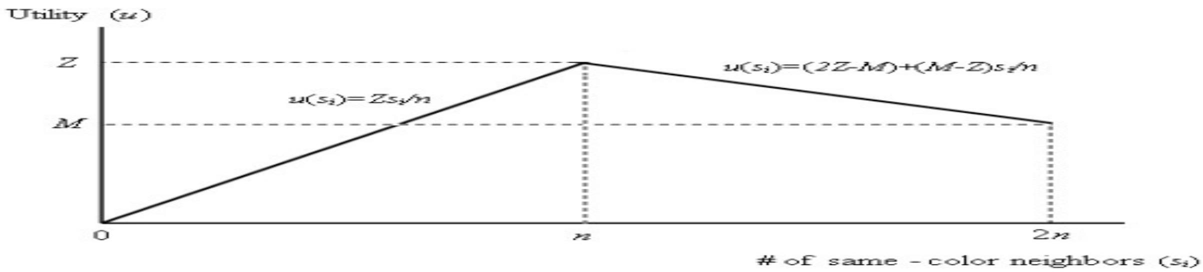
The von Neumann neighbourhood



The Moore neighbourhood

As your definition of neighbors approaches actual population, the incentive to move drops. Is there a critical value of extent of neighbors where you switch from moving to never moving? How many free spaces do you need for moving?

2)Preferences for neighbors: You are happy if at most 1/3rd of your neighbors differ from your group. With 8 neighbors, you are happy if two are different, unhappy if 3 are different. That makes utility a step function Could utility rise from one to two different, then fall with three different, and fall more with four, etc:



3.Moving rule that says when you are unhappy you move to nearest empty space that improves utility. This means **model needs empty space.** Moves --> rules for changing spaces depending on neighboring spaces. Since when you move you change the situation of neighbors in old and new neighborhoods, a move creates chain reaction: A moves and changes old neighbor B's neighborhood, and then changes new neighbor C's neighborhood, and so on.

4.**Size of groups**. Defines what is possible for the society. Simple numerics may rule out some situations that people want. If everyone wants an n-hood with 50% of the people like them but the minority consists of 3 people and neighborhoods are Moore neighborhoods with 8 neighbors, the desired is impossible.

SCHELLING model generates **segregation beyond what people want**. Example of how it works. Assume a Von Neumann neighborhood, where O and # are distributed and where – is for empty space.

But some people are unhappy with n-hood

--	#	O	#	O	–
#	O	#	O	#	O
O	#	O	#	O	–
–	–	O	–	#	#

So # moves

#	--	O	#	O	–
#	O	#	O	#	O
O	#	O	#	O	–
–	–	O	–	#	#

Now O moves

#	--	--	#	O	O
#	O	#	O	#	O
O	#	O	#	O	–
–	–	O	–	#	#

Rest of row 1 happy

#	#	--	--	O	O
#	O	#	O	#	O
O	#	O	#	O	--
–	–	O	–	#	#

What happens in row 2? First O is unhappy and moves → Complete segregation, or segregated areas.

II: Crowded Room CA – Men and women go to a party. There are two rooms. Prefer an even distribution of sexes; less crowded to more crowded room. Most unhappy move first, with random move if same unhappiness.

With 8 people, we have		Another man comes to the first room		-->Room 1 person moves to room 2	
Room 1	Room 2	Room 1	Room 2	Room 1	Room 2
MM	MM	MMM	MM	MM	MMM
FF	FF	FF	FF	FF	FF

Will get oscillating pattern, as M keeps bouncing back and forth.
BUT IF women move first, F in room 1 says too many men are in room 1 and shifts to room 2. Remaining woman shifts to room 2

Period 1		Period 2		Period 3	
Room 1	Room 2	Room 1	Room 2	Room 1	Room 2
MMM	MM	MMM	MM	MMM	MM
FF	FF	F	FFF		FFFF

The woman are now happy – closer to balance in room 2 than in room 1. But to find balance men crowd into room 2,

Room 1	Room 2
	MMMMM
	FFFF

If preferences is that people prefer to be in minority group, you get oscillating pattern.
Women move

