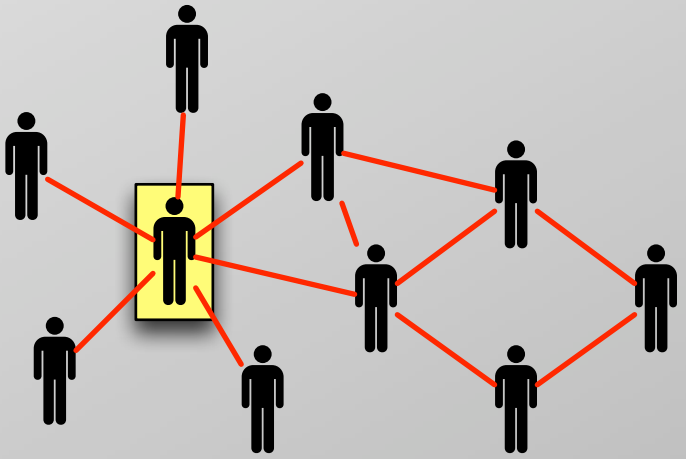
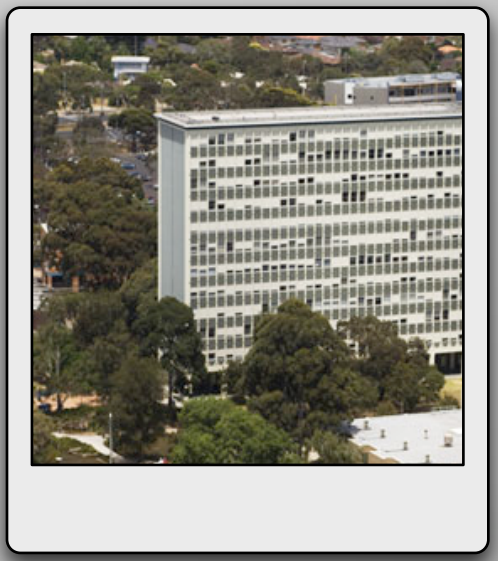
Dynamic Cooperation Networks





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Intro :: Agenda

- Games & Interactions
- Previous Approaches

A. Motivation

- Definitions
- Agents & Strategies
- The modified PD Network Game
- Interactions
- Learning
- Timing

B. The Model

- Static Interactions
- Dynamic Interactions
- Open ended evolutionary dynamics?

C. Results

- Where to from here?
- Network Analysis?
- Setup?

D. Discussion

Intro :: messages on cooperation & networks

Message (theory): dynamic networks open variety of outcome possibilities (e.g. Jackson & Watts (Games & EB, 2002))

Message (real): static networks (alone) don't necessarily buy cooperation & real networks are due to similarity (Cassar (Games & EB, 2007), Weinberg (NBER WP, 2007))

Message (sim): cooperation supported by stable, repeatable interactions (Vainstein (JTB, 2007))

A1. Stable cooperation networks arise through deliberate actions of individuals, behaving in contingent ways

A2. Interactions between agents motivated by similarity

Approach

Model :: Definitions

Population $\mathbf{N}$

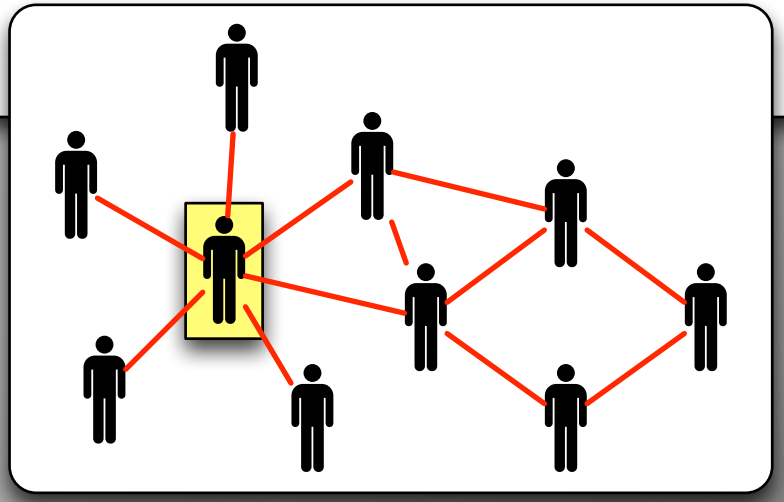
Individual i

Friend $\{j \in \mathbf{N},\ \exists\ i \longleftrightarrow j\}$

1-Neighbourhood $\mathcal{N}^i$

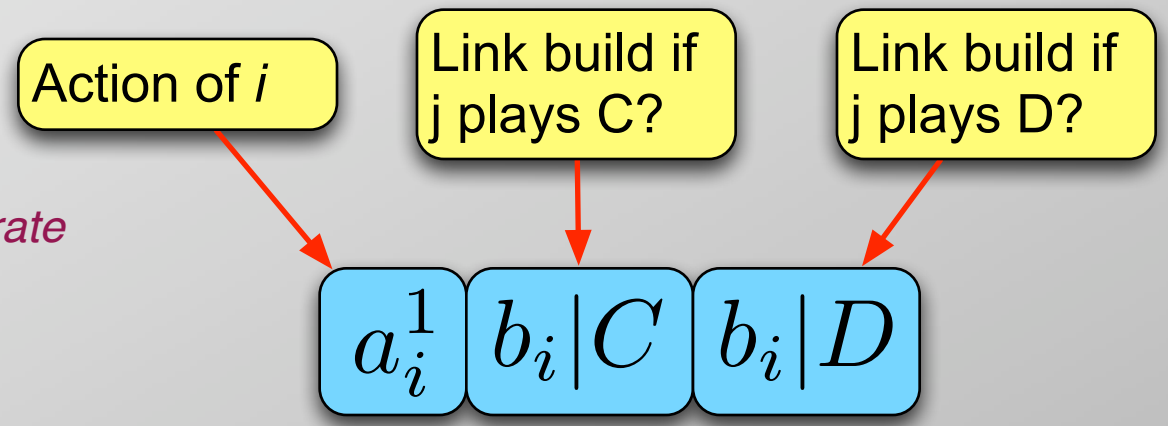
Friend of a friend $\{k \in \mathbf{N},\ \exists\ j \longleftrightarrow k\ \forall\ j \in \mathcal{N}^i\}$

