National Research Council (CNR),
Institute of Psychology, Rome.
18/12/2001

Dr David Hales

http://www.davidhales.com
dave@davidhales.ac.uk

Centre for Policy Modelling (CPM),
Manchester Metropolitan University.

Evolving cooperation in one-time interactions with strangers

Tags produce cooperation in the single round prisoner's dilemma and ***it's group selection!***

A quick note on methodology

- The model to be presented was found by searching (automatically) a large (10^{17}) space of possible models.
- Automated intelligent searching of the space was implemented.
- Machine Learning tools were used to identify the characteristics of models which produced desirable results (high cooperation in this case)
- Full details at www.davidhales.com/thesis

Why study cooperation?

- Many hard to explain cooperative interactions in human societies
- Production of large-scale open artificial agent based systems
- More generally, how low level entities can come to form internally cooperative higher level entities

Assumptions

- Agents are greedy (change behaviour to maximise utility)
- Agents are stupid (bounded rationality)
- Agents are envious (observe if others are getting more utility than themselves)
- Agents are imitators (copy behaviour of those they envy)

The Prisoner's Dilemma

Given: $T > R > P > S$ and $2R > T + S$

Player 1 / Player 2	C	D
C	R R	T S
D	S T	P P

Payoff values

- Temptation T > 1 (say, 1.5)
- Reward R = 1
- Punishment (P) and Sucker (S) set to small values (say, 0.0001 and 0.0002)
- Hence T > R > P > S and 2R > T + S

A one bit agent

- An agent represented by a single bit
- A value of “1” indicates the agent will cooperate in a game interaction
- A value of “0” indicates the agent will defect in a game interaction
- The value is not visible to other agents

An 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) at random from the population

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

The obvious result

- Agents quickly become all defectors
- A defector always does at least as well as his opponent and sometimes better
- This is the "Nash Equilibrium" for the single round PD game
- The evolutionary algorithm therefore evolves the "rational" strategy

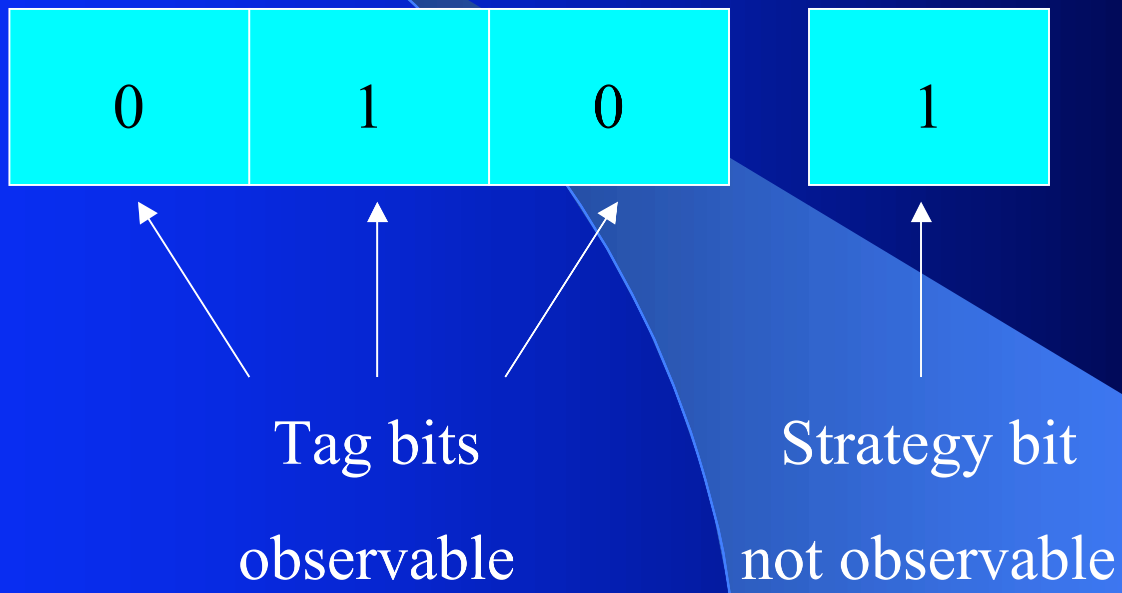
How can cooperation evolve?

