Networked Games:
Coloring, Consensus and Voting

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Networked Life

NETS 112

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Experimental Agenda

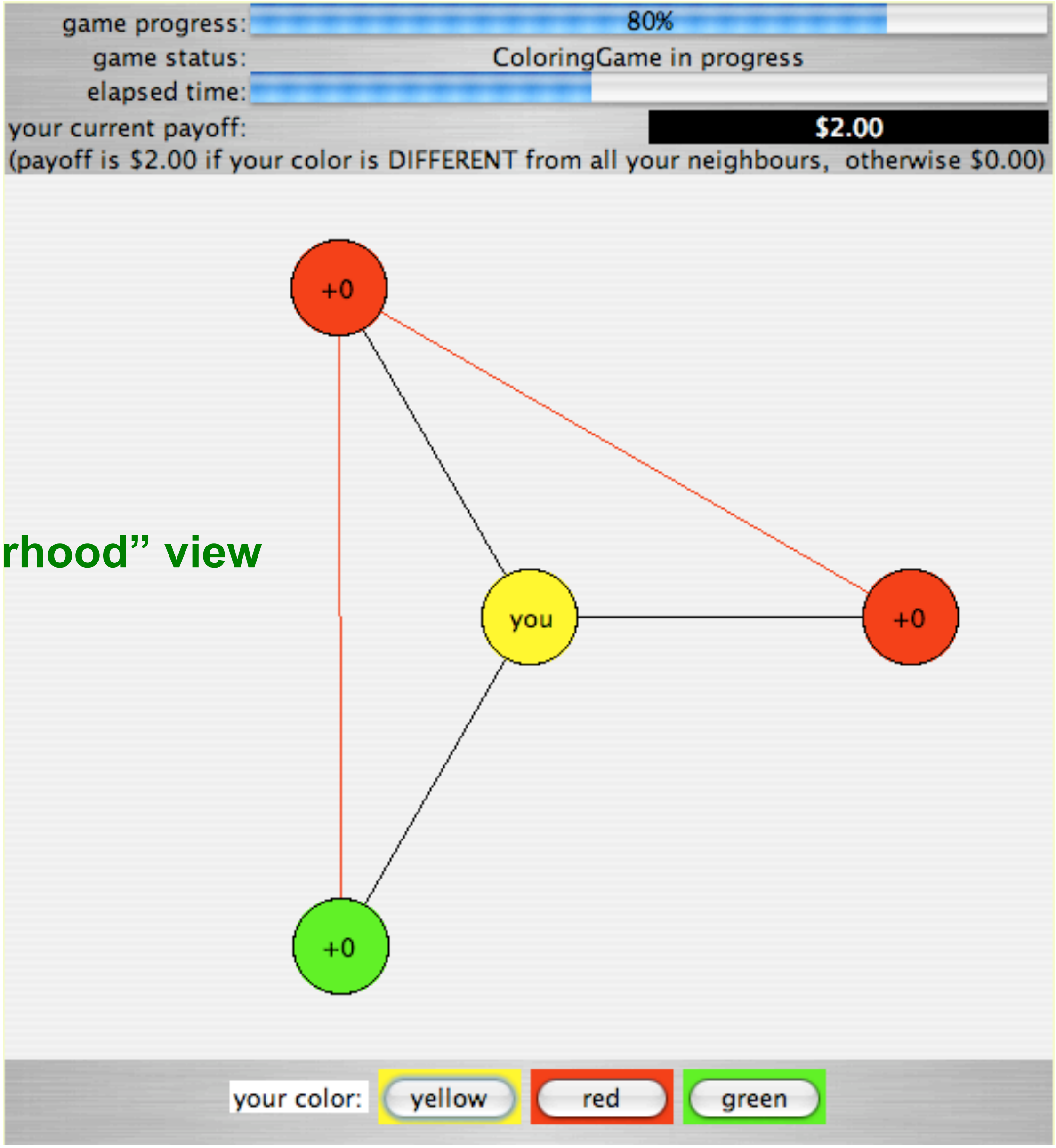
- Human-subject experiments at the intersection of CS, economics, sociology, “network science”
- Subjects simultaneously participate in groups of ~ 36 people
- Subjects sit at networked workstations
- Each subject controls some simple property of a single vertex in some underlying network
- Subjects have only *local* views of the activity: state of their own and neighboring vertices
- Subjects have (real) financial incentive to solve their “piece” of a collective (global) task
- Simple example: graph coloring (social differentiation)
  - choose a color for your vertex from fixed set
  - paid iff your color differs from all neighbors when time expires
  - max welfare solutions = proper colorings
- Across many experiments, have deliberately varied *network structure* and *task/game*
  - networks: inspired by models from network science (small worlds, preferential attachment, etc.)
  - tasks: chosen for diversity (cooperative vs. competitive) and (centralized) computational difficulty
- Goals:
  - structure/tasks→ performance/behavior
  - individual & collective modeling → prediction
  - computational and equilibrium theories