Room 1	Room 2		Room 1	Room 2
MMM	MM	–>	MMM	MM
FF	FF		FFF	F

Men move

Room 1	Room 2		Room 1	Room 2
MMM	MM	–>	MM	MMM
FF	FF		FF	FF

OUTCOME DEPENDS ON MOVING RULE AND PREFERENCES AND #s IN GROUPS

II. Cellular Automaton Model: discrete dynamical system based on a lattice where behavior depends on **local relation – near neighbors**. The sites of the lattice are occupied by things that change (representing objects moving or changing attributes). CA shows how local behavior generates macro results. This is BOTTOM-UP MODELING where the complexity of the system comes from the local rules.

"A cellular automaton is an array of "cells" which have a **STATE**, say union (1) or nonunion (0) or M, F and interact with other cells in specified **NEIGHBORHOOD – the set of cells that a given cell interacts with**.

Definition of neighborhood is critical. A model where the whole lattice is neighborhood does not fit CA structure. The rules of change depend on local conditions, not on global conditions. Could be geographic n-hood; facebook friends; family. The model has **RULES FOR CHANGE based on** difference equation or a look-up table.

Example: Elements along a line that are either Criminals (C) or Goodies (G) or followers (F) who follow the goodies or criminals. ahead of them in the line. We sprinkle C, G, F along the line. Then we have

Period 0	C	F	F	F	G	F	F	G	F	F –>
Period 1	C	C	C	C	G	G	G	C	C	C

Neighborhood effects → more concentration of behavior. In fact, crime is more concentrated by geography than any independent probability model based on characteristics would predict. 2017 homicide rates for cities.

St. Louis	66.07
Baltimore	55.77
Detroit	39.81
New Orleans	39.50
Baton Rouge	38.26
Kansas City	30.93
Cleveland	27.77
Memphis	27.73
Newark	27.14
Chicago	24.13
...	
Boston	8.35
...	
New York	3.39

Glaeser, et al compare the expected dispersion of crimes across cities to the actual variance: Using a **one-dimensional CA model** that has the runs of criminals or law-abiding folk that increase dispersion enough to fit the data per the Goodies-Criminal-Followers model they generate same wide dispersion of crime found in data.

But having a model that "fits" the pattern does not mean it is the right model.

LOOK-UP TABLE APPROACH: A look-up table shows how n-hood pattern changes. A one dimensional CA has state depend on surrounding two states. The look-up rule is function N (L, *, R), where * is the current state, L and R are the neighboring states and N gives the new value. Here is a look-up table of rules where the states are 0,1. Since there are 2 states for the cell and neighbors, there are $2^3 = 8$ rules for a complete "group".

RULE GROUP 1 – Rules set arbitrarily for the 8 possible configurations of 0/1 symbols with middle

000–> 0**0**0	100–> (1)**1**(0)	010–> **010**	001–> 0**1**1
011–> 0**0**1	101–> 1**1**1	110–> 1**0**0	111–> 1**0**1

Start with state **01001.** What happens? Need boundaries for the initial 0. Wrap-around gives you a circle, in which the first space 0 has n-hood 101 so it becomes 1. Then must decide whether to apply rules synchronously or asynchronously – ie is the second element 010 or as 110 given the change in the first? Change by the initial state. Then second space 1 has n-hood 010 which becomes 1, third space n-hood is 100 so 0 shifts to 1 by rule 100–> 1

The end result is 01001–> **1**1111. But 11111 –> 00000 –> 00000. So 01001 → an equilibrium of 00000

Say we started with **11001**. Then 11001 –> 00110 –> 01001 –> 11111--> 00000. Take any start and apply the rules to see where the system settles down. Is 0000 the only equilibrium? Why or why not?

Note there are MANY possible sets of rules: could have 000–>1 instead of 000–> 0. The 8 configuration inputs to N (L, *, R) function and 2 outcomes_--> space of 2^8 = 256 update rules --A lot of rules for simple model.

CA MODELS ARE USEFUL because it is "capable of universal computation".

1) for some sets of rules, cells "self-organize" into striking patterns:a limit point --single stable configuration; a limit cycle -- periodic repeating cycle; chaos --aperiodic pattern of complex behavior.