- Repeated interaction when agents remember the last strategy played by opponent
- Interaction restricted to spatial neighbours
- Agents observe the interactions of others before playing themselves (image and reputation)

However, these require agents with the ability to identify individuals or have strict spatial structures imposed on interaction

An agent with “tags”

Take the “one bit agent” and add extra bits “tags” which have no effect on the strategy played but are observable by other agents



Bias interaction by tag

- Change the evolutionary algorithm so agents bias their interaction towards those sharing the same tag bit pattern
- When an agent selects a game partner it is allowed some number (F) of refusals if the tags of the partner do not match
- After F refusals game interaction is forced on the next selected agent
- During reproduction mutation is applied to both strategy bit and tag bits with same probability

Parameter values and measures

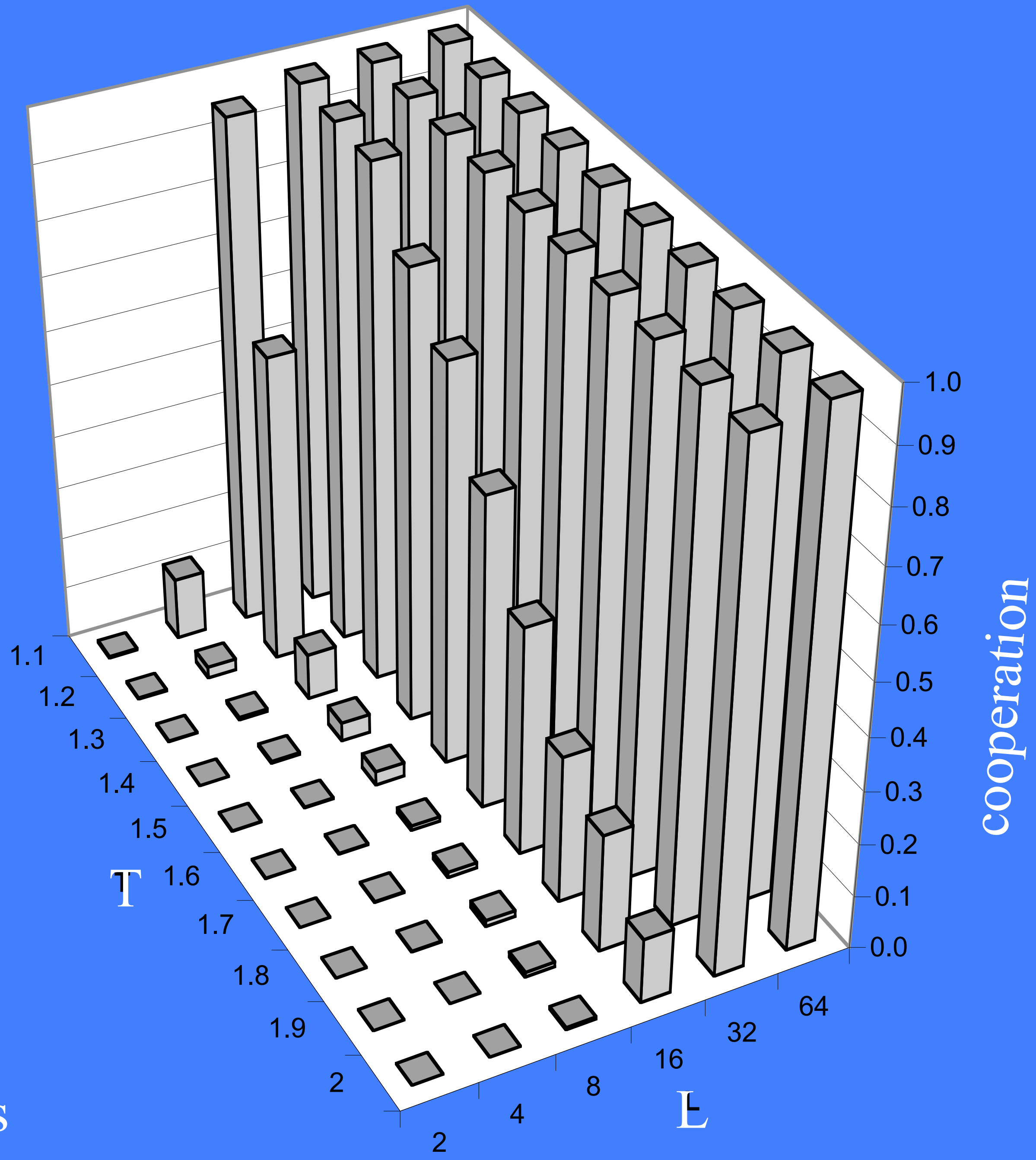
- Population size (N) = 100
- Length of tag (L) = [2..64] bits
- Refusals allowed (F) = 1000
- Mutation rate (M) = 0.001
- PD payoffs T = [1..2], R =1, P > S = small
- Execute algorithm for 100,000 generations
- Measure cooperation as proportion of total game interactions which are mutually cooperative

