

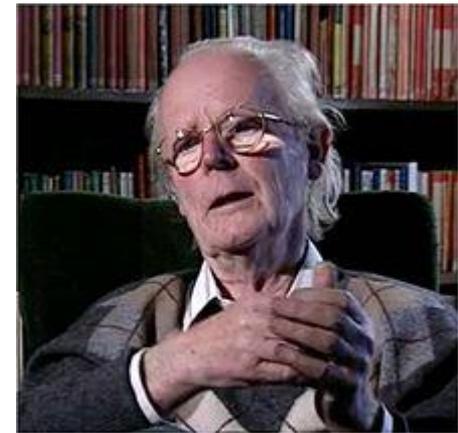
Evolutionary Game Theory and Iterated Prisoner's Dilemma

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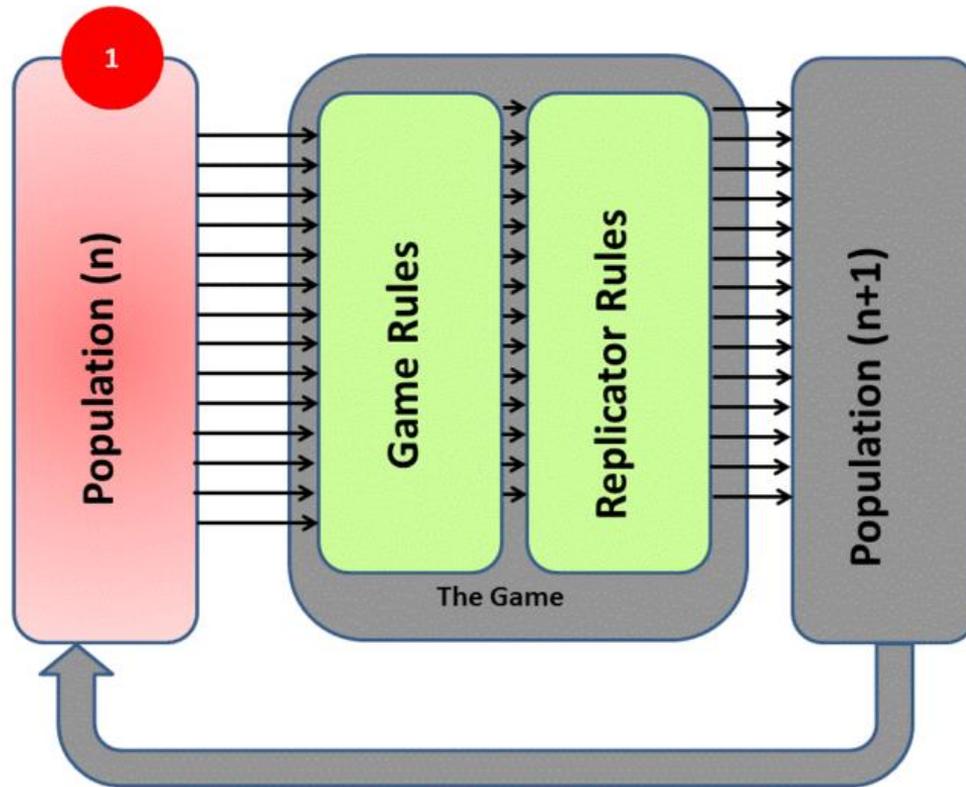
Evolutionary game theory

- Evolutionary game theory (**EGT**) originated as an application of the mathematical theory of games to biological contexts, arising from the realization that frequency dependent fitness introduces a strategic aspect to evolution. Recently, however, evolutionary game theory has become of increased interest to economists, sociologists, and anthropologists--and social scientists in general--as well as philosophers. (Stanford encyclopedia)
- EGT originated in 1973 when a paper by John Maynard Smith and George R. Price published on *Nature*.
- EGT thrived after Axelrod's Iterated Prisoner's Dilemma (**IPD**) competitions and book.