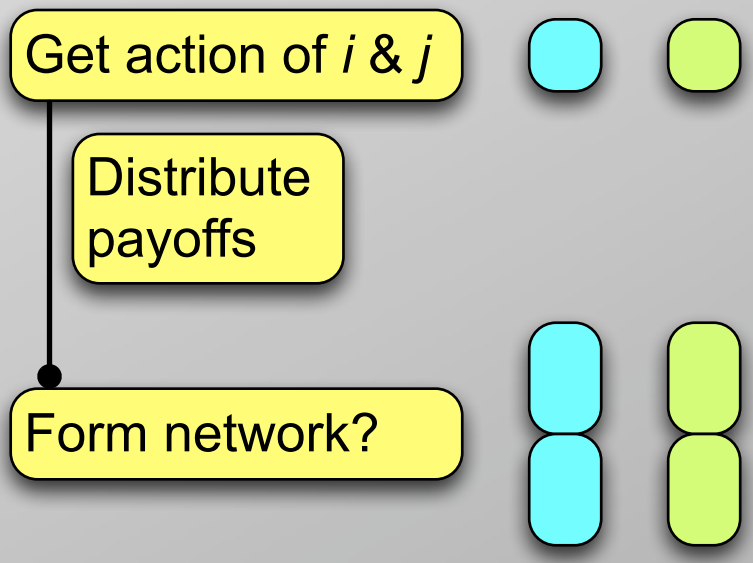
2-Neighbourhood $\mathcal{N}^{ii}$



Model :: Strategies & the Modified Game

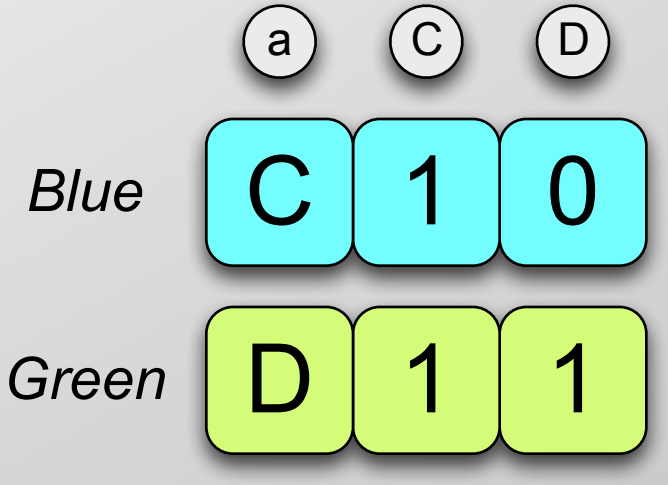
A1. Stable cooperation networks arise through deliberate actions of individuals, behaving in contingent ways



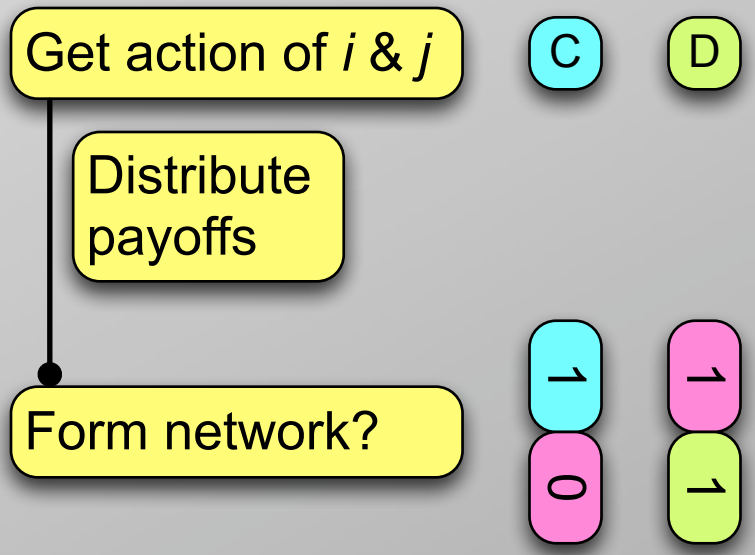


	C	D
C	3,3	0,5
D	5,0	1,1

Model :: An example



Player i plays C, j plays D, payoffs are received of 0 and 5 respectively, and they don't form a link (or break one if it existed previously).



	C	D
C	3,3	0,5
D	5,0	1,1

Model :: Interactions - choosing opponents

Choose an Agent *i*

Do H/2 times:

A2. Interactions between agents motivated by similarity

Choose a *friend* of *i*

Play Game: *(i,j)*

None?

j: uniform random *N*

Choose a *friend of a friend* of *i*

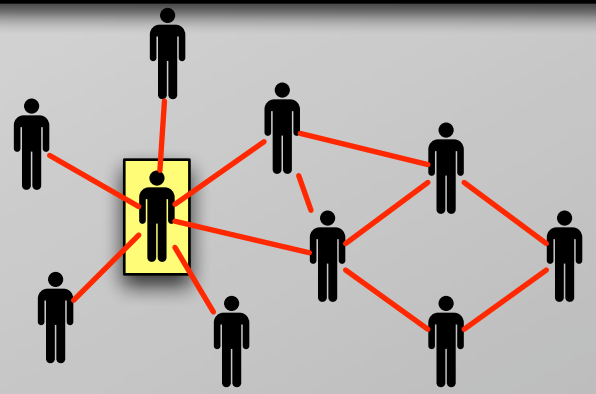
Play Game: *(i,k)*

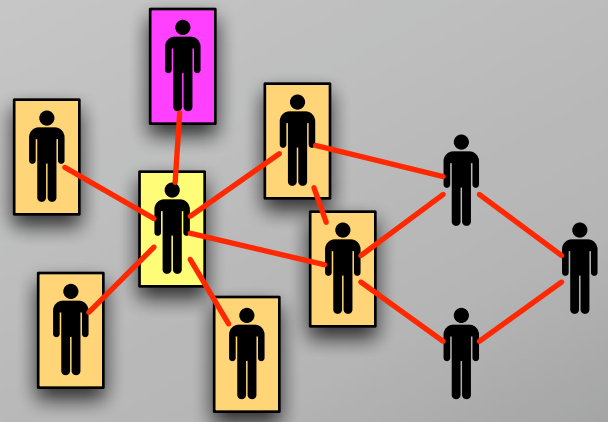
None?

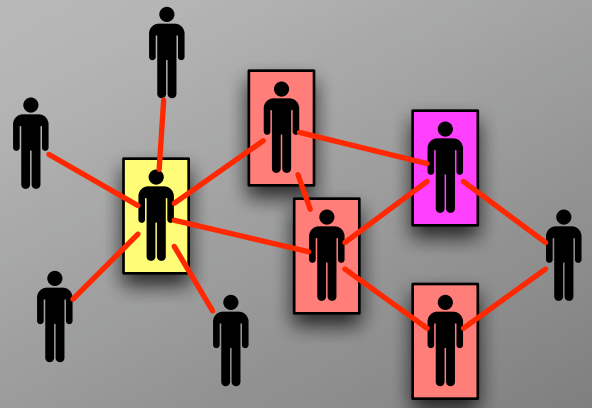
k: *Friend* of *i*

None?