Results

Cooperation increases:

- as T decreases
- as L increases

Each bar an average of 5 runs to 100,000 generations with different initial random number seeds



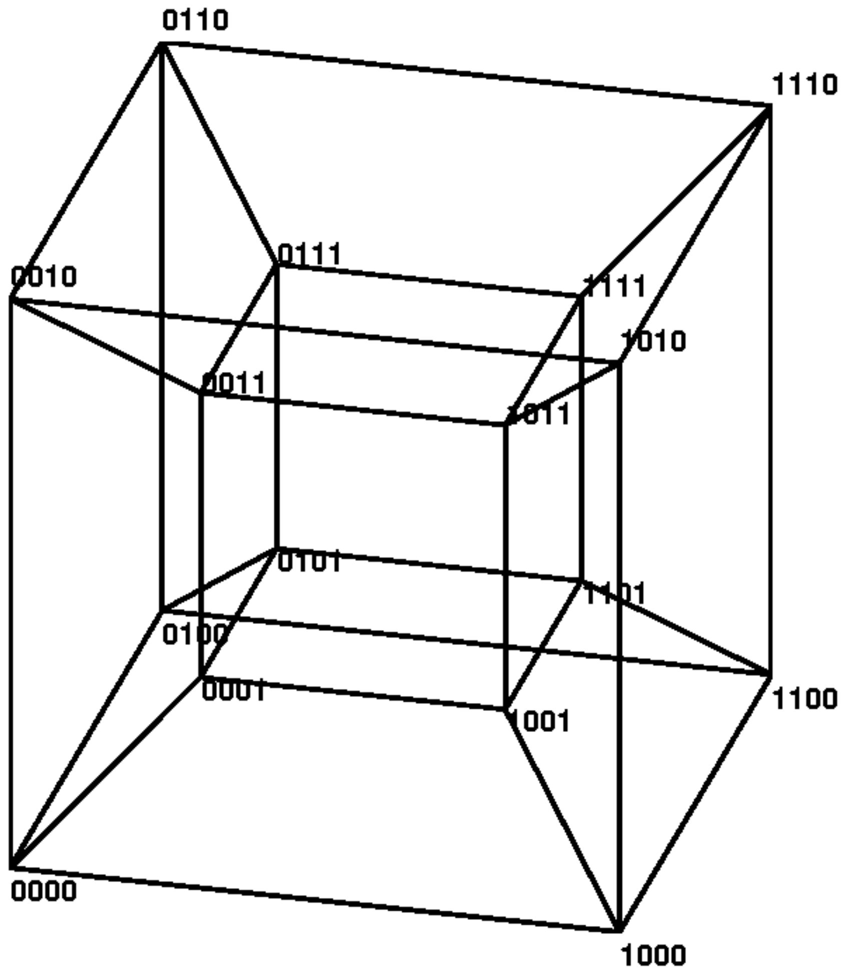
T = temptation payoff

L = length of tag in bits

What’s happening?

- We can consider agents holding identical tags to be sharing the corner of a hyper-cube
- Interaction is limited to agents sharing a corner (identical tag bits)
- Therefore cooperative “groups” are emerging in these corners