John Maynard Smith

Model of EGT



- The model deals with a Population.
- The individuals play game against each other.
- Based on this resulting fitness each member of the population then undergoes replication or culling determined by the exact mathematics of the Replicator Dynamics Process.
- The new generation then takes the place of the previous one and the cycle begins again

Why EGT?

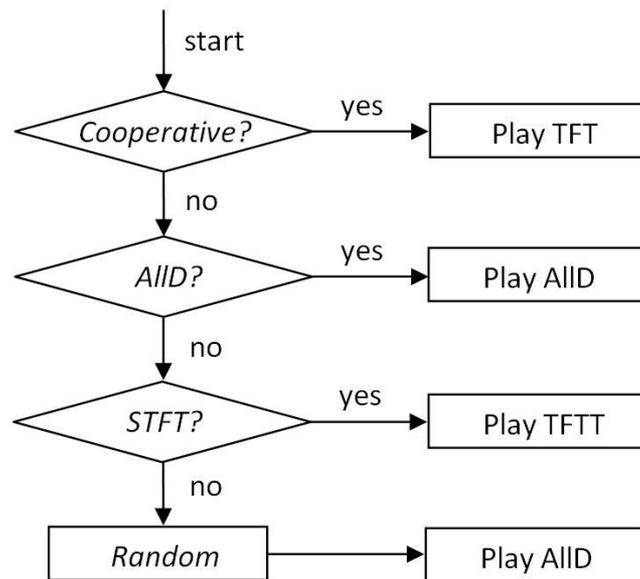
- Classical Game theory essentially requires that all of the players make rational choices (assumption of **rationality**).
- Equilibrium analysis depends on **rationality**.
- What if a player does not adopt equilibrium strategy?
- EGT does not require the assumption of **rationality**, it only requires that every player has a **strategy**.

Iterated Prisoner's Dilemma

- A open question: how cooperation emerges and persists in a population of selfish agents?
- **IPD** is the most frequently used game in EGT.
- Novel strategies for IPD
 - AI strategies
 - Collective strategies
 - Zero-determinant strategies