Experiments to Date

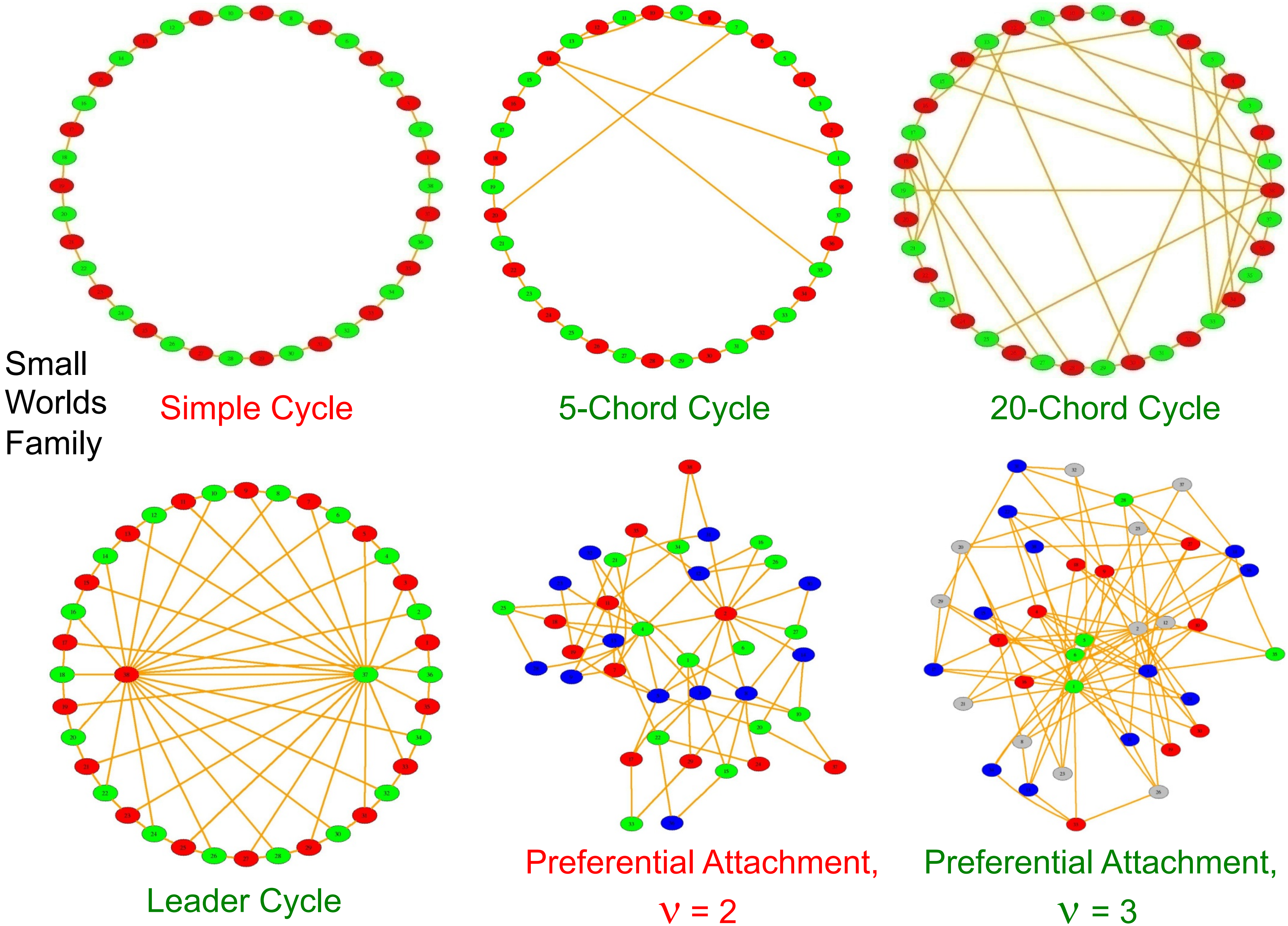
- Graph Coloring
  - player controls: color of vertex; number of choices = chromatic number payoffs: $2 if different color from all neighbors, else 0 max welfare states: optimal colorings centralized computation: hard even if approximations are allowed
- Consensus
  - player controls: color of vertex from 9 choices payoffs: $2 if same color as all neighbors, else 0 max welfare states: global consensus of color centralized computation: trivial
- Independent Set
  - player controls: decision to be a “King” or a “Pawn”; variant with King side payments allowed payoffs: $1/minute for Solo King; $0.50/minute for Pawn; 0 for Conflicted King; continuous accumulation max welfare states: maximum independent sets centralized computation: hard even if approximations are allowed
- Exchange Economy
  - player controls: limit orders offering to exchange goods payoffs: proportional to the amount of the other good obtained max welfare states: market clearing equilibrium centralized computation: at the limit of tractability (LP used as a subroutine)
- Biased Voting
  - player controls: choice of one of two colors payoffs: only under global agreement; different players prefer different colors max welfare states: all red and all blue centralized computation: trivial
- Networked Bargaining
  - player controls: offers on each edge to split a cash amount; may have hidden deal limits and “transaction costs” payoffs: on each edge, a bargaining game --- payoffs only if agreement max welfare states: all deals/edges closed centralized computation: nontrivial, possibly difficult
- Voting with Network Formation
  - player controls: edge purchases and choice of one of two colors payoffs: only under global agreement; different players prefer different colors max welfare states: ??? centralized computation: ???