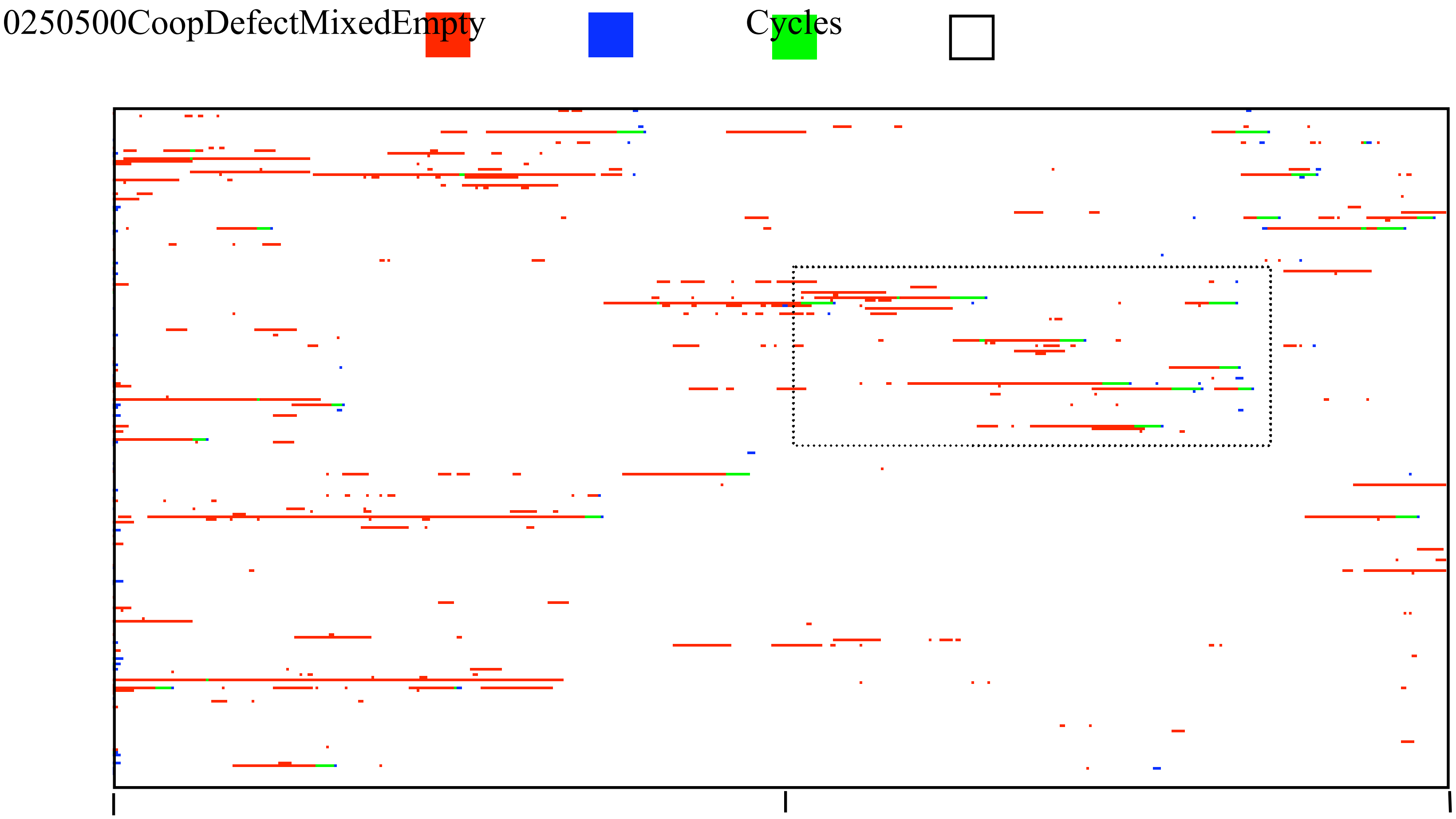
A hypercube for 4 bit tags



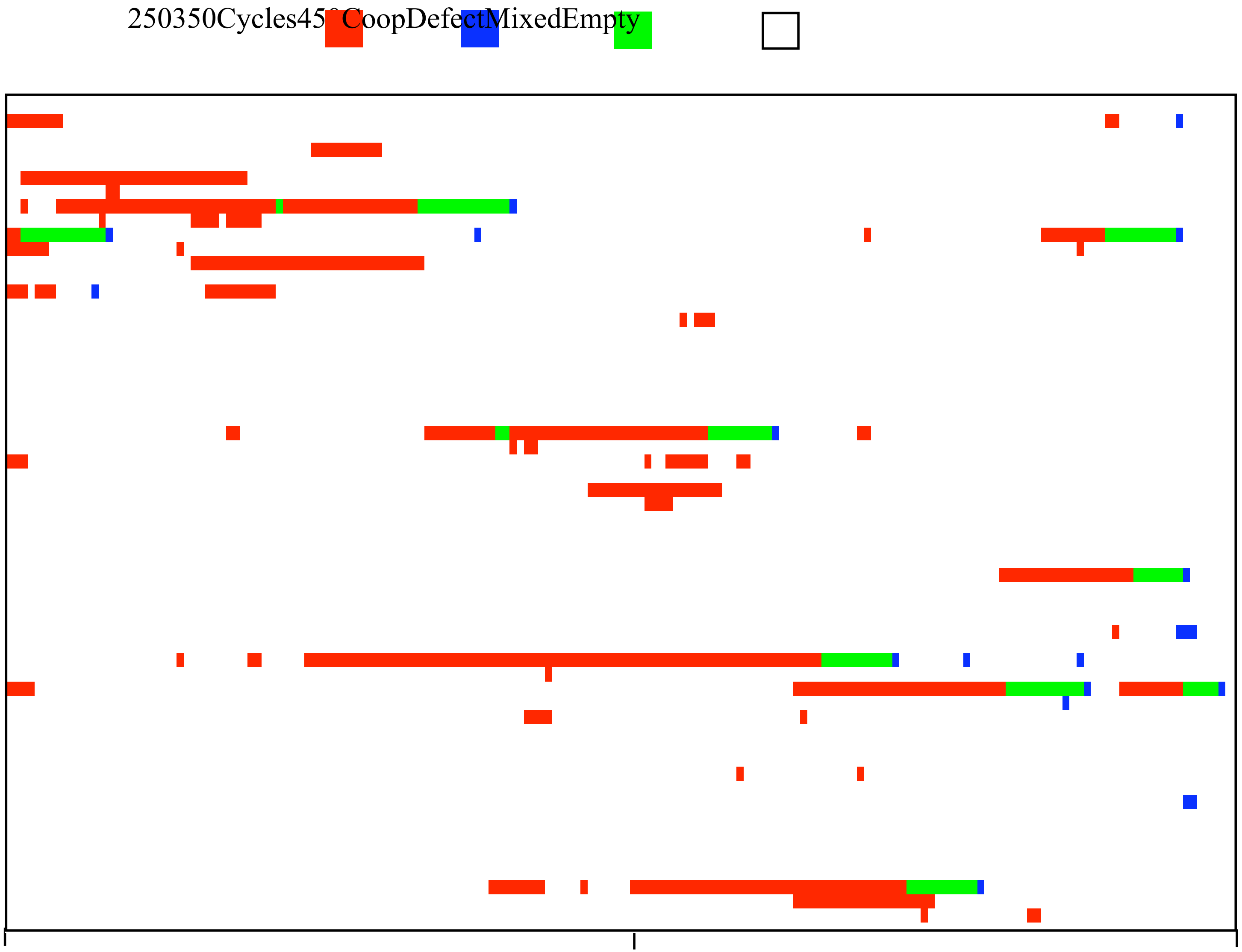
To visualise the process in time we produce a graph in which each horizontal line represents a single unique corner of the hypercube (set of unique tag bits)

We colour each line to indicate if it is occupied by all cooperative, all defective, mixed or no agents