j: uniform random *N*







Model :: Strategy Update

Choose an Agent *i*

If connected

$$\bar{\pi}^i = \max(\hat{\pi}_j),\ \forall\ j \in \mathcal{N}^i$$

else

$$\bar{\pi}^i = \max(\hat{\pi}_j),\ \forall\ j \in \mathbf{N}$$

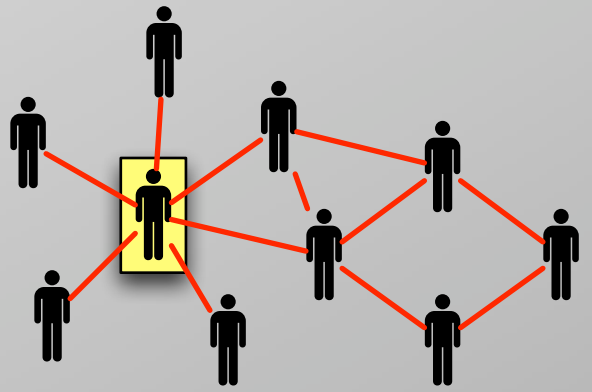
Compare fitness

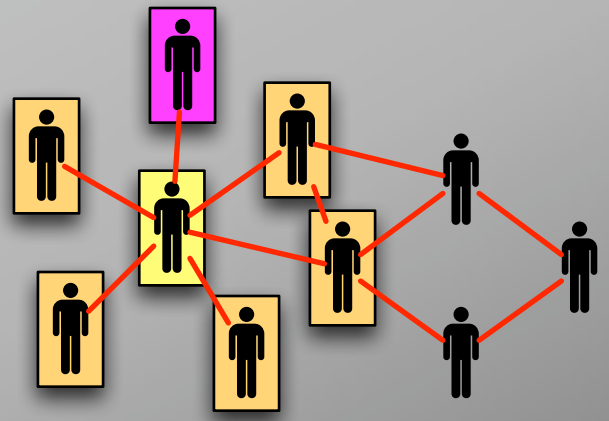
if $\pi^i < \bar{\pi}^i$

$$\text{set } s^i \leftarrow s^j,\ j : \hat{\pi}_j = \bar{\pi}^i$$

Make mistakes

A2. Interactions between agents motivated by similarity

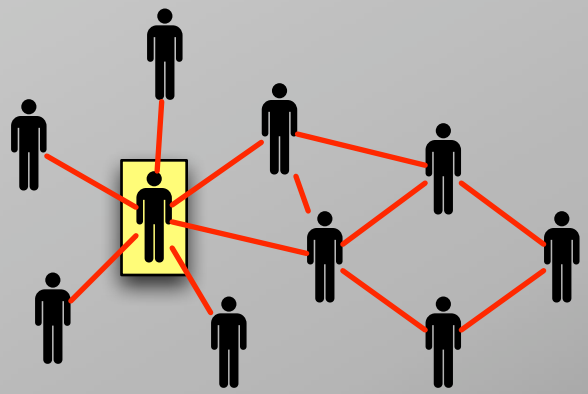




Model :: Timing

One Step

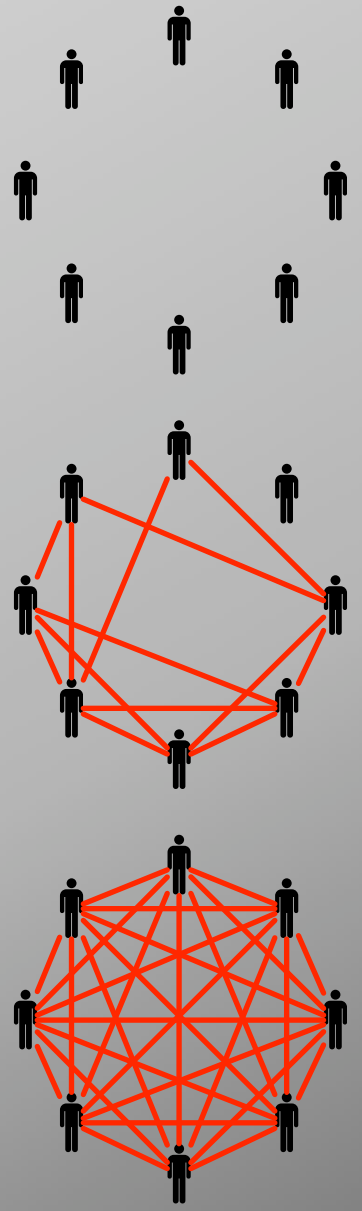
1. Choose an Agent *i*
   - Have *h interactions*
     - Play friend
     - Play friend of friend
2. Choose an Agent j
   - Update Strategy



Experiments :: parameters

Fixed		
Paramter	**Symbol**	**Value**
population size	*n*	40
steps/updates	*T*	60,000
trials	*K*	100
payoffs	*g*	3,0,5,1
link formation cost	*c*	0
mistake rate	*e*	0.01

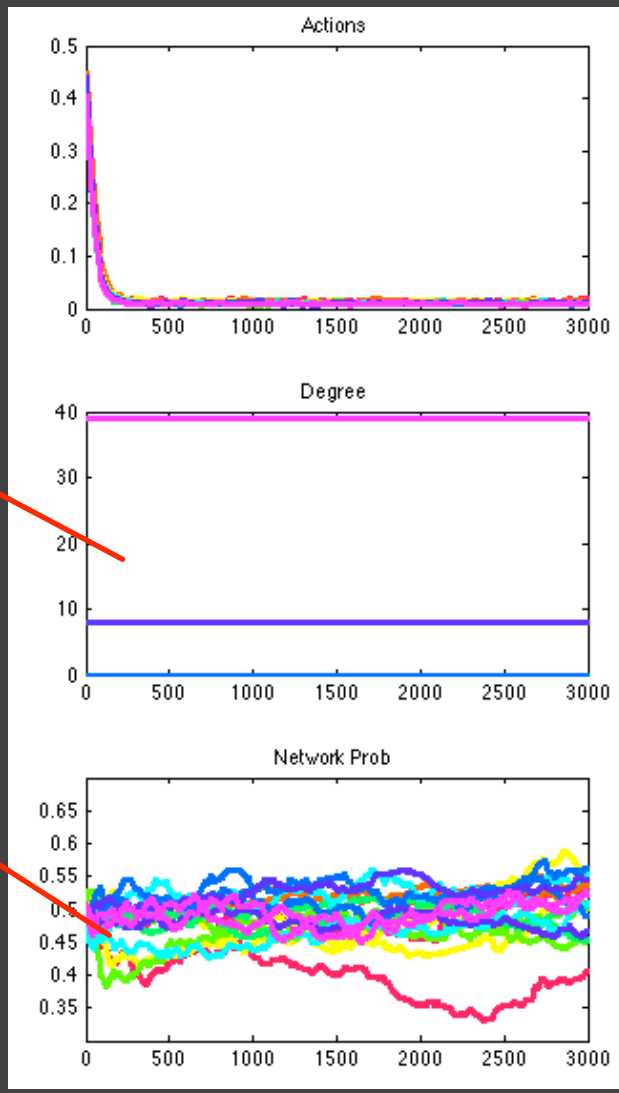
Experiments		
Paramter	**Symbol**	**Values**
network update	*p*	{0,1}
initial network	*net*	{empty, sparse, complete}
initial population type	*f*	{D00,D01,...,C10,C11}
number of interactions/history	*H*	{2,10,20,40}



