Interaction topologies:
The importance of who interacts with whom.

Example: Schelling's Tipping Model.

For the decision to move or not:

- Each interacts with (up to) 8 neighbors. Note that some neighbors are neighbors of each other.

- What if interact with 4 NEWS neighbors? Note A's neighbors are not neighbors of each other.

- What if interact with agents >1 away?

For deciding where to move:

- To random open place (no interaction).
- To nearest-acceptable place. (Look everywhere!)
- What if only sample other regions? What if biased by "friends"?

Interaction topologies:
The importance of who interacts with whom.

Example: infection transmission

- random mixing
- neighbors in 2D space
- neighbors in social space (AIDS; Buses)

Note that

- random mixing is the basis for using mean-field approximation models: the mean gives you the expected number of infected contacts from random meetings.

- biased interaction rates lead to pockets of high infection, which may be over a threshold for epidemic, even though the overall mean is below the threshold.

- thus random mixing may predict the infection should die out, but it doesn't, because of dense interactions in pockets.

Evolution of Cooperation:

Agents playing Prisoner's Dilemma.

- 1-play games, between pure strategies (D,C)

- Learning: higher payoff agents reproduce, lower payoff agents don't (so they die off).

- Start with p% cooperators.

- Random mixing: Play 8 chosen at random. Can cooperation survive?

- Regular Lattice: Play 8 neighbors.
  Can cooperation survive?
  Nowak and May Model (31 July Class)
  CSCS ipdm0 program implements a version of this model. See the ipdm0-writeHelp.txt for details.

Another model: Epstein's Demographic PD

Can cooperation emerge with 1-play games?

His model (obviously based on SugarScape):

- Agents:
  - Pure C or D strategy (no memory)
  - Vision (speed) = 1
  - Age, max age, wealth
- 2D torus world, max 1 agent/cell
- Asynchronous (knights tour) updating
- Basic schedule of activity:
  - Pick a open site in vision range
  - Go there, play neighbors, add payoffs to wealth
  - If $W < 0$, die
  - If $W >$ threshold, and open site in sight, then create offspring and it endow it with 60% of wealth

For T > R > P > S = (6 > 5 > -5 > -6)
Note population of D's can't survive!
Basic results: Yes, cooperation emerges, because offspring of cooperators play offspring of other cooperators!

- No max age, no mutation:
  stabilizes with full world, C/D = 6.5/1
- Max age = 100
  More cycling, C/D = 7.8/1
- Lower R to 2 (more tempation to D)
  Bigger, faster oscillations
- Lower R to 1
  Big, slow oscillations, not full world.
  D needs C to "eat", so sometimes they go extinct.
- Mutation = 50% (!), R=5 again
  C/D = 1/1, almost full world
- Alternative view of negative payoffs:
  Add 6 to all above, but have a metabolic rate / t = 6.

The IPD-m0 Swarm model implements a version of Epstein's model:

- Payoffs: T=b, R=1, P=S=0

- Agent looks at 8 neighbor cells for open site (for vision = 1)

- Agent plays one other neighbor after it moves

- metabolic rate can be
  - off
  - applied each time agent moves
  - applied each time agent plays another

Exercise in lab: play with these parameters. See if you can find regime that gives results similar to Epsteins. If not, what dynamics to you observe?

Choose partners based on "Tags"

Donation game: A simpler framework for studying the evolution of cooperation.
When A meets B, A may donate to B, at a cost c=0.1 to A and benefit b=1.0 to B.

- Strategy: when (to whom) to donate.
  Always Donate?
  Invadable by never donate!
  But that leads to no donations, bad for everyone!

- Learning/Adaptation: imitate (with mutation) strategy that is doing better (replicator dynamics).

- Tag-based strategy—each agent has:
  - "tag" in [0,1] (like a color marking)
  - threshold: t >= 0
- A meets Other at random;
  Donate iff differ(tagA,tagOther) <= t

- Results: Cycles of “tolerance”, changing tags. Why?
  - Group with similar tags, low t, donate to each other and spread
  - When most agents have same/similar tag, then threshold can drift up, because agent will almost always being giving to others with your tag.
  - But then a group with nearby tag can evolve low t, and (a) continue to receive from main group, but not give to them!
  - After a short while, the new group becomes dominant, with low t, and cycle begins anew.

- Tags and interaction topology:
  Change tag: change “neighborhood”
  Change t: change “size” of neighborhood

See Cohen,Axelrod,Riolo paper for tags in IPD setting.

Alternative network structures (Watts)

- Random links:
  - short path length
  ("6 degrees of separation")
  - no clustering (friends are not friends)

- Regular Lattice:
  - long path length
  - strong clustering

- "Small Worlds" – combine properties:
  - short path length
  - strong clustering

1. Lots of Small Worlds in the Real World:
   - worm neurons: evolvled
   - power grid: designed
   - co-actors: ?

2. Small Change in Structure ->
Large Change in Path Length.
Watts: Simple dial (prob re-link at random)

3. Implications for System Behavior

- Spread of disease
- Information contagion
- Evolution of cooperation
- Signal processing
- Axtell: Retirement age "norm"

Details (good or bad) depend on processes.

Other properties: power law distribution over number of neighbors.
Other origins: grow connections.

Axtell: Study Effects of Network Structures
Compare behavior of some models.

