THE EVOLUTION OF COOPERATION IN A COMPETITIVE WORLD

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I Motivation

Biological:

• World abounds with cooperation (from single cells coming together in multi-cellular organisms, to social insects and human society), but natural selection fails to explain how it would evolve.

• Natural selection should promote selfishness at the expense of others

Social:

• Humans cooperate in many games where rational agents would defect (i.e. Prisoner's dilemma)

• Humans are often willing to sacrifice their own well being for the well being of others or society at large

Use evolutionary game theory to study cooperation!

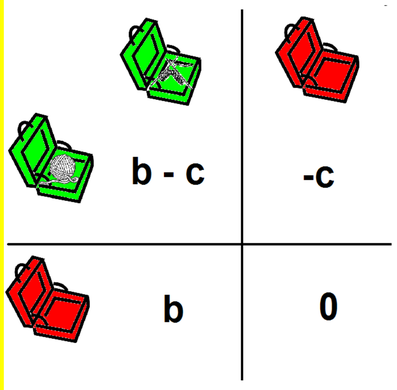
II Cooperation

• Two meanings: Evolutionary and Social

• Evolutionary: Behaviors that benefit members of the same species

• Social: choices that are beneficial to the society

• Often a trade off between helping the whole and helping the self



• Game theory is used to study cooperation

Prisoner's dilemma

• One of many possible games

• A rational player always defects, but humans often cooperate

• Popular game in current EGT.

III Applications

• Better understanding of evolution
• Abiogenesis
• Cancer research
• Self-organizing behavior
• Peace building and conflict resolution
• Structuring collaborative networks
• Distributed computing
• Neural net construction

IV Evolving cooperation

Complex

• Kin selection: favor your own family members

• Direct reciprocity: remember repeated interactions and cooperate with those that cooperate with you

• Indirect reciprocity: keep track of agents reputation and cooperate with those that have good reputation

• Social networks: certain social network structures favor cooperators

Simple

• Group selection: selection acts on both individuals and groups; groups of cooperators fare better than groups of defectors

• Highly viscous environment: children do not stray too far from parents

•Green-beard effect?

V Green-beard effect

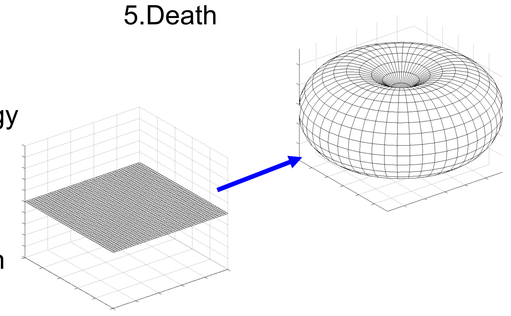
• Arbitrary tag used to guide behavior
• Allows dual strategy, one for same-tag (In-group) and one for different-tag (Out-group)
• Cooperation with same-tag, defection against different-tag
• Known as Ethnocentrism in humans
• Observed in: annual plans, ants, and human placenta

Strategy	In-group	Out-group
Selfish	Defect	Defect
Traitor	Defect	Cooperate
Ethnocentric	Cooperate	Defect
Humanitarian	Cooperate	Cooperate

VI Simulation

Basics
• Toroidal grid lattice (50 x 50)
• Agent characteristics:
  • Reproductive potential
  • **Tag-less** models:
    • Strategy
  • **Tag** models:
    • In-group strategy
    • Out-group strategy
    • Tag (1, 2, 3 or 4)
• Grid is initially empty
• Tracked data:
  • Interaction results
  • Strategy distribution

Procedure for each cycle
2.Immigration
3.Interaction
4.Reproduction:
5.Death



VII Some Math

• General utility function for an agent with strategy **a** interacting with other agents with strategy vectors **b**:

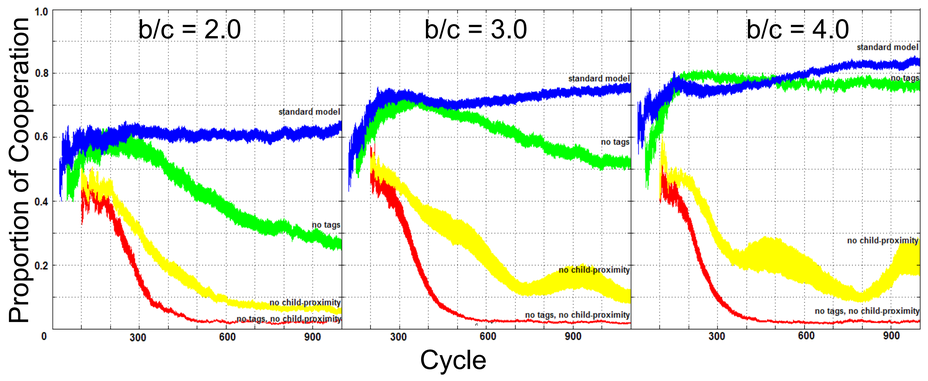
$$U(\mathbf{a}; \mathbf{b}, r, p_b) = r\mathbf{a}\cdot(\mathbf{P} + \mathbf{Q})\mathbf{a} + p_b\mathbf{a}\cdot\mathbf{P}\mathbf{b}$$

• r - chance of interacting with an identical agent; p_b – chance of interacting with an agent with strategy **b**; **P,Q** - game matrices

• Utility function is general enough to cover any two-player game (not only PD) and provides predictions for many cooperation mechanisms (not only Green-beard effect)

• **Green-beard effect:** *r-p* symmetry (blue) must be broken to give cooperators an edge over defectors in a tag environment; green-beards need aid of another mechanism to break *r-p* symmetry

VIII Results



•Proportion of cooperative interactions averaged over 30 simulations vs. evolutionary cycle

• Blue – tag and child-proximity (CP); green – no tag but CP; yellow – tag but no CP; red – no tag and no CP

•Line thickness indicates 1 SE around the mean.

Key observation

• Tags are not sufficient for cooperation, child-proximity is needed

IX Conclusion

• Green-beard effect cannot emerge as the primary mechanism for creating cooperation; it must co-evolve with other mechanisms

• **Social context**: ethnocentrism in humans is not essential for cooperation and could be overcome.

• **Future directions:** analyze cooperation-defection transitions, search for simpler methods for evolving cooperation, and explore evolutionary games on dynamic graphs

X Additional ongoing research

• World saturation and its effects on strategy distribution

• Generality of results between games (i.e Hawk-Dove game)

• Effects of higher-order tags on ethnocentrism

• Tag persistence and evolutionary effects on tag dominance

• Combining the general utility function with Lotka-Volterra equations to provide better mathematical predictions

XI References

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