Coloring and Consensus

"first neighborhood" view

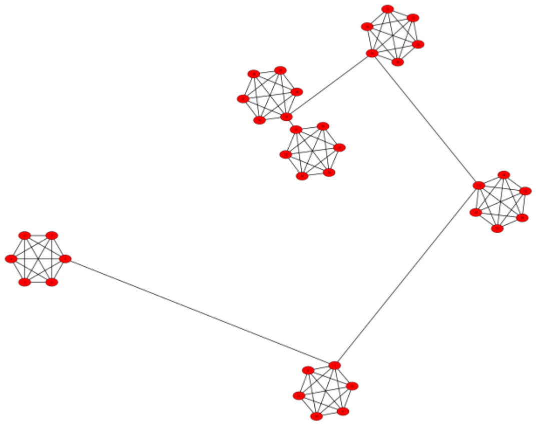


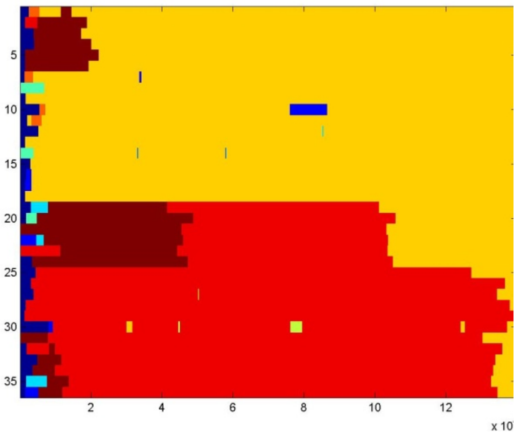
[demo]

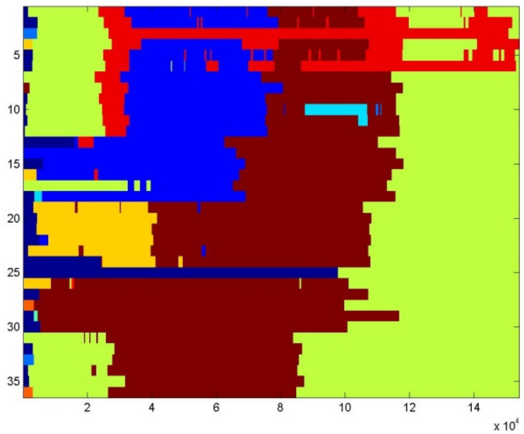


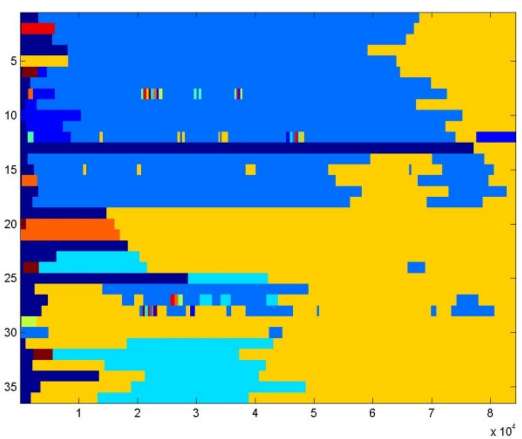
Small
Worlds
Family
Simple Cycle
5-Chord Cycle
20-Chord Cycle
Leader Cycle
Preferential Attachment,
ν = 2
Preferential Attachment,
ν = 3

