Cooperation through the endogenous evolution of social structure

David Hales & Shade Shutters
The Open University & Arizona State University
www.davidhales.com

For more details and references see:
http://davidhales.com/papers/complex2012.pdf

Santa Fe, NM, Thursday, Dec 6th

Questions

- Human societies appear pervaded by groups. Often show in-group pro-social behavior
- How can this be understood from the point of view of individuals who comprise those groups?
- How do selfish agents come to form groups that are not internally selfish?
- Individualism v. Collectivism (morality?)
- The origins of virtue – Matt Ridley 1996

Quotes

"There can be no doubt that a tribe including many members who.. were always ready to give aid to each other and to sacrifice themselves for the common good, would be victorious over other tribes; and this would be natural selection"

Darwin, C. (1871) The Descent of Man and Selection in Relation to Sex (Murray, London) 2nd Edition.

Models or thought experiments?

- Abstract models / artificial societies
- Agent based modeling
- Thought experiments
- Not empirically verified / or applied
- Relax assumptions of traditional game theory / rational action approach
- Copying (replication) and limited innovation (mutation) => cultural evolution?
- “Emergent” macro outcomes
- Focus on social dilemma / public goods type scenarios

Assumptions

- Agents interact producing individual payoffs (e.g. Prisoner's Dilemma game)
- Agent action determined by a trait (e.g. cooperate or defect)
- Agents select interaction partners based on further trait defining an "in-group" (a tag)
- Traits can be copied and mutated
- Agents copy traits that produce higher individual payoffs
- Evolutionary game theory

What are tags

- Tags = observable labels, markings or social cues
- Agent display and can observe tags
- Tags evolve like any other trait (or gene or meme)
- Agents may discriminate based on tags
- John Holland (1992) => tags powerful “symmetry breaking” function in “social-like” processes
- In GA-type interpretation, tags = parts of the genotype reflected directly in the phenotype

Tag Models

- Tags may be bit strings signifying some observable cultural cues
- Tags may be a single real number
- Any distinguishing detectable cue
- Most show cooperation / altruism between selfish, greedy (boundedly rational) agents

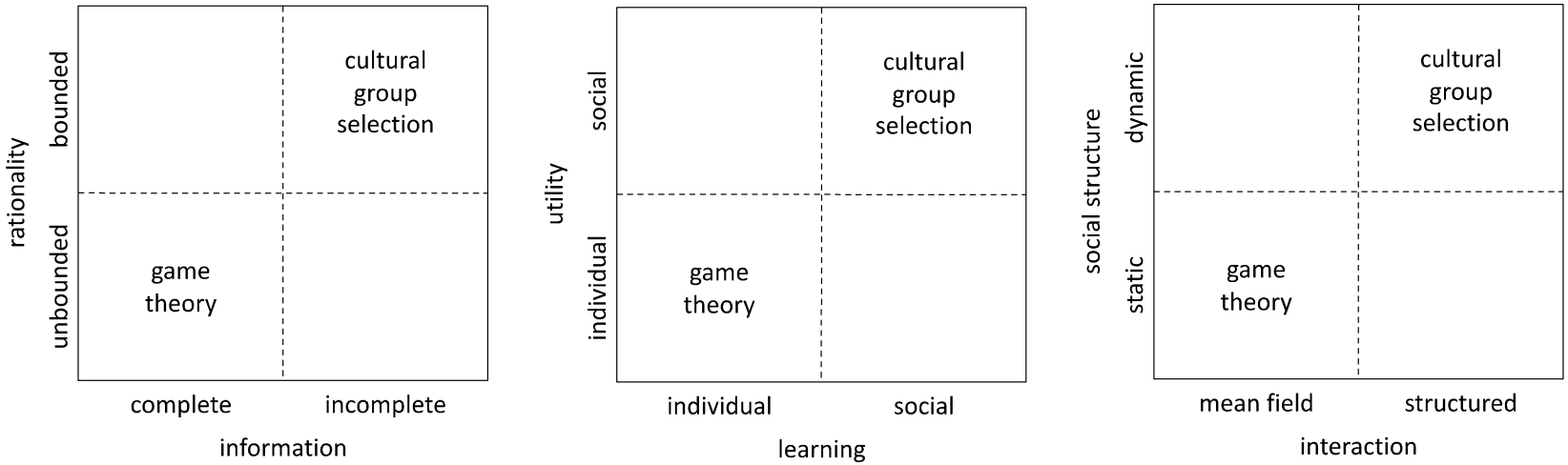
Tag models

- Riolo et al introduce a tag / tolerance model
- Tolerance is a strategy trait - how close another's tag should be to donate
- Tolerance = 0 means only donate to identically tagged others, Tolerance = 1 donate to all (assuming tags [0..1])
- Tolerance models explore less strict population structure – random sampling of population through “pairings” parameter
- Shade Shutters – detailed work on these models in combination with space and binary cooperation traits:
- *Shutters, S., Hales, D. (in press) Tag-mediated altruism is contingent on how cheaters are defined. Journal of Artificial Societies and Social Simulation.*