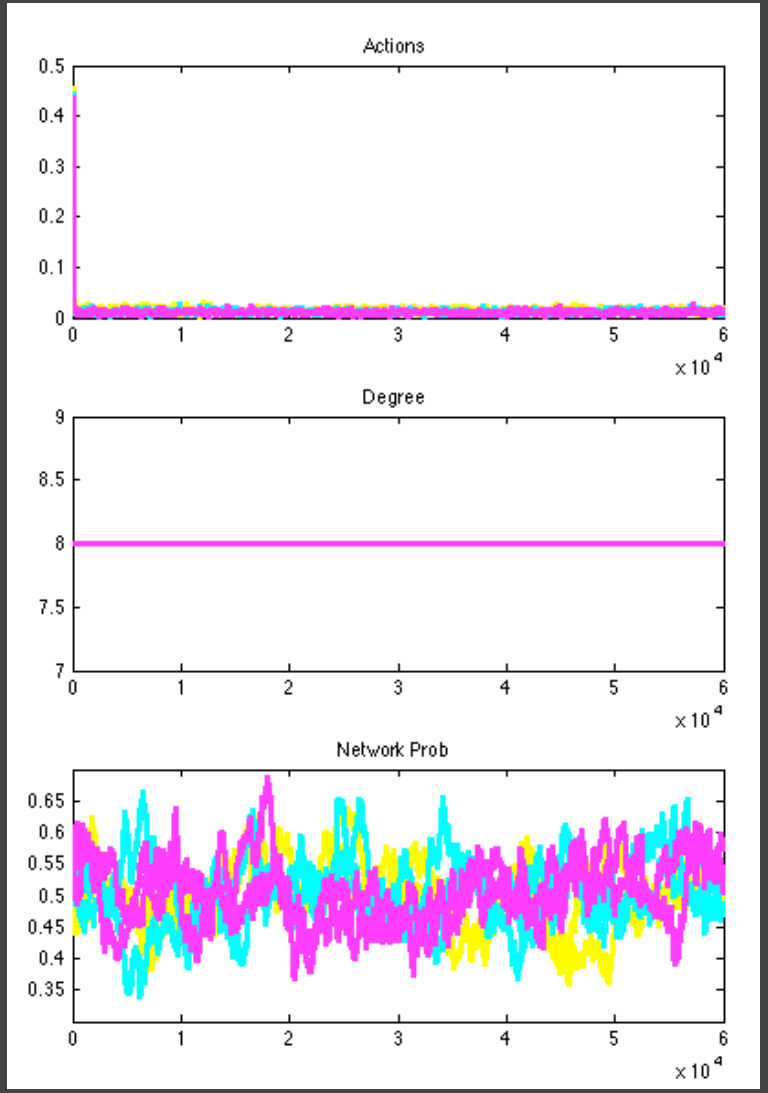
Results :: Static interactions

Static
Avg. degree

Aribitrary Use of Net Signals

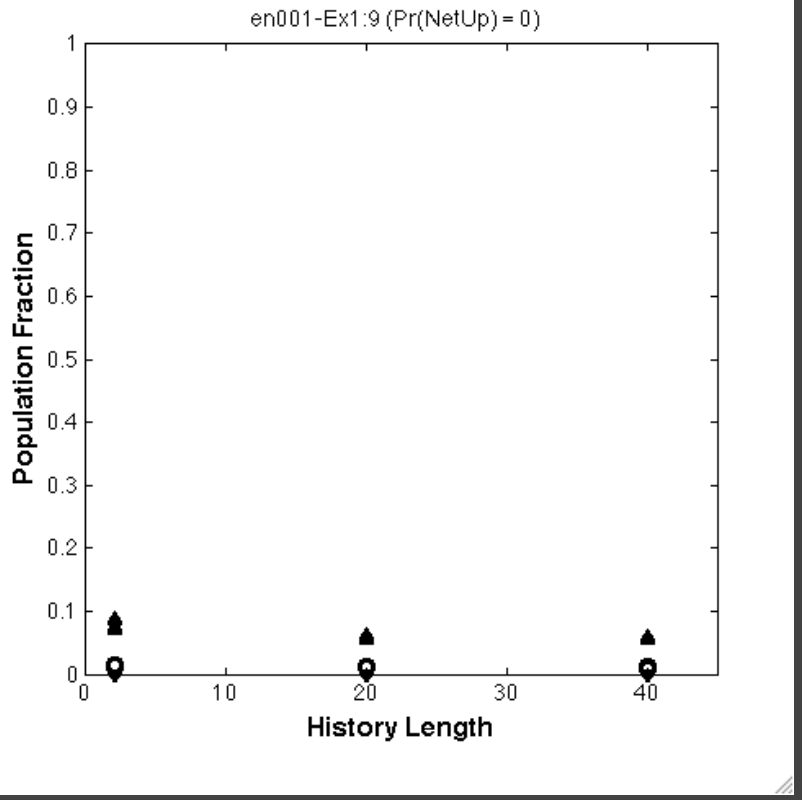


STATIC (3,000 updates)

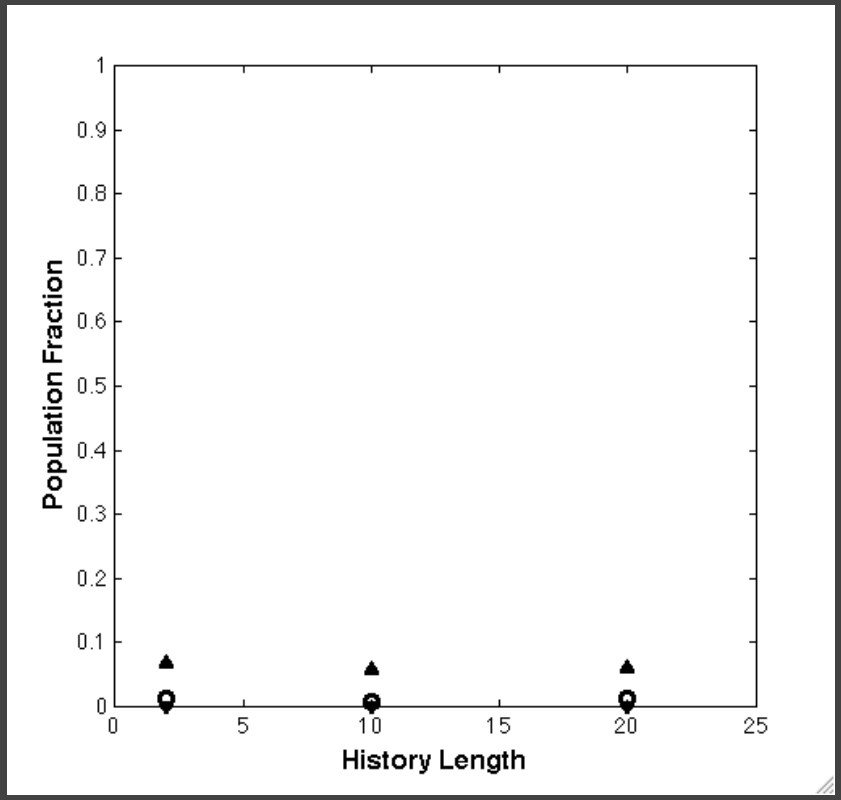


STATIC (60,000 updates)

Results :: Static interactions



STATIC
Initial-network: any | **Net updates**: off
Initial strategies: any | **Updates:** 3,000



STATIC
Updates: 60,000
Network: sparse

Results :: Static Interactions

Result 1: The model follows the canonical result for the one-shot PD with static, uniform (non-local) interactions (pD ~ 1.0)

Evidence:
* The upper bound on pC of all trials after 60,000 updates was << 0.1
* This result stands irrespective of using an empty, or complete graph (as expected .. both are 'uniform' interaction mechanisms)

Result 2: Local, static interactions (sparse network) also lead to the canonical one-shot PD result (pD ~ 1.0)