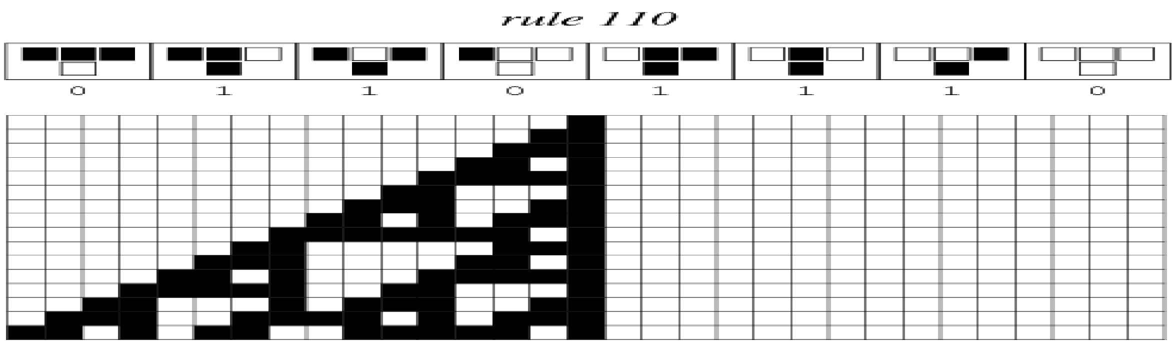
2)Model has simple structure to move from local interaction to macro-result;

3)CA interactions can solve optimization problems using the principle that you look at neighbors and select some feature (ie number) from neighbors which come closest to meeting the goal of the optimization.

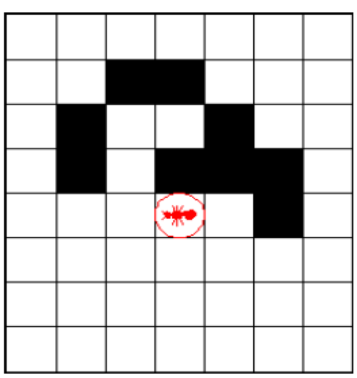
The most famous CA model is the **Game of Life(** http://www.bitstorm.org/gameoflife/) which has Moore nhood – 8 neighboring cells. Rule for space that is populated: If have one or no neighbors, cell dies – loneliness
If have four or more neighbors, cell dies – overpopulation
If have 2-3 neighbors , survive
Rule for empty space: If have 3 neighbors, become populated.

CA models used to analyze cooperation in spatial PD game, where player interacts with neighbors . **A clique of cooperators can survive in a world of defectors by interacting mostly with other cooperators.**

Wolfram of Mathematica's 1280 page A NEW KIND OF SCIENCE claims that CAs dominate all other modes of analysis (for a review see www.ams.org/ notices/200302/fea-gray.pdf. Wolfram 's key CA is rule 110, which simulates universal Turing machine. The diagram shows how middle cell changes depending on its value and the value of its two neighbors.



Another CA model: **Langton's two dimensional: Ant rule.**



A 4-state two-dimensional Turing machine invented in the 1980s. The ant starts out on a containing black and white cells, and then follows the following set of rules.

1. If the ant is on a black square, it turns right 90 ° and moves forward one unit.

2. If the ant is on a white square, it turns left 90 ° and moves forward one unit.

3. When the ant leaves a square, it inverts the color.

SEE CA MODELS IN ACTION. For general program for discrete dynamic models, try www.ddlab.com/

Cultural Conforming Models: To capture social behavior define states/nhoods in more subtle ways. In one model (Axelrod) individuals have 5 attributes that vary from 0 to 9 so that one person might be a 09456 (beer-drinking; professional wrestling fan; accountant; Republican, wears hat) and someone else a 60832, where the difference in numbers reflects the difference in attributes so if you and X differ by 1 you are closer than if you differ by 2 etc.

You interact with folks like you in your nhood. Your interaction changes one of your attributes to be one of theirs --> similar people become more alike over time: a trend toward cultural conformity. Think of a SF Giants fan at Harvard surrounded by Red Sox fans. How long before the SF fan changes allegiance? If there are enough SF Giants fans maybe they interact and preserve Giants fandom. **Homophily can preserve cultural diversity**.