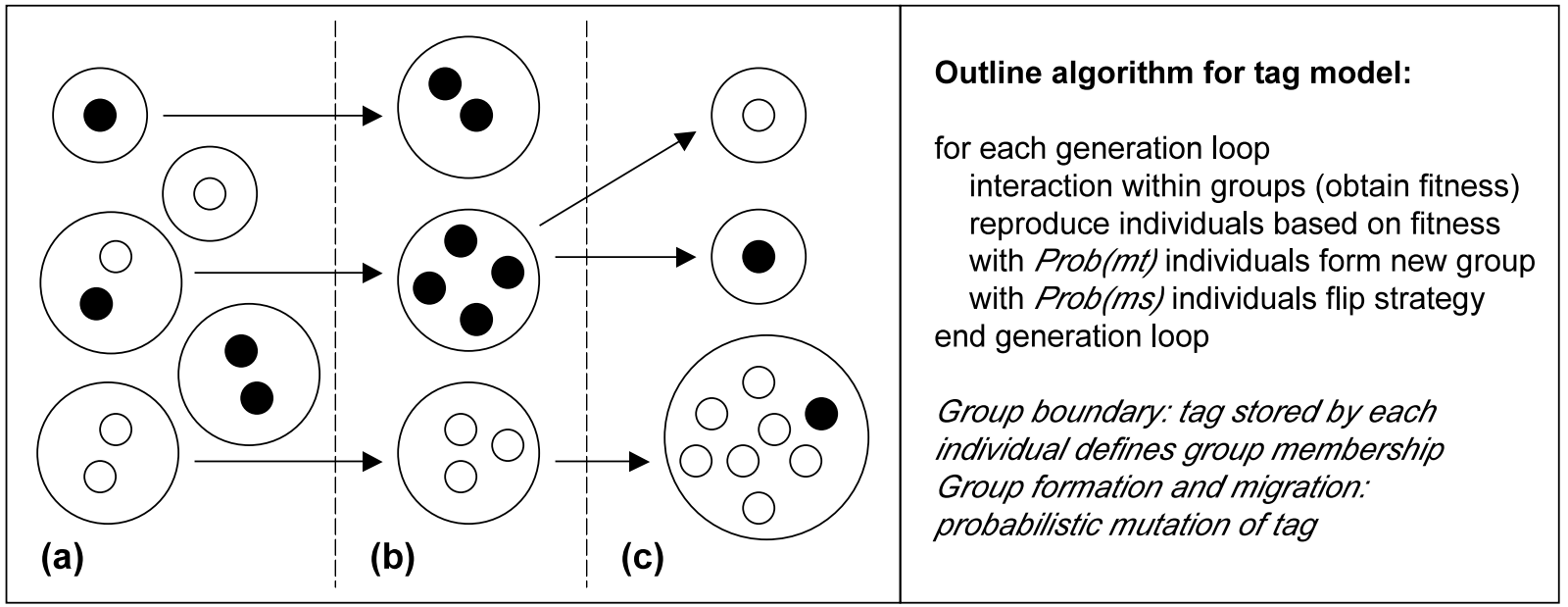
Tags in the literature

Year	*Author(s)*	*Tag Type*	*Model*	*Interp.*	*Task*	*Ref*
1993	Holland	general / real no.	none	socio. / bio	IPD	SFI WP
1997	Riolo	real number	bio.	bio.	IPD	SFI WP
2000	Hales	binary string	socio.	socio.	PD	MABS2000
2001	Riolo et al	real number	socio.	socio.	giving game	Nature
2002	Hales	real number	socio.	socio.	special-isation	MABS2002
2003	Hales & Edmonds	binary string	agents	agents	help giving	AAMAS2003
2003	Hales & Edmonds	various	agents	agents	various	ESOA2003
2004	Hales	network links	p2p	p2p	PD	ESOA2004
2004	Hales	network links	p2p	p2p	file-sharing	IEEE p2p2004