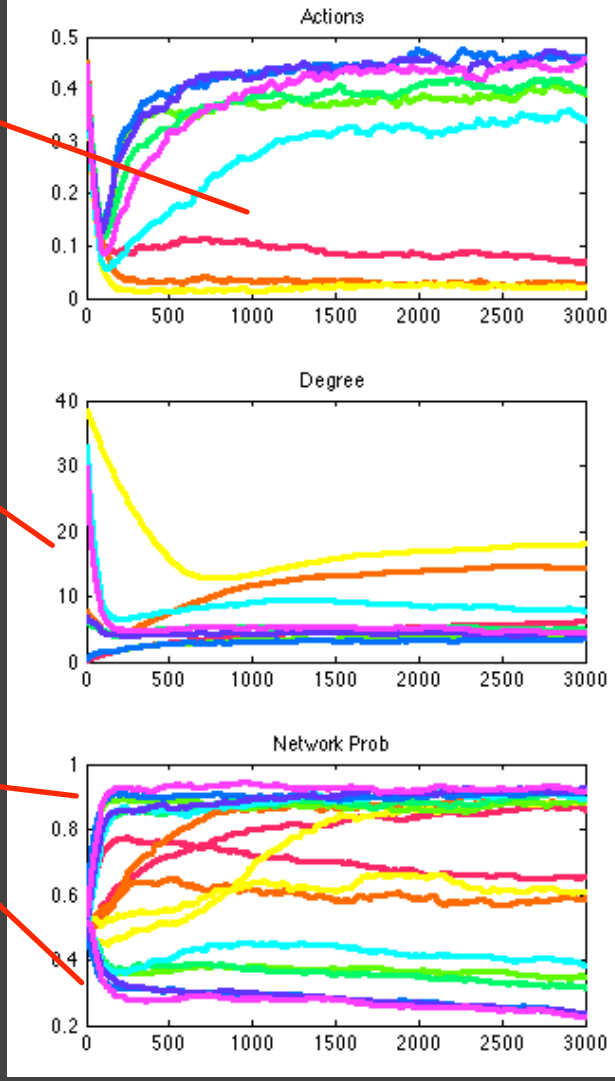
Evidence:
* The upper bound on pC of all trials after 60,000 updates was << 0.1

Results :: Dynamic cooperation networks

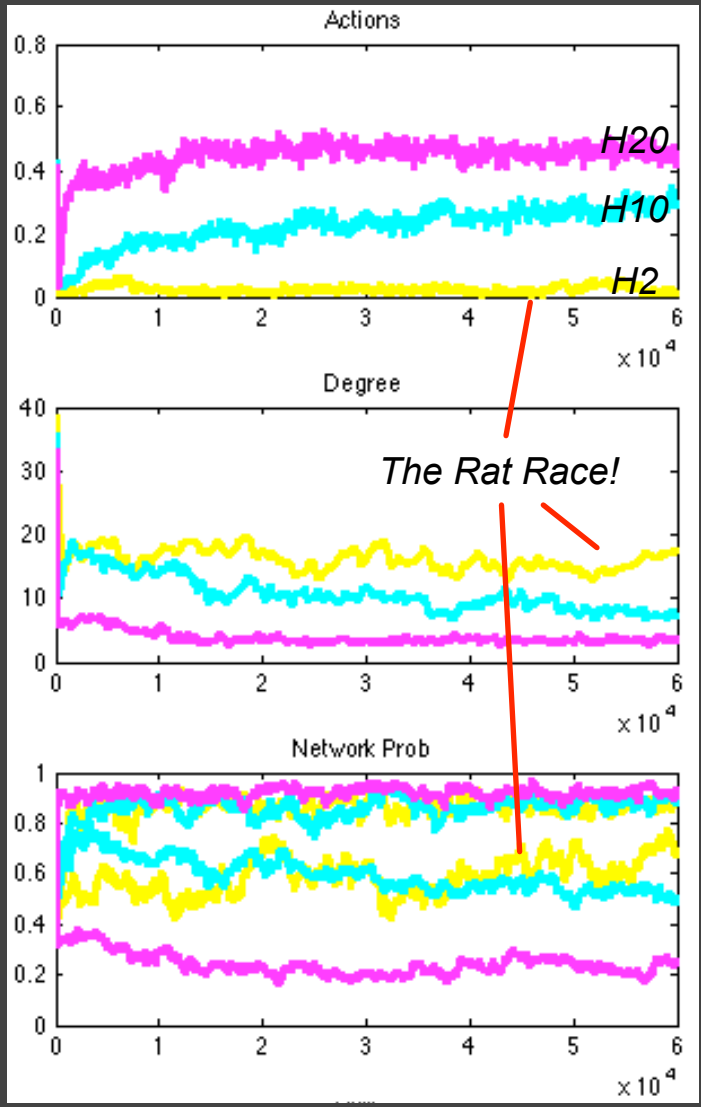
Cooperation (but not always)

Stable Net Formation

Signal Separation

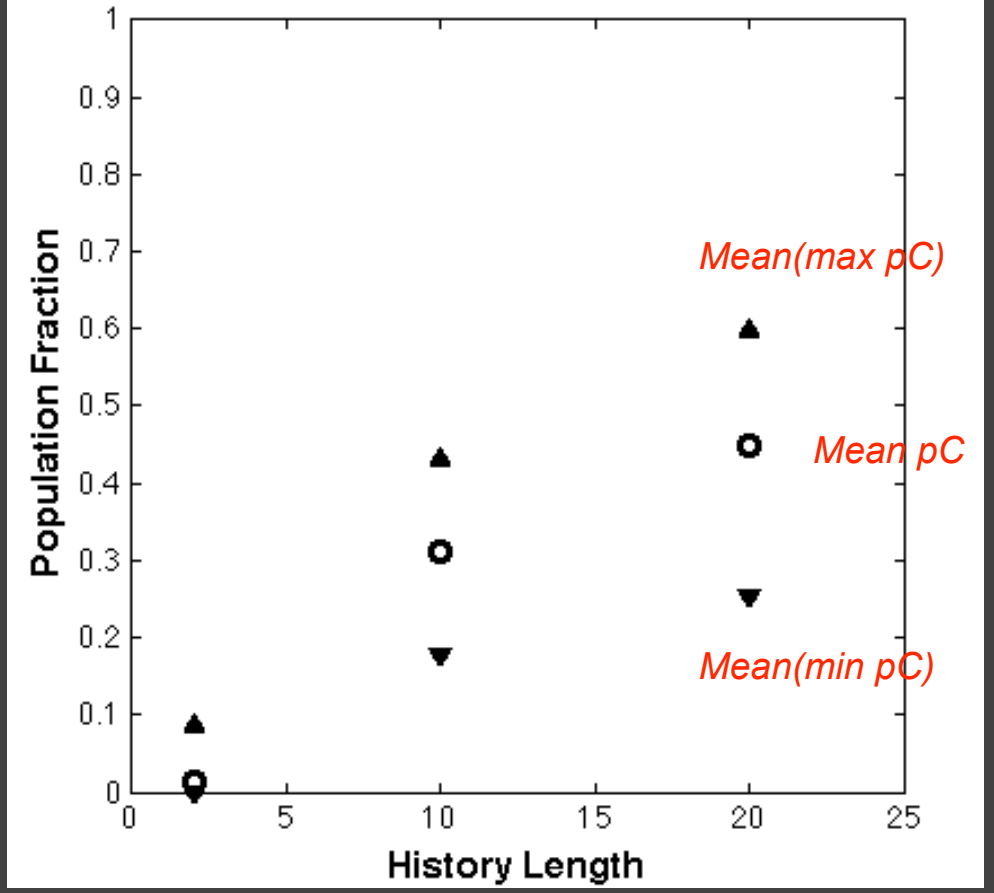


DYNAMIC (3,000 updates)