Visualising the process



Visualising the process



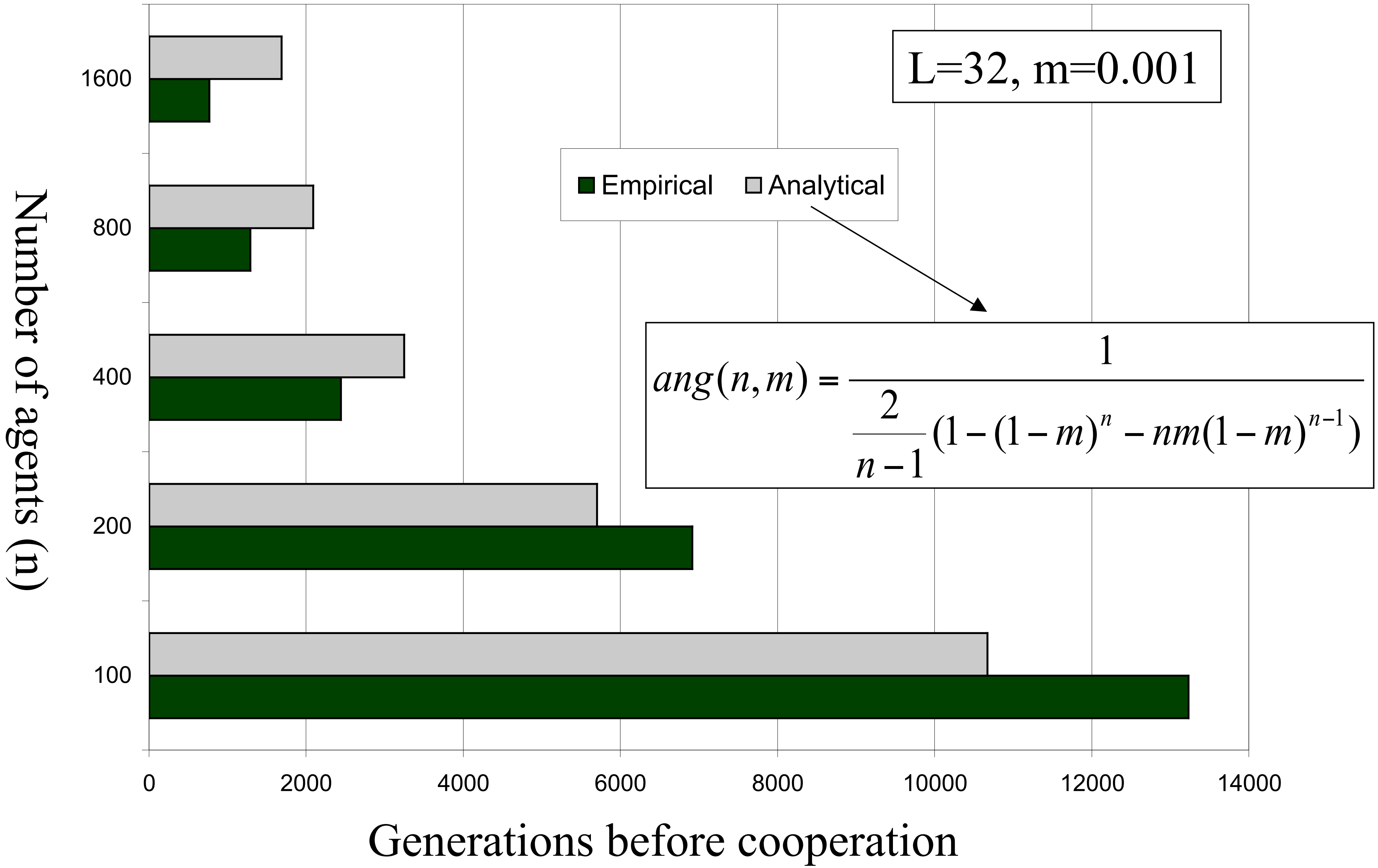
What's happening?

- Defectors only do better than cooperators if they are in a mixed group (have cooperators to exploit)
- But by exploiting those cooperators they turn the group into all defectors quickly
- Agents in an "all defective group" do worse than agents in an "all cooperative group"
- So long as an all cooperative group exists the agents within it will out perform an all defective group, thus reproducing the group – mutation of tag bits spreads the cooperative group to neigbouring corners of the hypercube

Cooperation from total defection

- If we start the run such that all strategy bits are set to defection, does cooperation evolve?
- Yes, from observation of the runs, cooperation emerges as soon as two agents sharing tag bits cooperate
- We can produce a crude analytical model predicting how long before cooperation evolves

Cooperation from total defection



Some conclusions

- A very simple mechanism can produce cooperation between strangers in the single round PD game
- Culturally, the tags can be interpreted as “social cues” or “cultural markers” which identify some kind of cultural group
- The “groups” exist in an abstract “tag space” not real physical space
- The easy *movement between groups* (via mutation and imitation) but strict game *interaction within groups* is the key to producing high cooperation

Some general mechanisms of group selection

- Communication and adaptation of *group boundaries*.
- Positive interactions *limited within those boundaries*.
- High cognitive mechanisms such as the communication of group level reputation could make the process more pronounced at the cultural level – on going work with Rosaria and Mario.

Other on-going work

- A similar tag model producing similar results was recently published by Riolo, Cohen and Axelrod in Nature.
- Commentary by Sigmund & Nowak explains results as kin selection – since group members in successful groups are identical.
- Currently have an extended model which produces specialization between agents within groups hence indicating that the process is a form of group selection – *Sigmund & Nowak are wrong*.