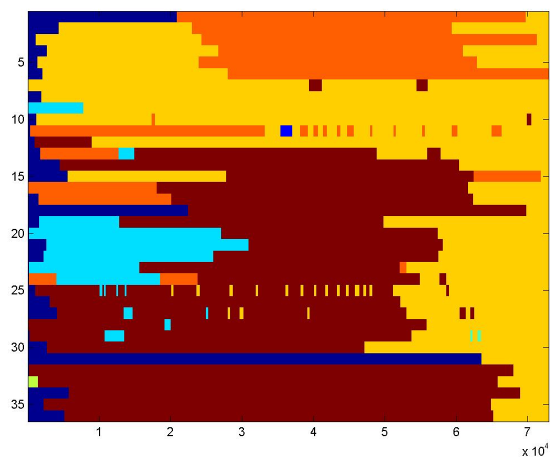
Art by Consensus

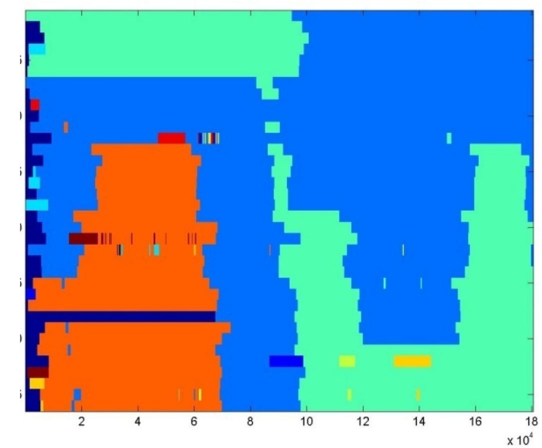






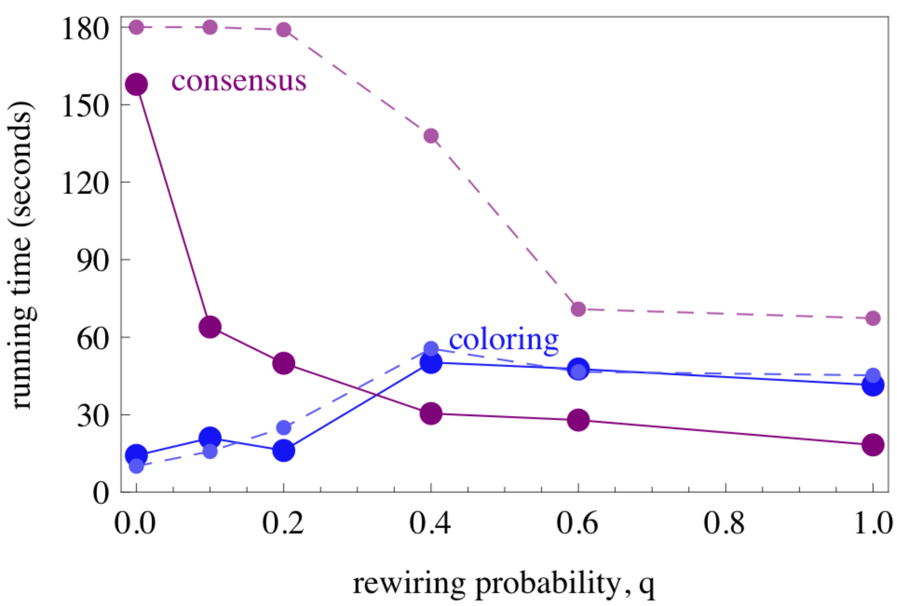


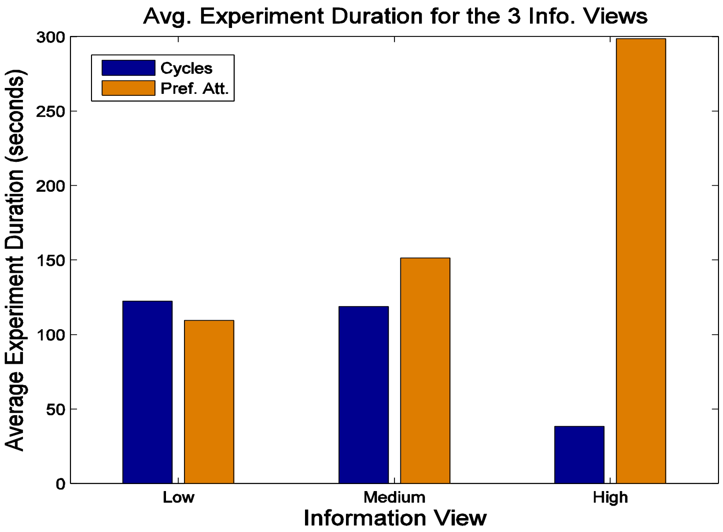




Sample Findings

- Generally strong collective performance
  - nearly all problems globally solved in a couple minutes or less
- Systematic effects of structure on performance and behavior:
  - *rewiring harms* coloring performance in "clique chain" family
  - *rewiring helps* consensus performance in clique chain family
- Preferential attachment much harder than small worlds for coloring
  - natural heuristics can give reverse order of difficulty
- Providing more global views of activity:
  - helps coloring performance in small world family
  - harms coloring performance in preferential attachment
- Coloring problems solved more rapidly than consensus
  - easier to get people to disagree than agree