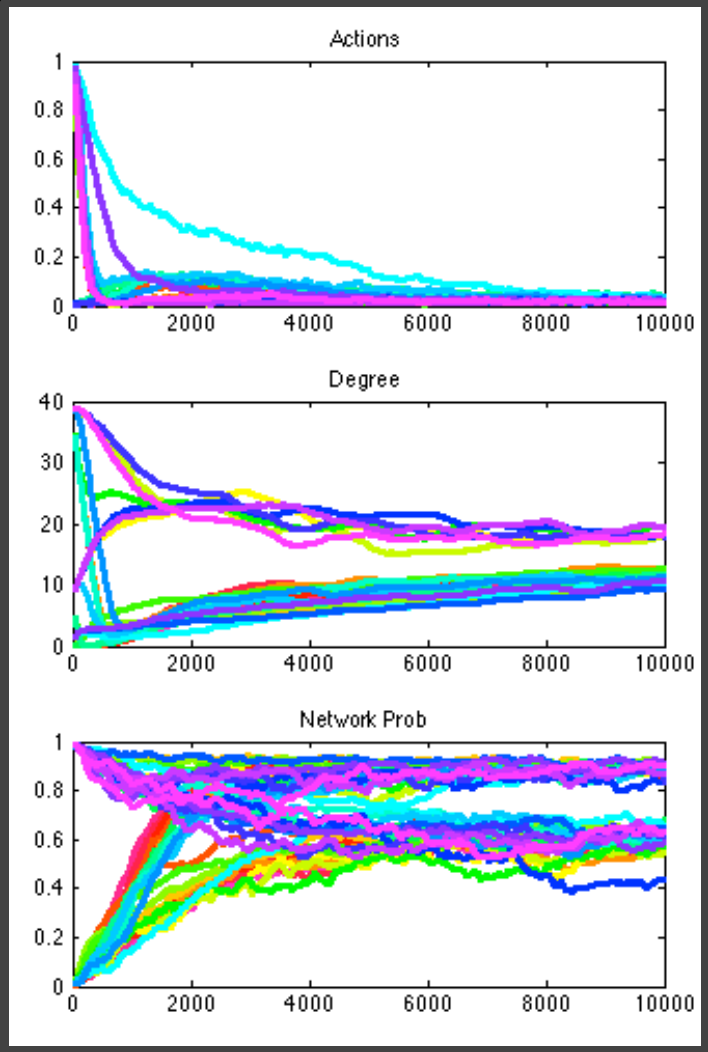
DYNAMIC (60,000 updates)

Results :: Dynamic cooperation networks

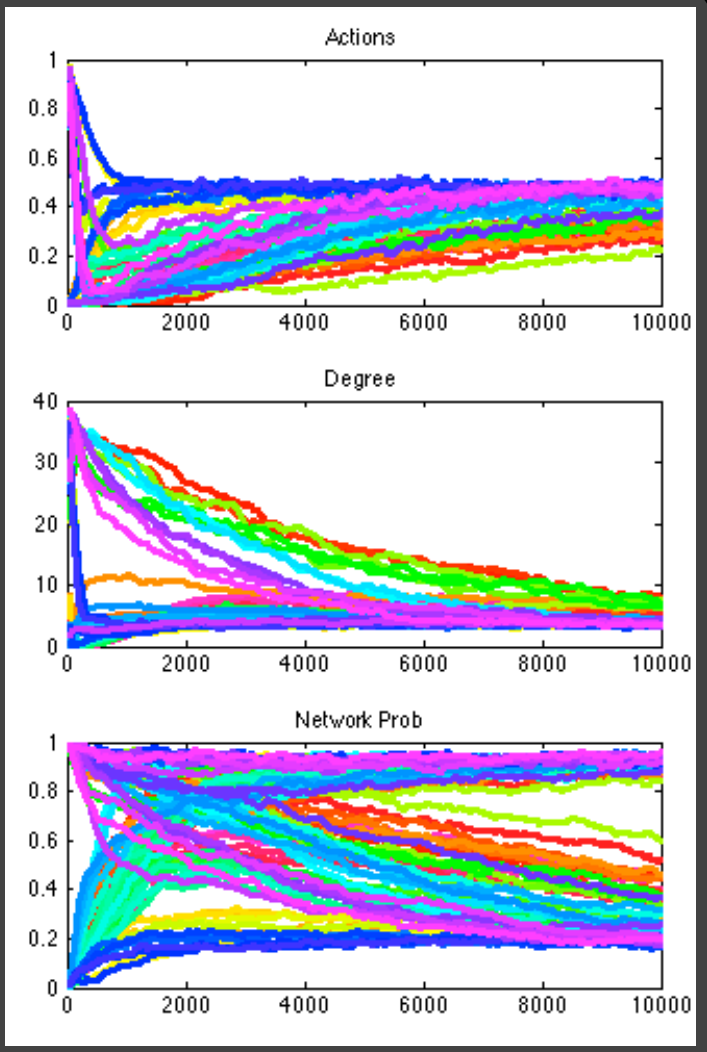


DYNAMIC
Updates: 60,000 | **Initial population:** any
Initial net: any

Results :: Biased Initial conditions?



Biased, H2



Biased, H10, H20

Results :: Static Interactions

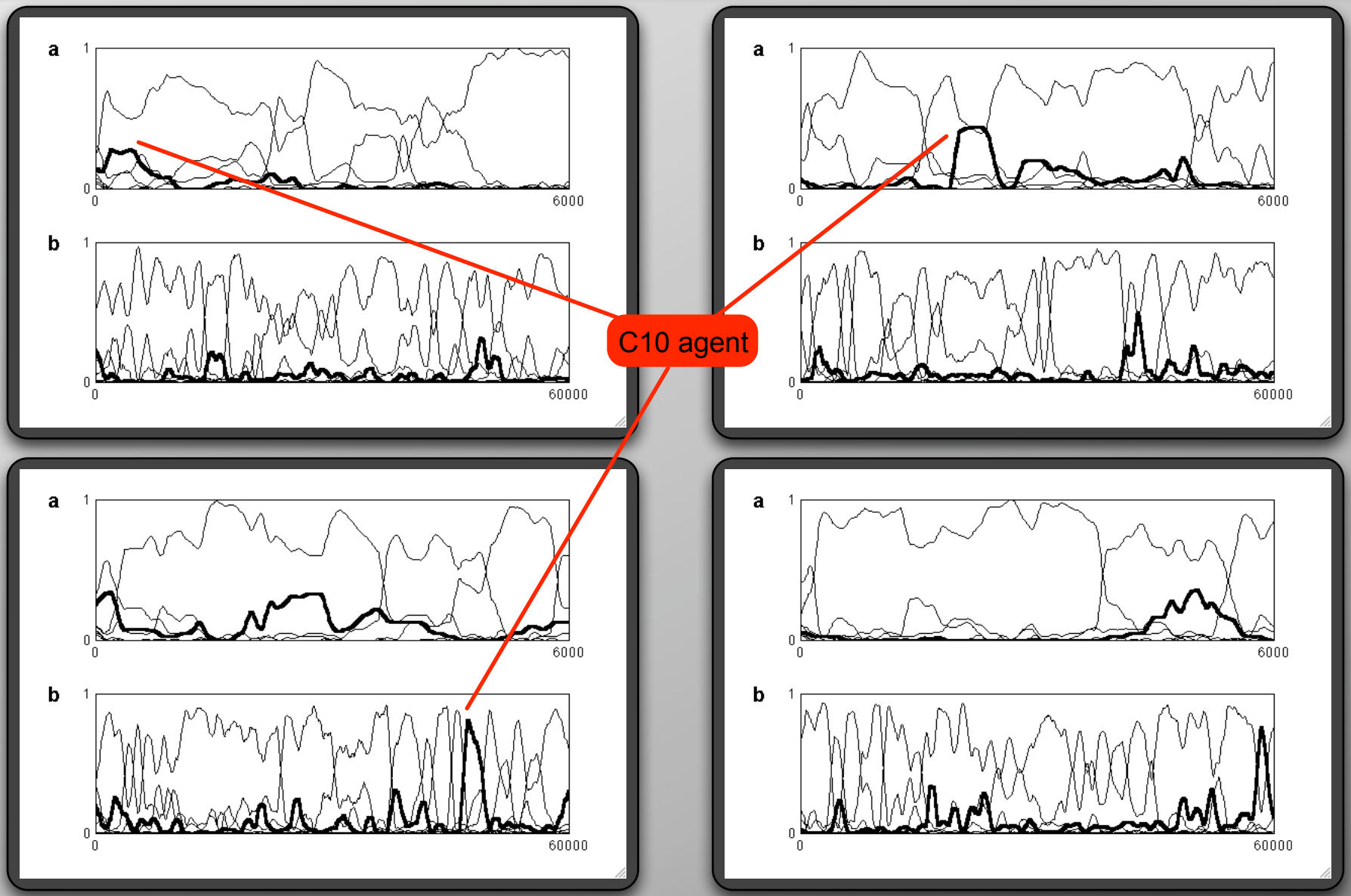
Result 3: Long-run, stable cooperation arises when interactions are dynamic and H >> 2 (many interactions per agent)

