Report on the evolution of cooperation in relation to game-theory and different game-theoretic mechanisms to aid it

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Abstract

Since the early days of Darwinian evolutionary theory the phrase "Survival of the fittest" has become synonymous with much thinking on evolutionary dynamics. This idea has come along way since then but is still seen by many to promote selfish attitudes. However, we can see throughout nature that cooperation between biological agents is prevalent. So how did cooperation evolve and why has it flourished? This question fundamentally challenges what seemed concrete ideas about evolutionary dynamics, and has been approached from many angles. Game-theory is a branch of mathematics that has spawned many mathematical models of evolutionary dynamics in an attempt to solve the problem, some have been formulated programmatically to analyse the results. Study of the evolution of cooperation also has wider impacts in the world of computer science - namely on agent-based systems. A large component of agent-based system design is how interactions between agents works and how cooperation can be garnered within societies of agents. In this report, I shall explore past game-theoretic approaches to this problem. This exploration will help me gather a deeper understanding of evolutionary dynamics and the reasoning behind these mathematical approaches to the problem of the evolution of cooperation.

I. Introduction

In the seminal paper on the evolution of cooperation [1] Axelrod and Hamilton highlighted the failure of past ideas on Darwinian evolutionary theory to account for cooperative phenomena. Their paper identifies two theories proposed to solve the problem: kinship theory and reciprocation theory, focusing on the latter - particularly the Iterated Prisoner's Dilemma.

In relation to kinship theory Richard Dawkins [2] put forward the view that cooperation has evolved due to genes that have the aim of replicating in future generations. This appears to Axelrod and Hamilton to limit cooperation to those who have related genes. However, in an earlier paper [3] Hamilton appears to be a proponent of kin selection, arguing that agents act to improve inclusive fitness - even formulating the biological model in a mathematical way. Inclusive fitness also takes into account the fitness of other related players.

There are a number of game-theoretic models proposed to solve the problem posed. The Iterated Prisoner's Dilemma is a popular example, and the one described in Axelrod and Hamilton's paper. Martin A. Nowak explores this dilemma and multiple other models [7] and also the mathematics behind cooperation [11]. It is both these mathematical models and models from kinship theory that in this report I will describe including their motivation, reasoning and any conclusions that can be drawn from them. I will also attempt to relate them to multi-agent systems or even point out how they are inapplicable to this domain if appropriate.

II. Content and Knowledge

i. Kinship Theory

As I have described above kinship theory approached the evolution of cooperation problem by claiming that agents are given incentive to cooperate with other agents that are sufficiently related to them.

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[1]
[3]

ii. The Iterated Prisoner's Dilemma

The Iterated Prisoner's Dilemma is one such example of a game-theoretic model that uses direct reciprocity to attempt to solve the problem that the evolution of cooperation puts forward. This Dilemma is in fact a game played between two individuals. The game is made up of rounds in which the two players can choose between cooperating with or defecting against each other. A payoff matrix is provided such as the one in figure 1 on page 2. In a single round game it is mathematically best to defect, however as you can see cooperation between two individuals actually pays more than defection.

iii. Strategies

iv. Other Game-Theoretic Models

v. Strategies

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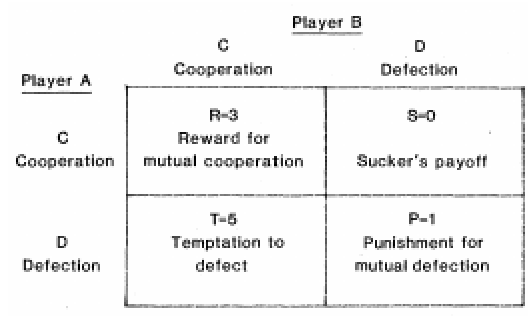

Player A \ Player B	C Cooperation	D Defection
C Cooperation	R=3 Reward for mutual cooperation	S=0 Sucker's payoff
D Defection	T=5 Temptation to defect	P=1 Punishment for mutual defection

Figure 1: *The payoff matrix given in Axelrod and Hamilton's paper [1]*

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III. Discussion and Conclusion

Talk about impact in real life and multi-agent systems.
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References

[1] Robert Axelrod and William D. Hamilton. The evolution of cooperation. *Science*, 211:1390–1396, 1981.

[2] Richard Dawkins. *The Selfish Gene*. Oxford University Press, 2016.

[3] W. D. Hamilton. The genetical evolution of social behaviour. *Journal of Theoretical Biology*, 7:1–16, July 1964.

[4] Doug Jones. Kin selection and ethnic group selection. *Evolution and Human Behavior*, 39:9–18, August 2017.

[5] Menusch Khadjavi and Andreas Lange. Prisoner's and their dilemma. *Journal of*

Economic Behavior and Organisation, 92:163–175, August 2013.

[6] M. Milinski. Tit for tat in sticklebacks and the evolution of cooperation. *Nature*, 325:433–435, January 1987.

[7] Martin A. Nowak. Five rules for the evolution of cooperation. *Science*, 314, 2006.

[8] Martin A. Nowak and Robert M. May. Evolutionary games and spatial chaos. *Nature*, 359:826–829, 1992.

[9] Martin A. Nowak and Karl Sigmund. Tit for tat in heterogenous populations. *Nature*, 355:250–252, January 1992.

[10] Martin A. Nowak and Karl Sigmund. Evolution of indirect reciprocity by image scoring. *Nature*, 393:573–577, 1998.

[11] Martin A. Nowak, Karl Sigmund, and Robert M. May. The arithmetics of mutual help. *Scientific American*, 272:76–86, 1995.

[12] Steve Phelps. An empirical game-theoretic analysis of the dynamics of cooperation in small groups. 2016.

[13] Gilbert Roberts. Evolution of direct and indirect reciprocity. *Proceedings of The Royal Society*, 275:173–179, September 2008.

[14] Alexander J. Stewart and Joshua B. Plotkin. Extortion and cooperation in the prisoner's dilemma. *Proceedings of the National Academy of Sciences of the United States of America*, 109:10134–10135, June 2012.

[15] György Szabó and Gábor Fáth. Evolutionary games on graphs. *Physics Reports*, 446:96–216, 2007.

[16] Arne Traulsen and Martin A. Nowak. Evolution of cooperation by multilevel selection. *Proceedings of the National Academy of Sciences of the United States of America*, 103:10952–10955, 2006.