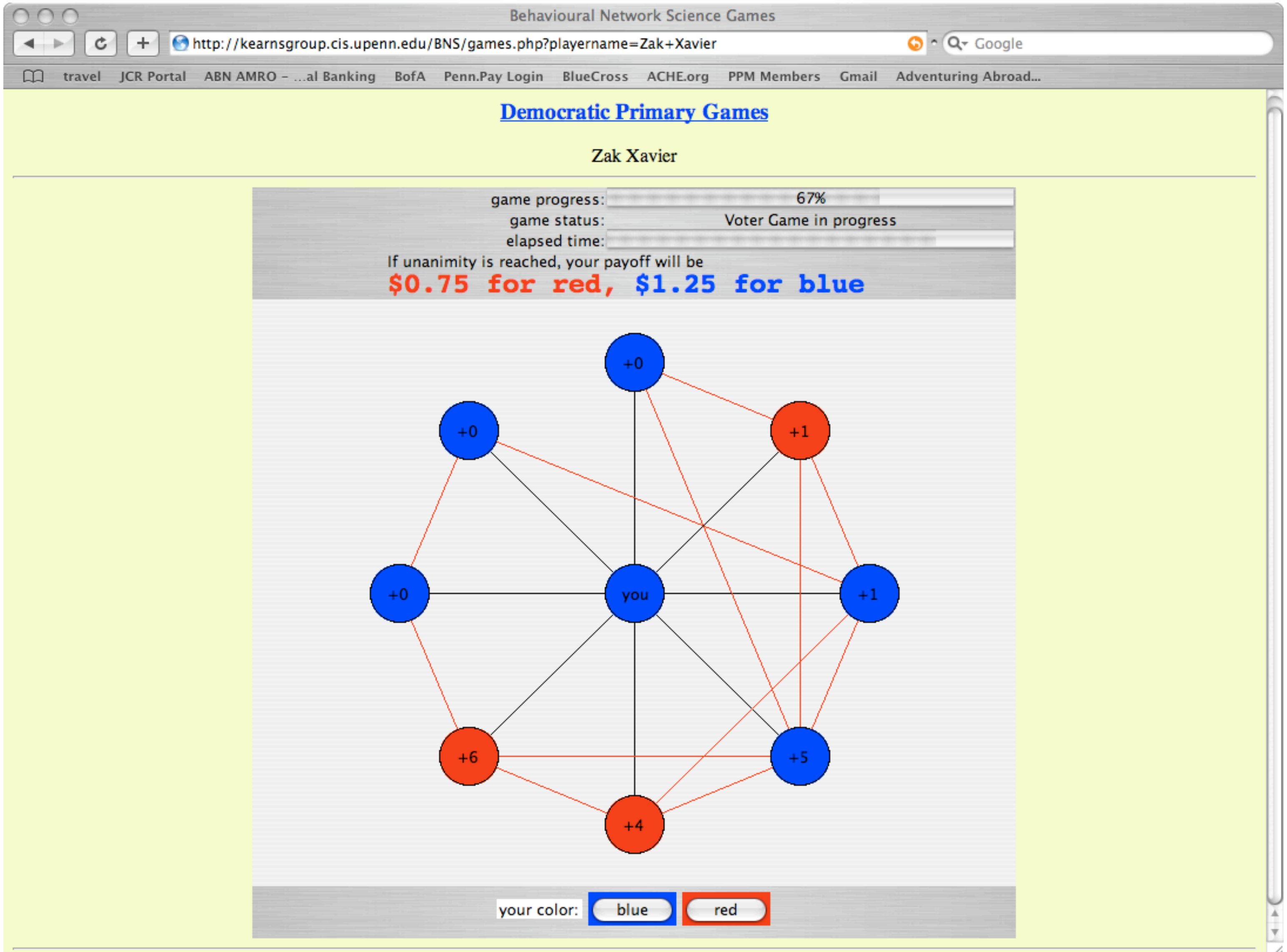




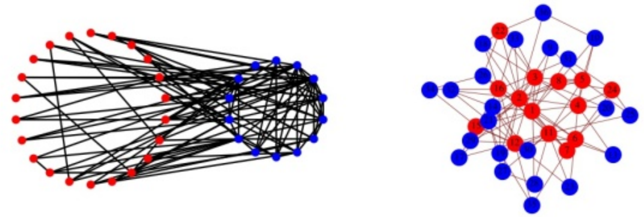
Biased Voting in Networks

Biased Voting in Networks

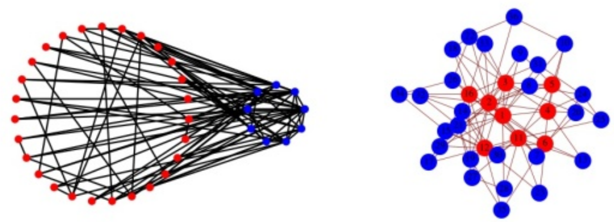
- Cosmetically similar to consensus, with a crucial strategic difference
- Deliberately introduce a tension between:
  - individual preferences
  - desire for collective unity
- Only two color choices; challenge comes from competing incentives
- If everyone converges to same color, everyone gets some payoff
- But different players have different preferences
  - each player has payoffs for their preferred and non-preferred color
  - e.g. $1.50 red/$0.50 blue vs. $0.50 red/$1.50 blue
  - can have symmetric and asymmetric payoffs
- High-level experimental design:
  - choice of network structures
  - arrangement of types (red/blue prefs) & strengths of incentives
  - most interesting to coordinate network structure and types