Evidence:
* With H2, networks are predominantly defection-based;
* With H >> 2, networks are predominantly cooperation based

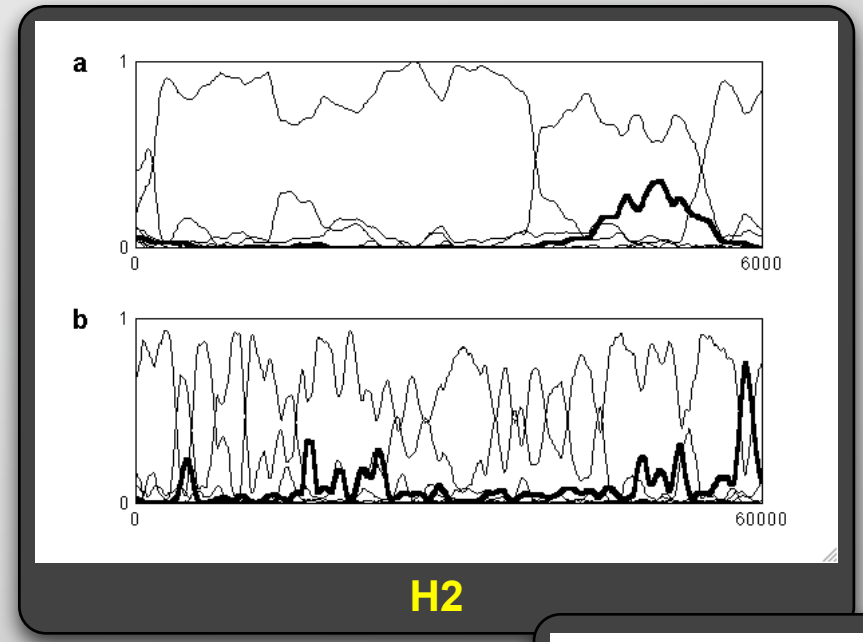
Result 3b: Result 3 holds, regardless of initial conditions (strategies, networks): for this parameterisation, network formation appears to be an inevitable equilibrium outcome

Evidence:
* Biased initial strategic conditions (including all D01) made no difference
* Biased network conditions (SW, complete, empty) made no difference

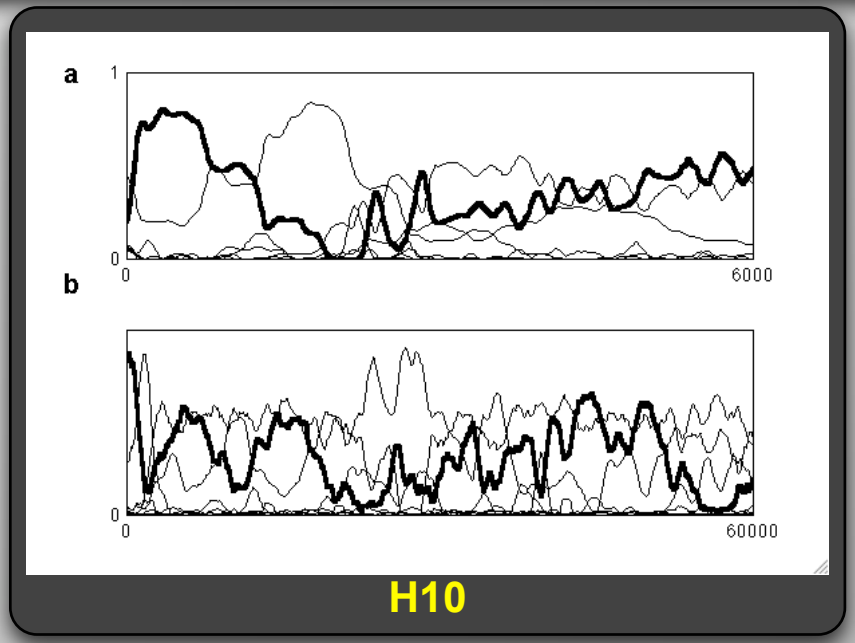
Results :: H2 Short-run cooperation?