An AI strategy

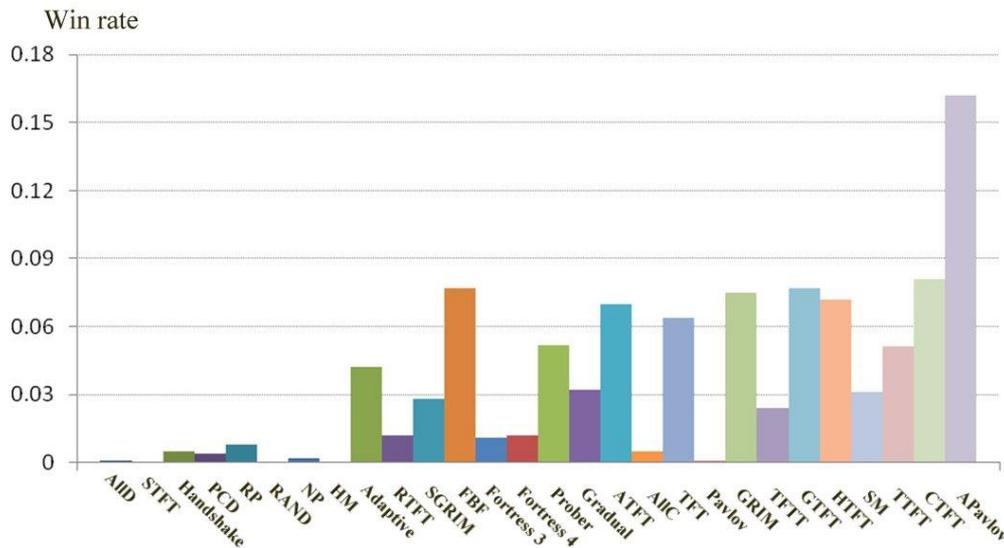
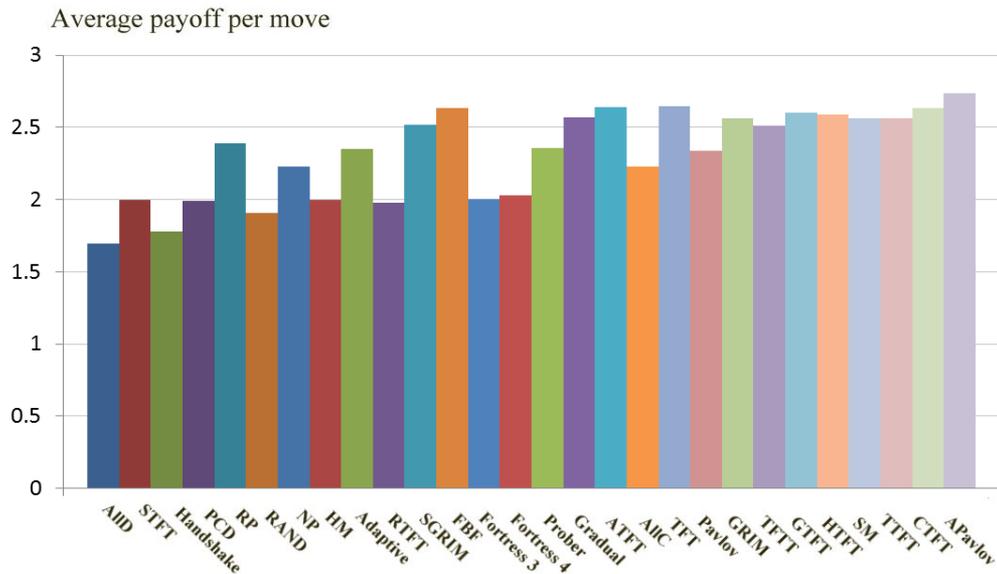
This strategy uses a simple rule based identification mechanism to explore and exploit the opponent. It adopts TFT in the first six moves and identifies the opponent according to the result of the interaction. In the following six rounds, a corresponding reaction will be adopted.



Strategy	Score	Strategy	Score
AI	3.045	PAVLOV	2.362
GRIM	2.799	HM	2.314
GRADUAL	2.749	AllC	2.283
TFT	2.668	STFT	2.246
FBF	2.608	PCD	2.243
GTFT	2.598	AllD	2.221
CTFT	2.587	RAND	2.149
TFTT	2.529	RTFT	2.132
RP	2.399	NEG	2.081
NP	2.364		

A statistical method to evaluate IPD strategies

- Since the outcome of a single competition is **biased**, a statistical methodology to evaluate the performance of strategies for IPD is proposed .
- We run a large number of competitions in which the strategies of the participants are randomly chosen from a set of representative strategies. **Statistics** are gathered to evaluate the performance of each strategy.
- The performance of a strategy is evaluated based on its ***average payoff*** and its ***win rate***.