Behavioural Network Science Games
http://kearnsgroup.cis.upenn.edu/BNS/games.php?playername=Zak+Xavier
Google
travel
JCR Portal
ABN AMRO – ...al Banking
BofA
Penn.Pay Login
BlueCross
ACHE.org
PPM Members
Gmail
Adventuring Abroad...
Democratic Primary Games
Zak Xavier
game progress:
67%
game status:
Voter Game in progress
elapsed time:
If unanimity is reached, your payoff will be
$0.75 for red, $1.25 for blue
+0
+0
+1
+0
you
+1
+6
+5
+4
your color:
blue
red

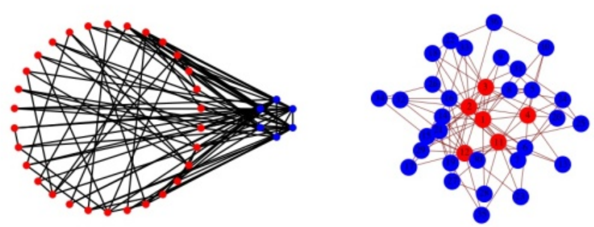
power22



power27



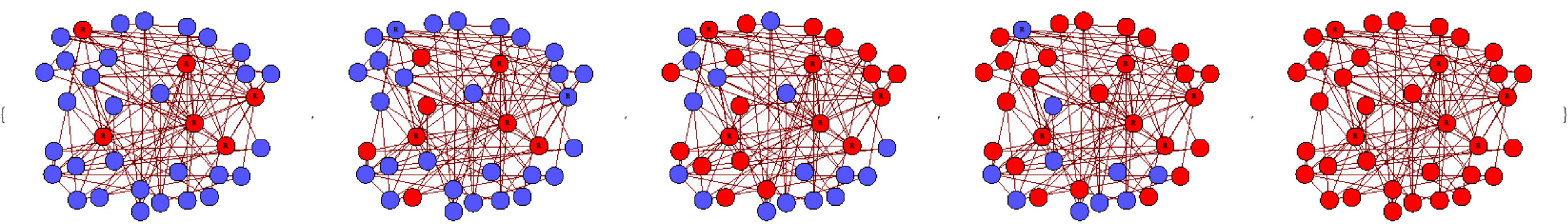
power30



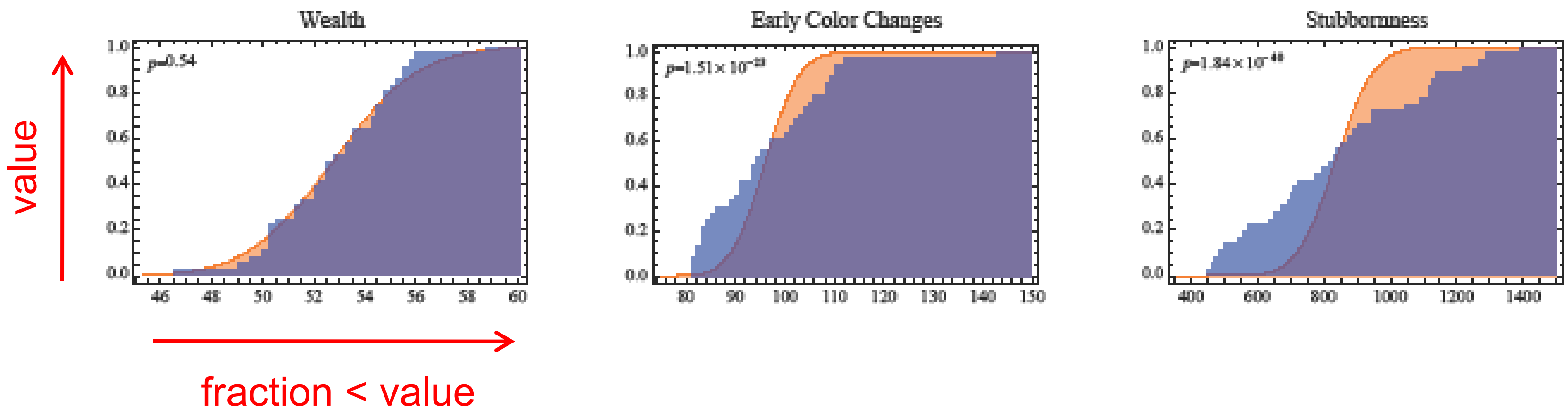
Minority Power: Preferential Attachment

Summary of Findings