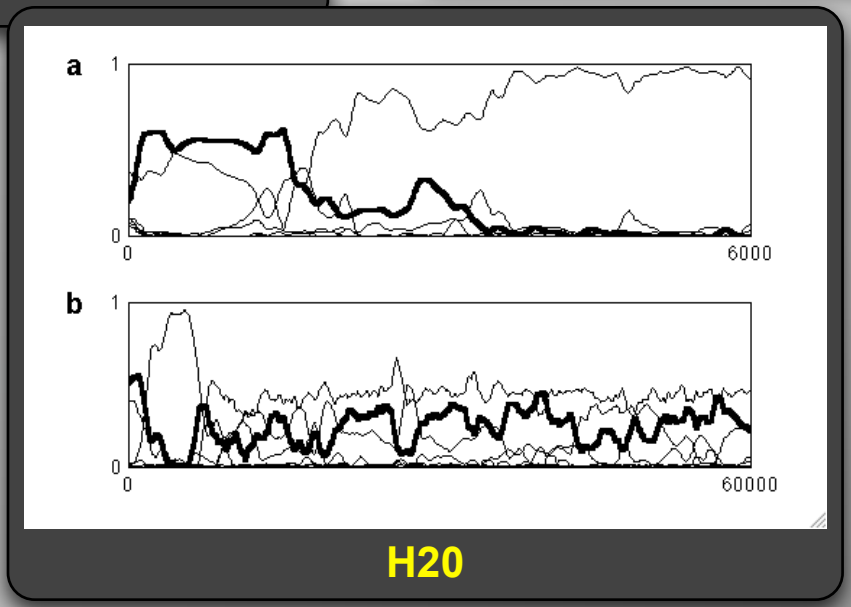
Results :: H2, H10, H20 compared



H2



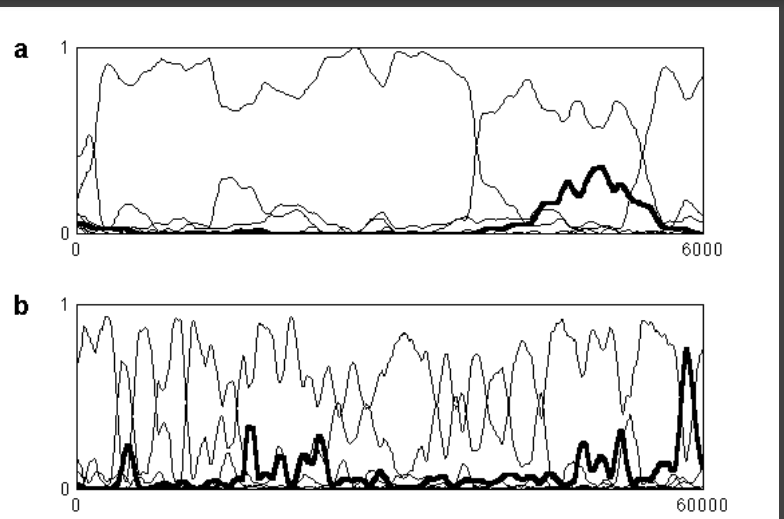
H10



H20

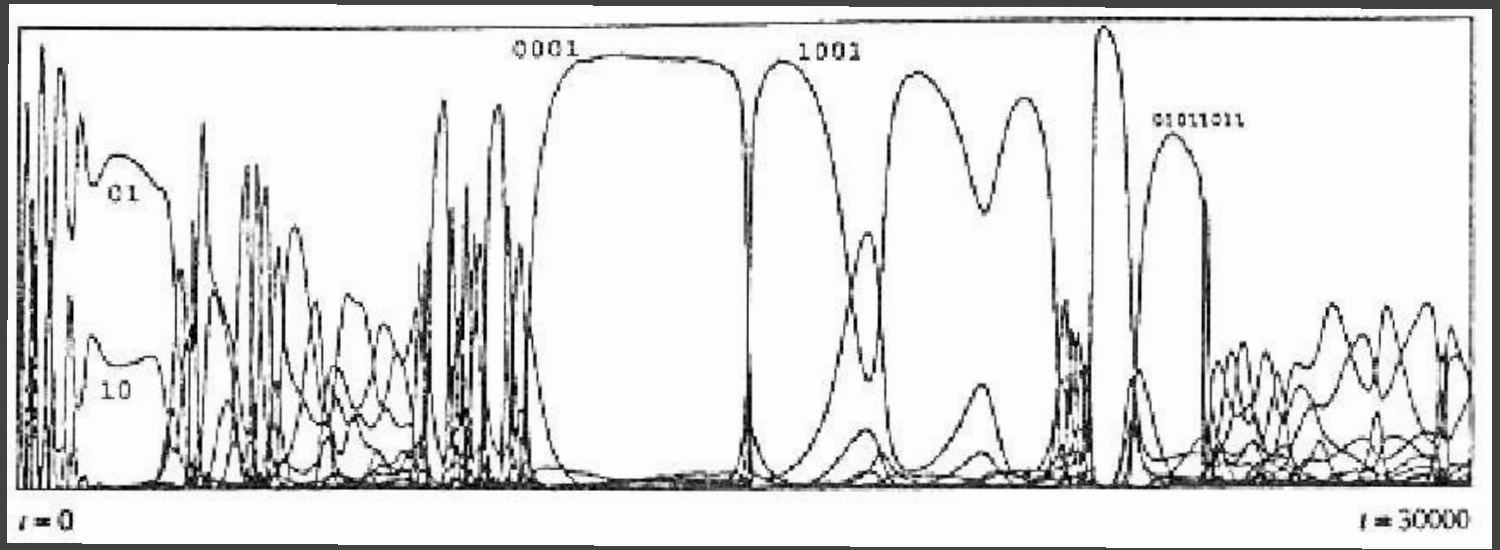
Higher 'interplay' damps dynamics

Results :: Open-ended evolution?



H2

"Almost all simulations have in common that during the evolution the system passes a number of long-lived metastable states (periods of stasis) that appear in a certain order. These periods are usually interrupted by fast transitions to unstable dynamic behaviour or to new periods of stasis." (p.301)



Lindgren's 1992 model of Open-ended Evolution

Results :: Long-run dynamics

Result 4: Under dynmic network formation, and short histories (H2), cooperation episodes do occur, but are short-lived.

Result 5: Longer histories (H>>2) serve to *damp* the oscillations in the dynamics, favouring long-lived cooperative network-building agents.

Result 6: Long-run (60,000 update) dynamics for short-histories (H=2) appear to mimic the so-called 'open-ended evolutionary dynamics' of Lindgren's 1992 repeated PD game.

Discussion ::

Episodes of cooperative behaviour can emerge amongst otherwise non-cooperative populations

Even though ...

+ Interactions are *not always* with *known* friends (will be on the receiving end of island agents)
+ Nature of friends' behaviour can *change at any time*

Necessary conditions?

+ Ability to *engage* in repeated interactions with *known opponents* (partners)
+ Ability to *disengage* with partners who *change their behaviour*
+ Ability to *never engage* with *unwanted partners* (after costly interaction)
+ An *introduction mechanism* exists (A2. 'Similarities')
+ Costless link formation?

Episodes of cooperation are not stable unless other institution supports 'good' interactions

That is, cooperation can emerge from the ashes, but will not stay unless cooperative agents can make most of their new relationships

Options for further analysis ...

Back to the lab ...

What are necessary conditions?

+ Lack of discrimination between opponents (e.g. {C,D}{0,1} only)?
+ Costly link formation?
+ Costly link severance?
+ Costly link maintenance?

What kind of networks arise in the model?

What is really the difference between H2 .. H20+, measure of long-run dynamic non-equilibrium activity?

+ Floating value of H? (how to determine this?)

Sensitivity to introduction mechanism (friend, friend-of-friend)?

Sensitivity to BR (rather than imitation?)

Intro :: motivation

Theory

Strategic Stability (contingent play) with Endogenous Networks

e.g. Jackson & Watts (Games & EB, 2002)

+ Strategies: players BR to neighbours in coordination games
+ Timing: 1. update one link (ass. static plays); 2. update one strategy (BR)
+ Loners: play with random other

=> Static nets: multiple stochastically stable states possible

=> Dynamic nets: equilibria on non-efficient, non risk-dominant strategies

=> highly dependent on payoffs and costs of link formation

Network Stability (given non-contingent play)

e.g. Bala & Goyal (Econometrica, 2000), Jackson & Wolinsky (JET, 1996)

+ Which networks are 'pairwise stable', under different network/utility specifications?
+ e.g. co-author networks, communications networks

Message: dynamic networks open variety of outcome possibilities

Intro :: motivation

Experiments

Static Nets

e.g. Cassar (Games, 2007)

+ Coordination & cooperation on Random, SW, Regular (local) nets

=> Cooperation hard to reach in all three static nets (worse for SW)

=> In SW nets: defection reached faster, stay there longer

=> Individual behaviour affected by (only) 2 elements:

i. path-length at the individual level (longer paths improve C)

ii. number of neighbours (more neighbours improve C)

Econometric

Dynamic Nets

e.g. Weinberg (NBER WP, 2007)

=> people associate with others who's behaviours and attributes are similar to their own

=> But .. variation in attributes within and between macro groups (e.g. the similar attribute they 'coalesce around' can be variable)

Message: static networks (alone) don't buy cooperation & real networks are due to similarity

Intro :: motivation

Simulation

Variable interactions

e.g. Vainstein (JTB, 2007)

+ PD with non-contingent mobility on a grid
+ Agents play PD with all neighbours on grid
+ Then move with constant prob. to a different site

=> low values of mobility lead to stable cooperation, high values lead to full D

Message: cooperation supported by stable, repeatable interactions