Game theory v. these models



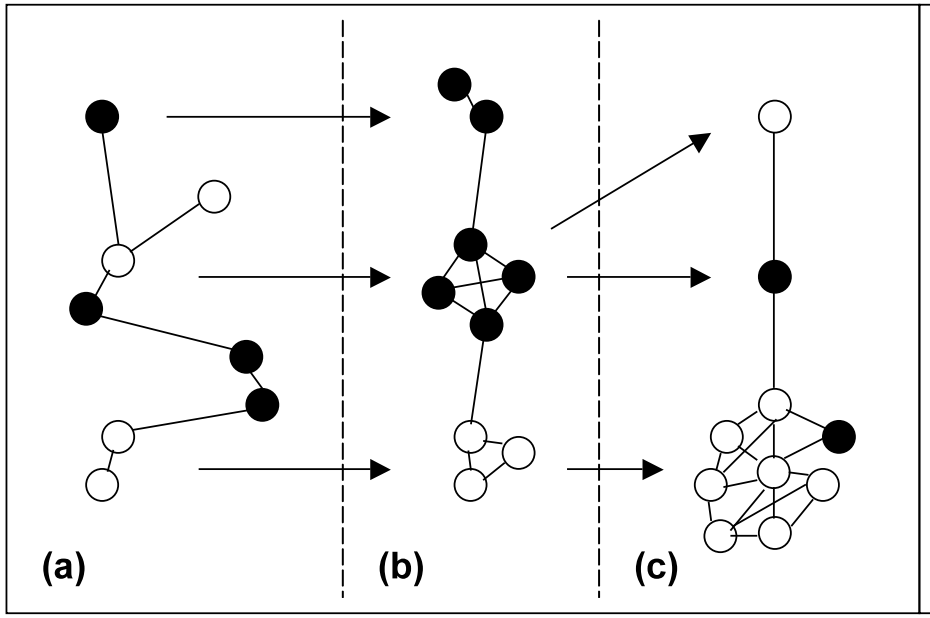
Six qualitative dimensions distinguishing traditional game theory models and many cultural group selection models



Schematic of the evolution of groups in the tag model.
Three generations (a-c) are shown. White individuals are pro-social, black are selfish. Individuals sharing the same tag are shown clustered and bounded by large circles. Arrows indicate group linage. Migration between groups is not shown. When b is the benefit a pro-social agent can confer on another and c is the cost to that agent then the condition for group selection of pro-social groups is: b > c and mt >> ms

Riolo, Axelrod, Cohen, Holland, Hales, Edmonds, shutters…

Traulsen, A., Nowak, M. A.: Chromodynamics of Cooperation in Finite Populations. Plos One, 2(3), e270 (2007)



Outline algorithm for network model:

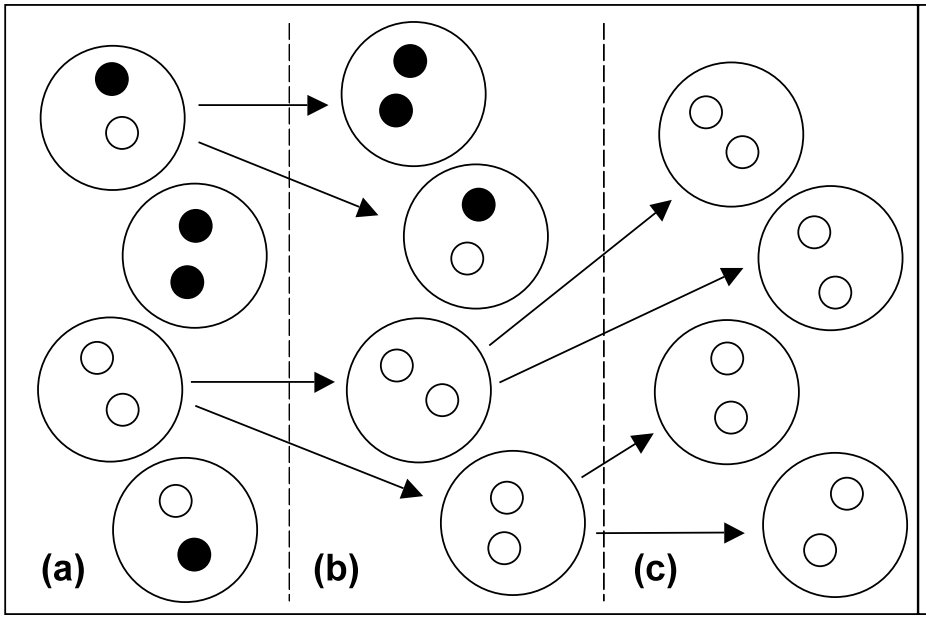
for each generation loop
interaction within groups (obtain fitness)
reproduce individuals based on fitness
with *Prob(t) copy new links*
with *Prob(ms)* individuals flip strategy
end generation loop

Group boundary: individuals directly linked in the network
Group formation and migration:copying of links probabilistically

Schematic of the evolution of groups (cliques) in the network-rewiring model. Three generations (a-c) are shown. White individuals are pro-social, black are selfish. Arrows indicate group linage. Altruism selected when b > c and mt >> ms. When t = 1, get disconnected components, when 1 > t > 0.5, get small-world networks