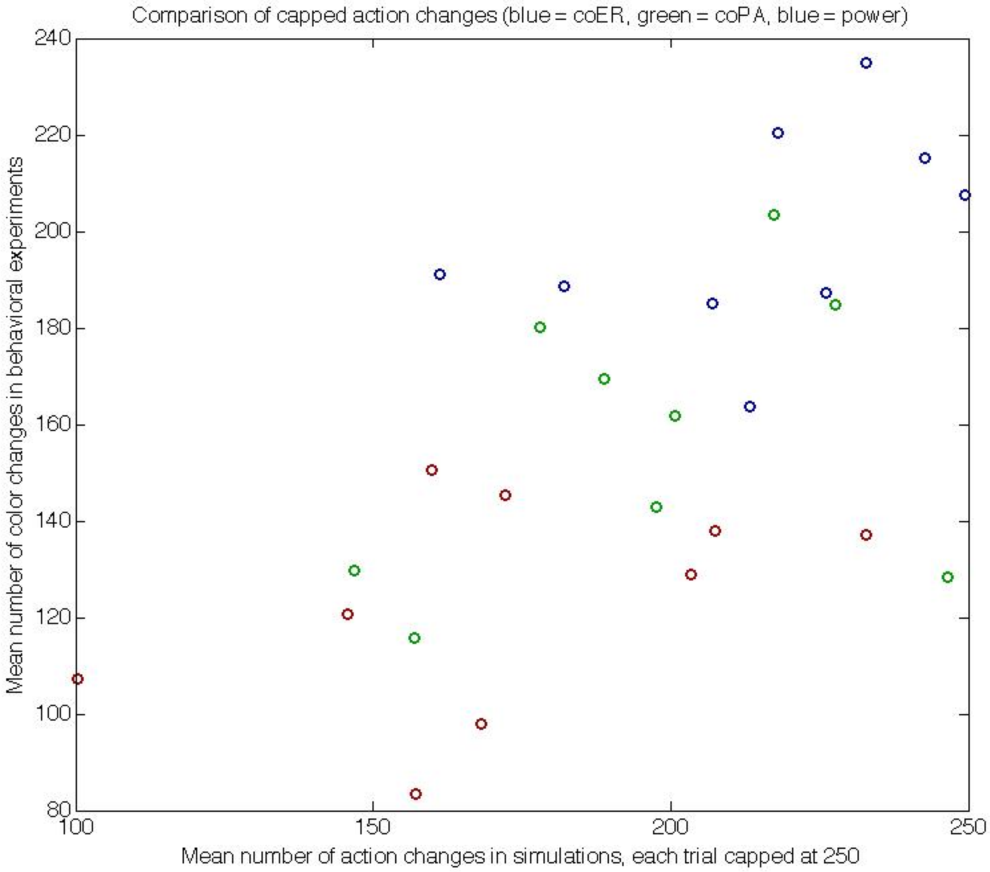
- 55/81 experiments reached global consensus in 1 minute allowed
  - mean of successful ~ 44s
- Effects of network structure:
  - Cohesion harder than Minority Power: 31/54 Cohesion, 24/27 Minority Power
  - all 24 successful Minority Powers converge to minority preference!
  - Cohesion P.A. (20/27) easier than Cohesion E-R
  - overall, P.A. easier than E-R (contrast w/coloring)
  - within Cohesion, increased inter-group communication helps
    - some notable exceptions…
- Effects of incentives:
  - asymmetric beats weak symmetric beats strong symmetric
  - the value of “extremists”



Effects of “Personality”