Class paper compared sports allegiance between seniors and freshman at Harvard and found a statistically higher rate of Boston fans among seniors. Given all Boston team publicity, how do the non-Boston fans keep their allegiance? THE INTERNET -- neighborhood that differs from their geographic local. Research on homophily of sites people go to finds that similar people go to similar sites and possibly become more similar.

INTERACTION MODE: Discontinuity

A car slows down on the highway. Will this cause a traffic jam? See the traffic module CA lecture in the reading list. The Argentine financial system collapsed. Will this --> loss of confidence in LDCs and a run on the currency of Brazil, impacting world economy? The sub-prime mortgage crisis leads to Bear-Stearns failure, then Lehman Brothers. This --> banking crisis and recession.

A fire starts on the edge of the forest. What is the chance this burns down the whole forest? Global warming raises temperature another 2-3 degrees. What is the chance this sets of cascade of environmental disasters.

In interaction models, **local decisions produce global changes when the behavior of many agents cumulates.** Decisions based **on what others do** can be destabilizing and produce discontinuities.

Percolation theory models this: two (more) objects intermingle and fight for dominance. In the case of traffic jam/fire, the objects are cars/trees, which support the jam/fire, and empty space, which inhibits it. In investor model, the objects are short term investors/customers who pay attention to others, and long-term investors, who inhibit runs by maintaining existing behavior.

Models predict sharp transitions around a critical density or level of interaction of cars/trees/ investors/customers. If there are *few* cars on the road, if *most* decisions are independent, if a forest is *sparsely* populated, not much happens. But if there are many cars, if most investors are lemmings, if a forest is densely populated, the result will be jams, market collapse/ bank runs/bubbles, forest fires.

The probability of transition does not increase linearly with density/interactions but rather shows a discontinuous jump like the sudden shift from liquid to ice with temperature cooling (phase transition).

Resnick simulates a fire model with different densities in Turtles, Termites, and Traffic Jams. (http://ccl.northwestern.edu/netlogo/models/Fire)

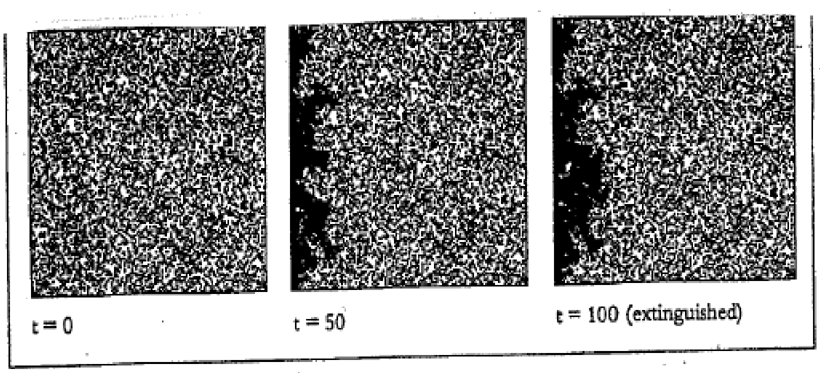
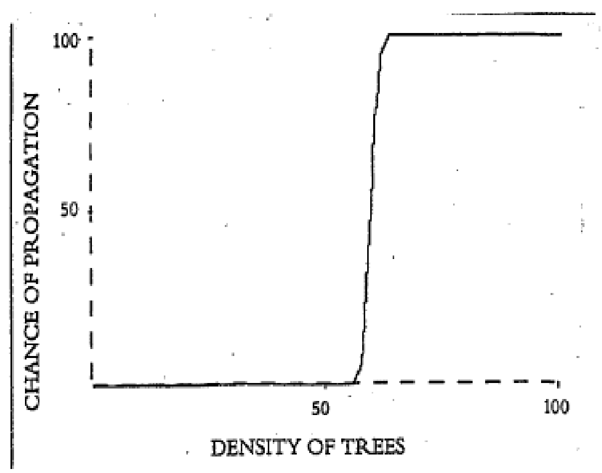


Figure 3.9
Fire in forest with 55% tree density (trees in white, fire starts at left edge)



At around 59% density there is jump in the probability of the fire destroying the forest. The curve above shows a sharp transition. It looks like a **logistic curve**. What is going on? At 100 percent density, you always have neighbors so the fire spreads. With near 0 density, you rarely have neighbors so the fire dies out. The fire dies with 55% density almost always but reaches the other side of the forest with 63% density.