Hales, D. & Arteconi, S. (2006) Article: SLACER: A Self-Organizing Protocol for Coordination in P2P Networks. IEEE Intelligent Systems, 21(2):29-35

Santos F. C., Pacheco J. M., Lenaerts T. (2006) Cooperation prevails when individuals adjust their social ties. PLoS Comput Biol 2(10)



Outline algorithm for split model:

for each generation loop
interaction within groups (obtain fitness)
reproduce individuals based on fitness
with *Prob(q) split any group > m in size*
eliminate random group
end generation loop

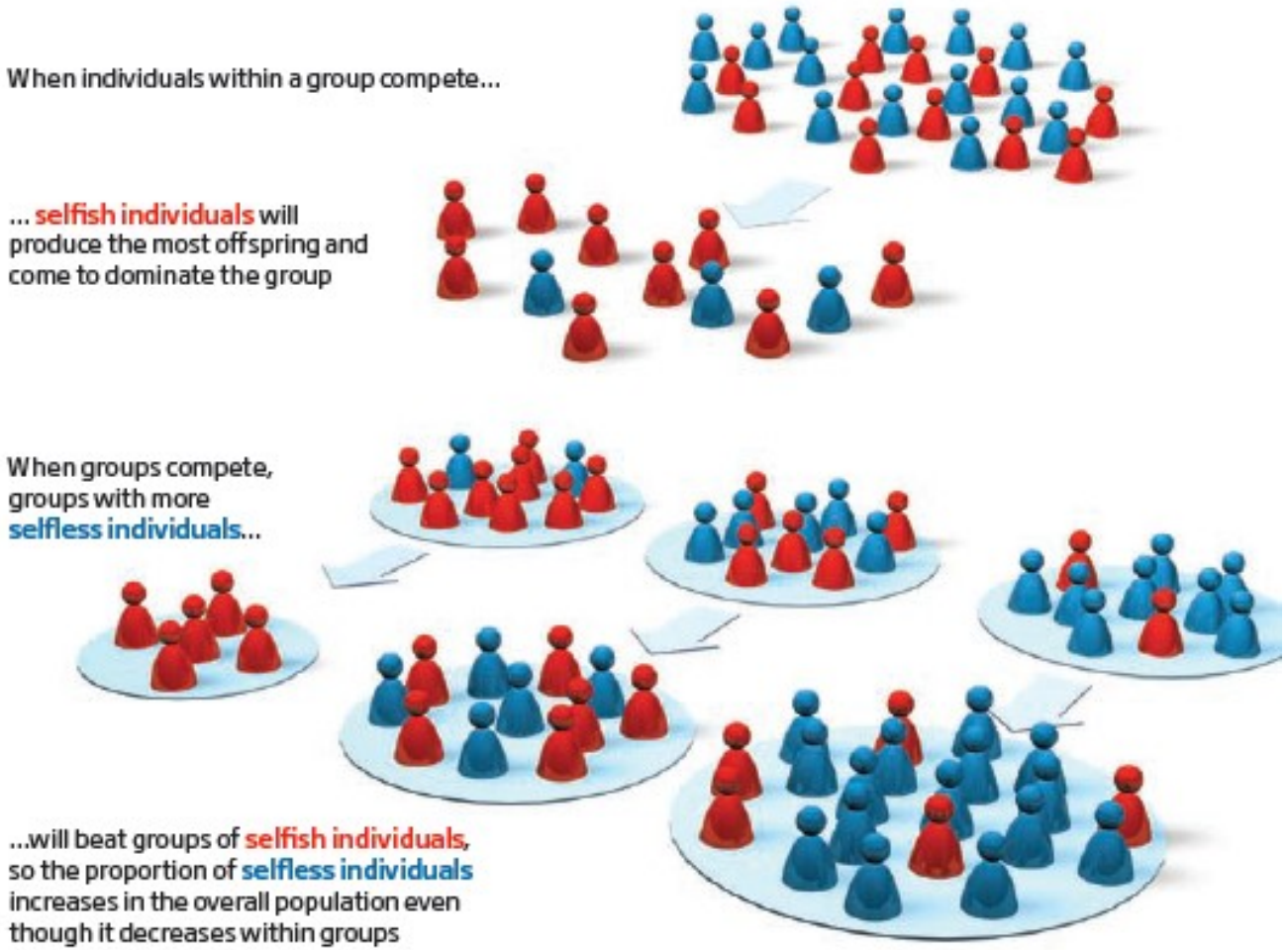
Group boundary: individuals exogenously given group membership
Group formation and migration: splitting of group when size > m.

Schematic of the evolution of groups in the group-splitting model. Three generations (a-c) are shown. Altruism is selected if the population is partitioned into m groups of maximum size n and b / c > 1 + n / m.