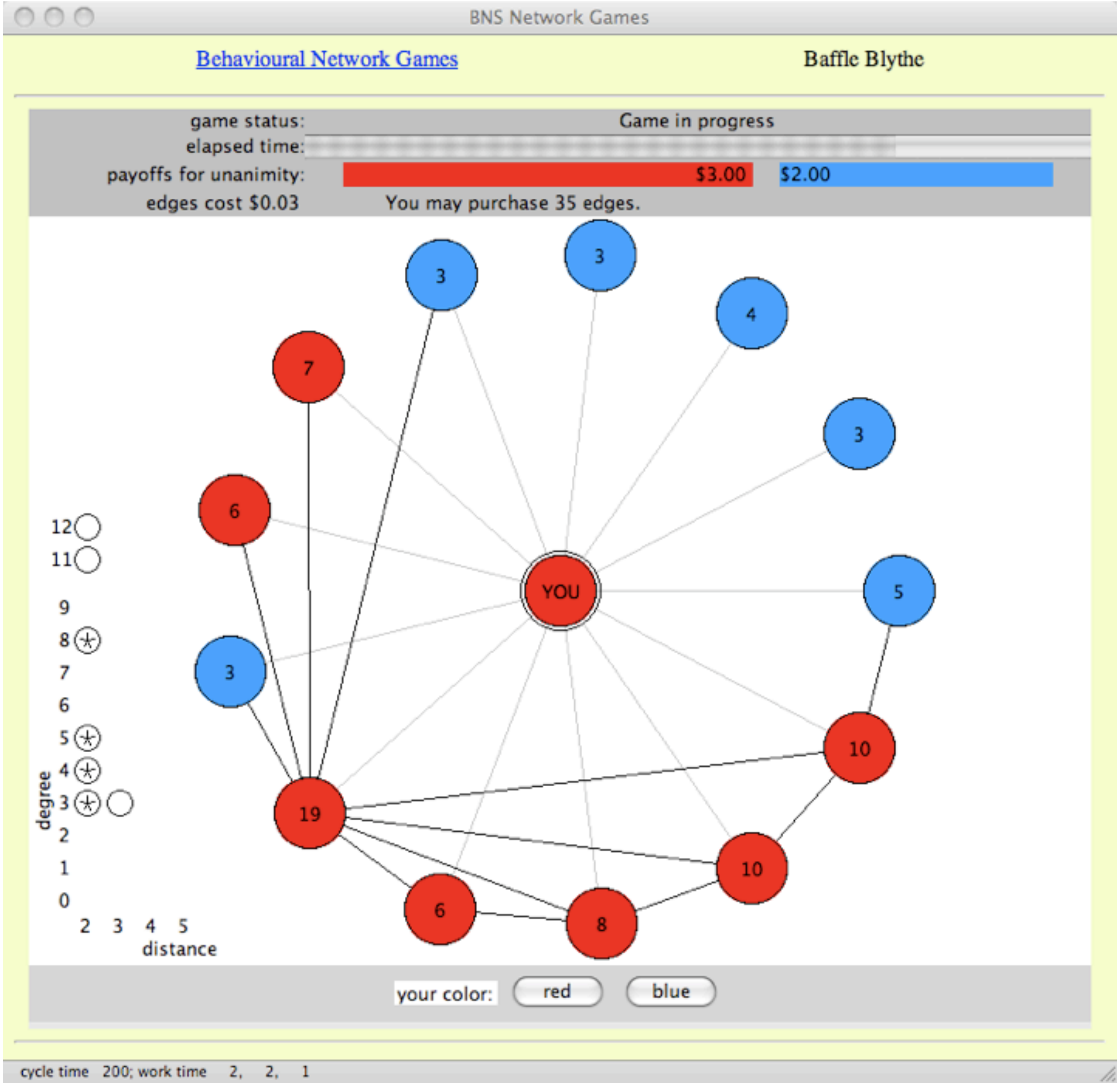
Behavioral Modeling



model: play color c with probability ~ payoff(c) x fraction in neighborhood playing c

Lessons Learned, 2005-2011

- At least for n=36, human subjects remarkably good
  - diverse set of collective tasks
  - diverse set of network topologies
  - efficiency ~ 90% across all tasks/topologies
- Network structure matters; interaction with task
  - contrast with emphasis on topology alone
- Importance of subject variability and style/personality
- Most recently: endogenized creation of the network
  - network formation games
  - challenging computationally (best response) and analytically



BNS Network Games
Behavioural Network Games
Baffle Blythe
game status:
Game in progress
elapsed time:
payoffs for unanimity:
$3.00
$2.00
edges cost $0.03
You may purchase 35 edges.
YOU
3
3
4
3
5
7
6
3
19
6
8
10
10
12
11
9
8
7
6
5
4
3
2
1
0
degree
2 3 4 5
distance
your color:
red
blue
cycle time 200; work time 2, 2, 1

Edge Purchases: Strategic Tensions

- Buy edges or not?
- For information or influence?
- Early in the game or late?
- To high degree or low degree players?
- Nearby or far away?

Experimental Design

- Session A: 99 experiments
  - 63 “unseeded” with varying payoffs, imbalances, asymmetries
  - 36 seeded with Minority Power settings
- Session B: 72 experiments
  - mixture of unseeded and variety of seeded (cliques, torus)
- A: 47/99 solved (47%): 25/63 unseeded, MP 22/36
- B: 27/72 solved (38%)
- Session C: 72 experiments
  - final networks from “hard” settings in Session A
  - permitted 0 or 1 edge purchases per player
  - started with both initial and final incentives from Session A
- C: 25/72 (35%); All: 99/243 (41%)
- Subjects seem to build difficult networks!

[tape]