The notion of a **phase transition** is that a small modification of local behavior/agents around the critical value has huge effects on the aggregate outcome.

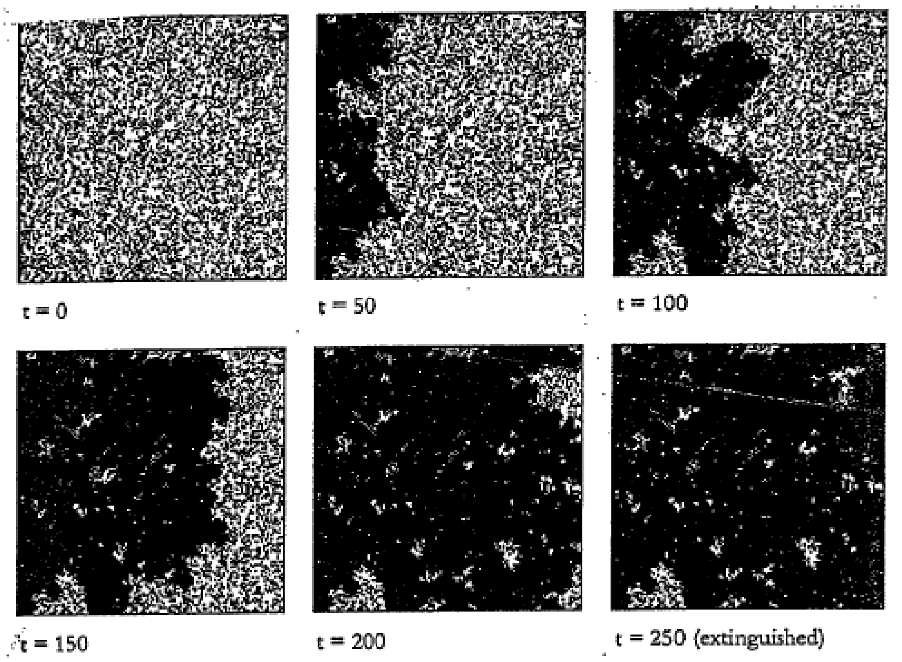


Figure 3.10
Fire in forest with 63% tree density (trees in white, fire starts at left edge)

Figure 3.11
Sharp transition in forest-fire behavior

DENSITY OF TREES	CHANCE OF PROPAGATION (100 TRIALS)	
	128 x 128 forest	512 x 512 forest
55.0	0	0
55.5	0	0
56.0	1	0
56.5	3	0
57.0	6	1
57.5	10	1
58.0	19	5
58.5	36	21
59.0	50	60
59.5	61	84
60.0	76	98
60.5	80	100
61.0	93	100
61.5	96	100
62.0	96	100
62.5	98	100
63.0	100	100

Figure 3.12
The larger the forest, the sharper the transition

MORE: Download NetLogoUser Manualversion 6.0 at https://ccl.northwestern.edu/netlogo/docs/
Check out what others have been doing. http://ccl.northwestern.edu/netlogo/models/community/ See residential mobility as a result of gentrification by Mohammad Hadi Kaboli (Submitted: 06/27/2015).

FREE books MULTIAGENT SYSTEMS Vidal, Fundamentals of Multiagent Systems with NetLogo Examples March 19, 2009 http://multiagent.com/2009/03/fundamentals-of-multiagent-systems.html
Also, Algorithmic, Game-Theoretic, and Logical Foundations by Yoav Shoham Stanford University and Kevin Leyton-Brown University of British Columbia http://www.masfoundations.org/mas.pdf

Do papers/books on cellular automata constitute a distinct group of studies in network of science and engineering papers? How would you investigate the links between CA models and rest of research universe?