Traulsen, A. & Nowak, M. A. (2006). Evolution of cooperation by multilevel selection. Proceedings of the National Academy of Sciences 130(29): 10952-10955.

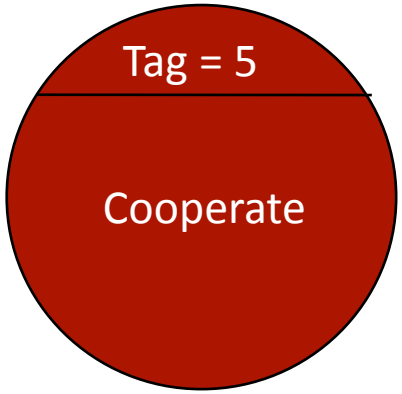
evolutionary algorithm

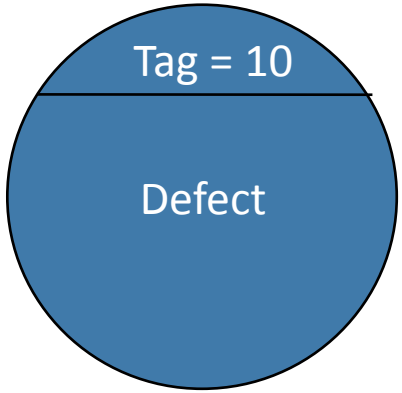
Initialise all agents with randomly selected strategies
LOOP some number of generations
    LOOP for each agent (a) in the population
        Select a game partner (b) from the population
        select a random partner with matching tag
        Agent (a) and (b) invoke their strategies
                receiving the appropriate payoff
    END LOOP
    Reproduce agents in proportion to their average payoff
            with some small probability of mutation (M)
END LOOP