Simple Agents – ignore details of cognition.
standard approach in social science (econ, etc):

- Lack of universal model of cognition
- Easier to understand how macro-dynamics emerge

Important to consider interactions between agents.

- Interaction topology
- Activation schedule

Axtell's Retirement Age Model:
Explain lag between change in policy and behavior.

Population = mix of 3 Agent types:

- Rational: retire as early as possible
- Random: retire with prob = p
- Imitators: utility based on what friends do.

Each year, each agent ages, and decides to Retire or Not Retire.

Imitators behavior depends on what "friends" do, i.e., it depends on the topology of friends:

- Regular Lattice
- Small-World
- Random

- Lag times greatly affected by structure:

- Retired state percolates from older cohorts.
- Result is an emergent “norm”.
- With clustering, need fewer rationals to greatly reduce time to establish new norm.

Axtell also showed how interaction topology affects behavior of a model of Firm formation.

Axtell paper also looks at Activation schedules.

- Uniform: each active once per step.
  -> How many to shuffle to avoid bias?
- Random: mean is once per step.
  Expected time to activation?

Flache and Hegselmann: Irregular Grids

JASSS – J. Artificial Societies and Social Simulation

Regular 2D grids are common:

- Simple, Easy to display
- "Geographical" reality (locality,clustering)

Constraints to explore:

- non-homogenous interactions
- continuous vs discrete space
- static structure
- synchronous vs asynchronous updating
- heterogenous agents

Results: "Qualitatively" the same, but some differences in details of outcomes and especially in dynamics.
(Differences in dynamics, e.g., time to some final state, can be critical in systems with adaptation at multiple time scales!)

Example: IPD model of Cohen,Riolo,Axelrod
Interaction topology -> level of cooperation.

Basic model:

- 256 Agents, 1-Memory strategies (i,p,q)
  i = prob. cooperate on first move
  p = prob. cooperate if other co-op'd last
  q = prob. cooperate if other defected last
  (1,1,0) = Tit-For-Tat (citizen);
  (0,0,0) = AllD (BadGuy);
  (1,1,1) = All-C (saint)

- Each generation, play 4 others.

- Play each 4 rounds, accumulate score.
  Total score depends on who you play!

- After all play, use total score in learning:
  - copy strategy of best played (10% error)
  - 10% of time mutate (guassian noise)

Who does an agent play? I. Random mixing. Pick the 4 to play uniform randomly.
Note expect to play 8 games, but some play more or less (minimum of 4).

What happens to level of cooperation (F = pop. avg. score) over time?

- Initial F = 2.25
- BadGuys (allD) make a fortune off saints (allC), some off TFT.
- Lots of agents copy the huns...
- When all the saints are gone, low F (allD vs allD)
- Hard to get cooperation started:
- Mutation leads to isolated TFT, but it plays mostly BadGuys, does poorly, so it copies the BadGuys.
- Occasionally there might be a few TFT's playing each other. They prosper and copies are made, but then those copies play random others, which means they play BadGuys!

II. Agents play 4 NEWS neighbors (2D space)

- Initial F = 2.25
- BadGuys (allD) make a fortune off saints (allC), some off TFT.
- Lots of agents copy the allD...but...
- Some TFT have TFT neighbors, so they prosper.
- Agents around those rich TFT copy them...
- Their offspring then play theTFT copies...
- TFT takes over the world!!
- Hard for a allD to invade, since they play TFT who are playing other TFTs.

Axelrod idea of a long "shadow of the future" promoting cooperation: lots of plays against same agent favors cooperators.

Generalized "adaptive shadow of the future" – lots of plays against the offspring of the agent you played also promotes cooperation.

Also of note:
Cycle of waxing and waning Social Vigilence.

- When mostly TFT, saints can survive.
- Mutation causes "drift" to higher q (saintly) agents.
- Once there are saints, they act as a niche for allD to exploit.
- But once the allDs "eat" the saints, they are left in a sea of TFT players with constant TFT neighbors, so...
- The allD rapidly die out, leaving a world of TFT, so...
- The cycle begins again with drift toward more saints.

The magnitude of the cycle depends on the interaction topology (among other things)...

III. Choose partners based on “Tags”

Each agent has “tag” [0,1], a random number.
Think of tag as a “color” visible to others.
Bias to play others with similar tag value.
Tags are mutated just as are (i,p,q).
The dynamics?

- Initial F = 2.25
- BadGuys (allD) make a fortune off saints (allC), some off TFT.
- Lots of agents copy the allD...but...

- Some TFT have similar tags, so they play each other and prosper. In effect, they are “near” each other in the tag-based interaction topology.

- Those TFT players then spread, leading to more cooperation, and also to most agents having similar tags (they are “near” each other). The tag has taken on a meaning “we play TFT”!

- But in a group of TFT players, saints can survive, so
- There is drift to saintliness “in” that tag group, so

- A chance mutation of an agent to have that tag and play All-D will lead to a rapid spread of that agent.
  The all-D is like a mimic...its tag is taken to mean it plays TFT, but it doesn’t!!

- Again, the BadGuys “eat” the saints, and drive out most others with that tag, too; then the cycle starts again.

Why better than random mixing?
Because as one tag group is invaded by “mimics” another tag group can prosper, so the population as a whole recovers faster.