From: http://gneisslife.blogspot.co.uk/2011/08/group-selection-revisited.html

Agents – a tag and a PD strategy

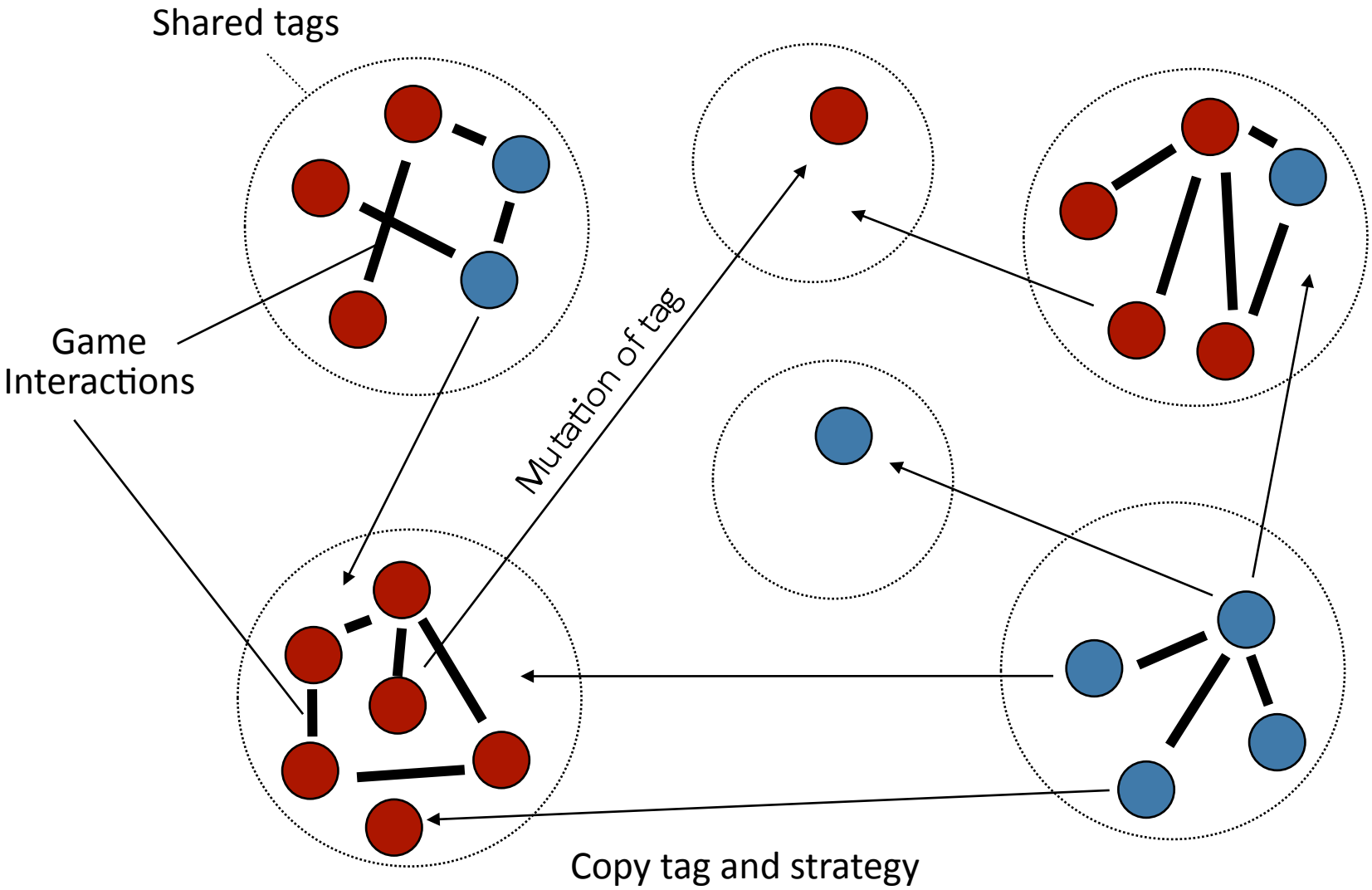




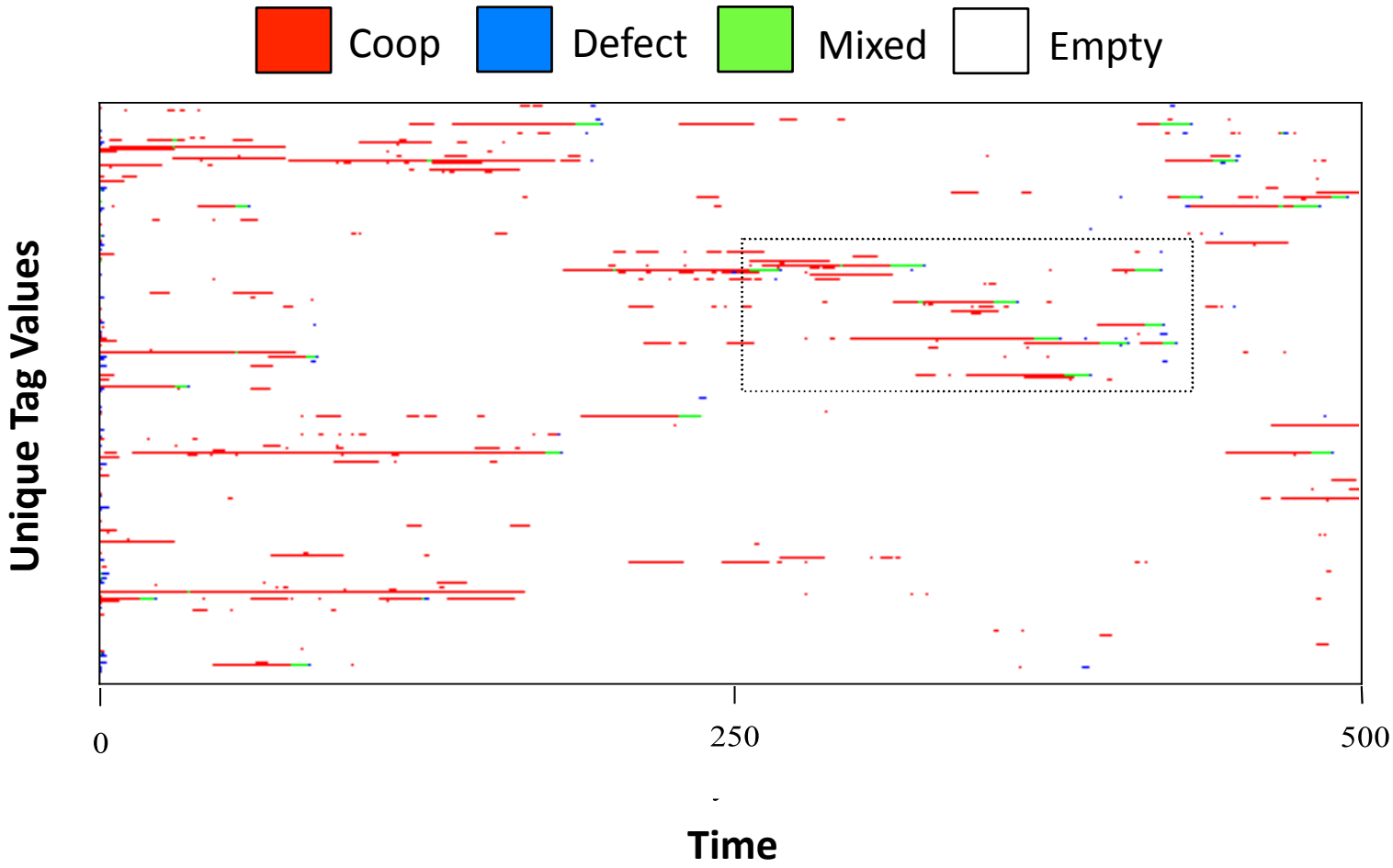
Tag = (say) Some Integer

Game interaction between those with same tag (if possible)

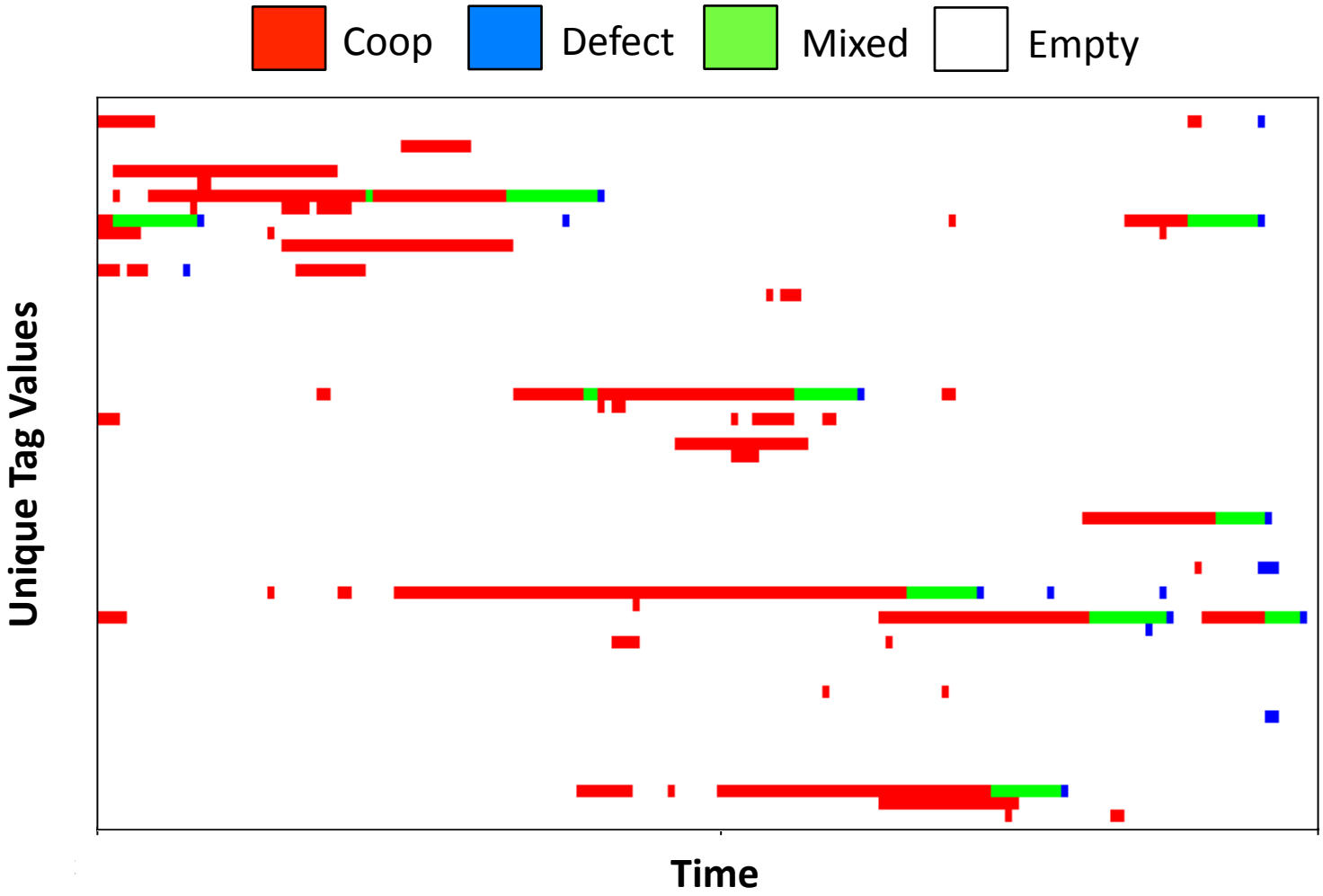
How tags work



Visualising the process



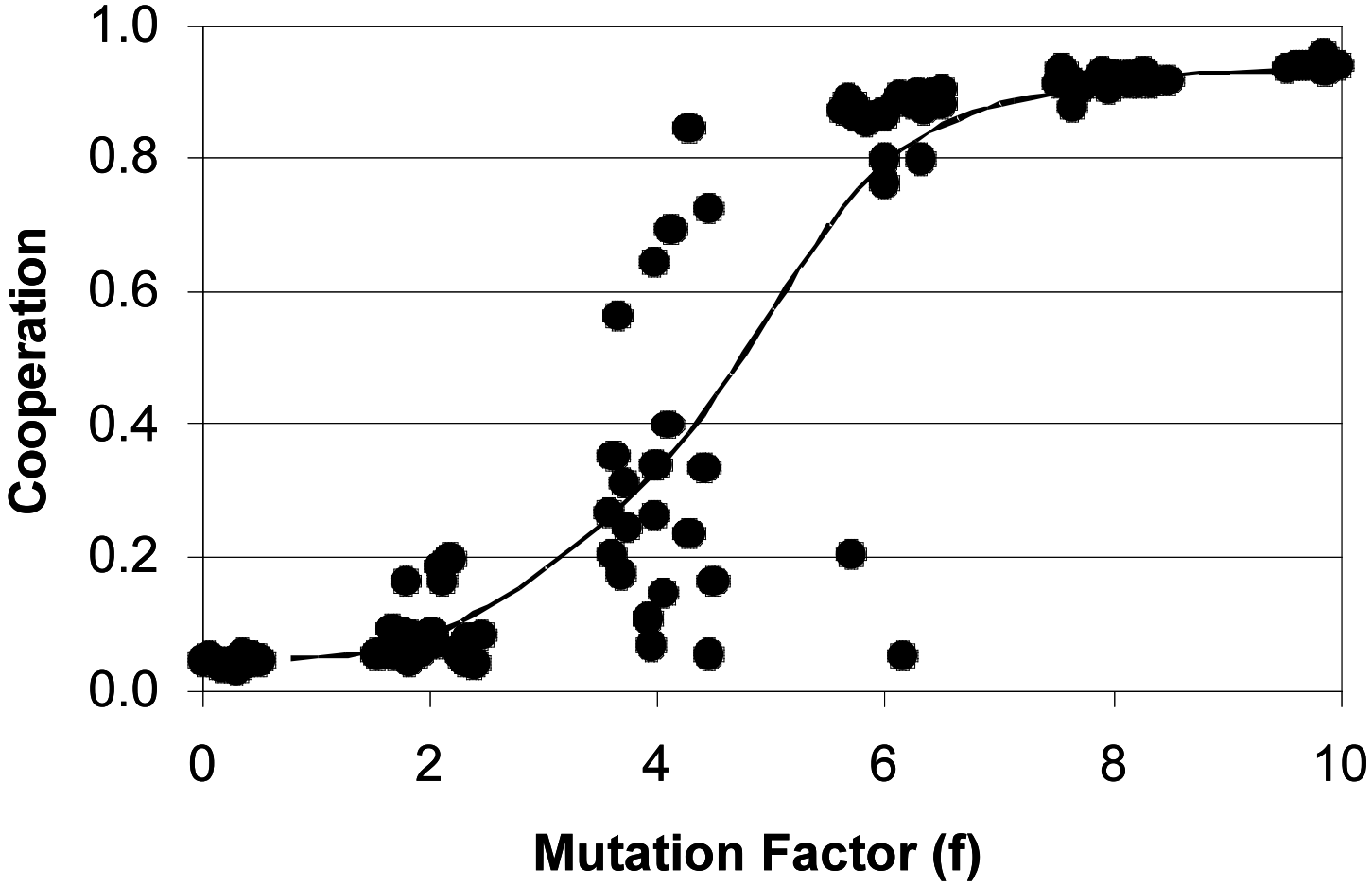
Visualising the process



Change your tags fast…

- Groups have to be formed more quickly than they invaded and killed
- New groups are formed by mutation on the tag
- Old groups are killed by mutation on the strategy
- So if tag mutation > strategy mutation this should promote cooperation?
- Test it by looking at the existing models and implementing a new one

Tag / strategy mutation rate



Network rewire model

Each node *p* periodically performs a game interaction with a randomly chosen neighbor

Each node *p* periodically executes the following:

q = SelectRandomPeer()

If $\text{utility}_q > \text{utility}_p$

drop all current links

link to node *q* and copy its strategy and links

mutate (with low probability) strategy and links

Network rewiring movie

thoughts

- Simple copying heuristics based on individual utility with social structure => “as if” a motivating force higher than self-interest towards to in-group
- Agents “vote with their feet” by moving to better groups via copying
- History of system important to understand behavior at any given point in time
- Compare some ideas from Ibn Khaldun (14th Century)
- But here an interpretation can be not of physical movement but of cultural movement (memetic reproduction)
- Memes are selected that support social interaction structures that perpetuate them
- Proto-institutions linking evolutionary models to some of the work of Olson (rational action) and Ostrom (self-organized social institutions)?

Any Use?

- Can such processes be observed in real systems? How could they be measured?
- Models assume the rapid ability to create new groups and free movement between groups – is this valid in real systems?
- Online communities? Ephemeral groups? Twitter tags?
- Can such models be adapted from the abstract to particular scenarios? Vary assumptions?