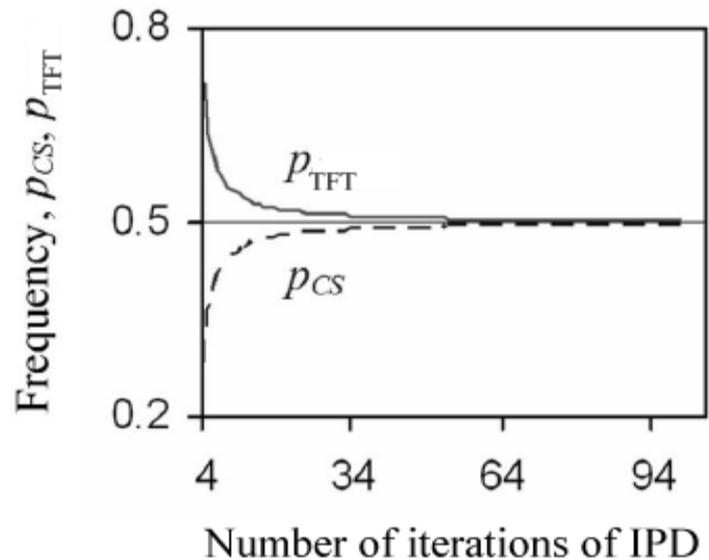
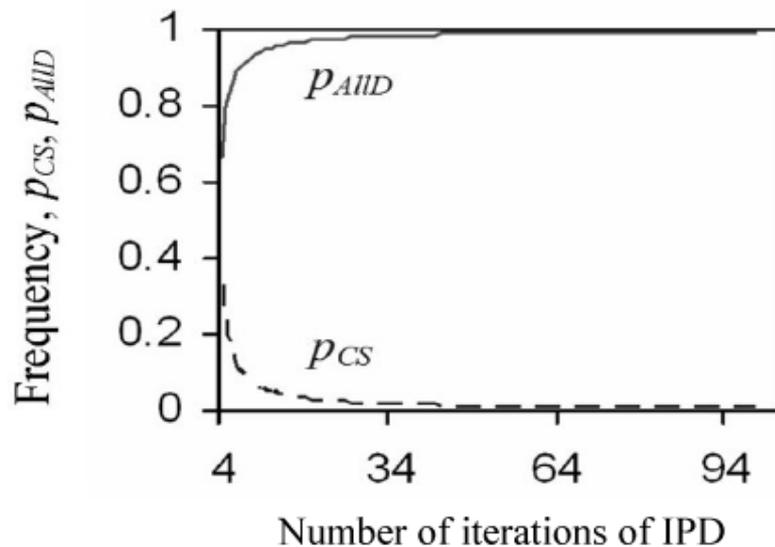
- We run **100,000** competitions. For each competition, we randomly choose **10** IPD strategies from a set of **32** strategies that have ever appeared in scientific research papers. The strategies play **50** rounds of IPD with each other and the winner is the strategy that receives the highest average payoff in those games in which it is involved.
- The AI strategy statistically outperforms TFT.

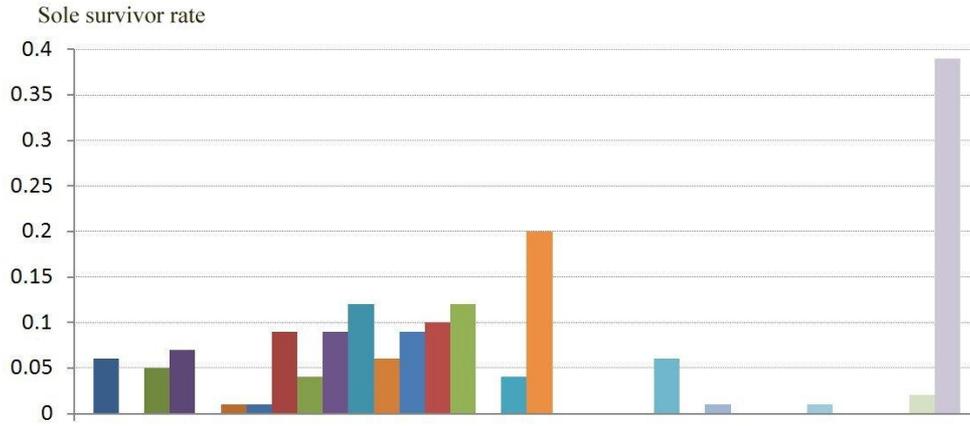
Collective strategies

- Based on a **hand-shaking mechanism**, collective strategies (**CS**) cooperate with their kin members and defect against other strategies.
- When two CSs meet, they both play a **predetermined sequence of C and D moves**. Then they are identified as 'kin' and they will cooperate.
- When the opponent does not play the predetermined sequence, it is identified as non-kin by CS and defection will be triggered.
- CSs are conditional cooperators, they are especially strong in maintaining a homogeneous population.

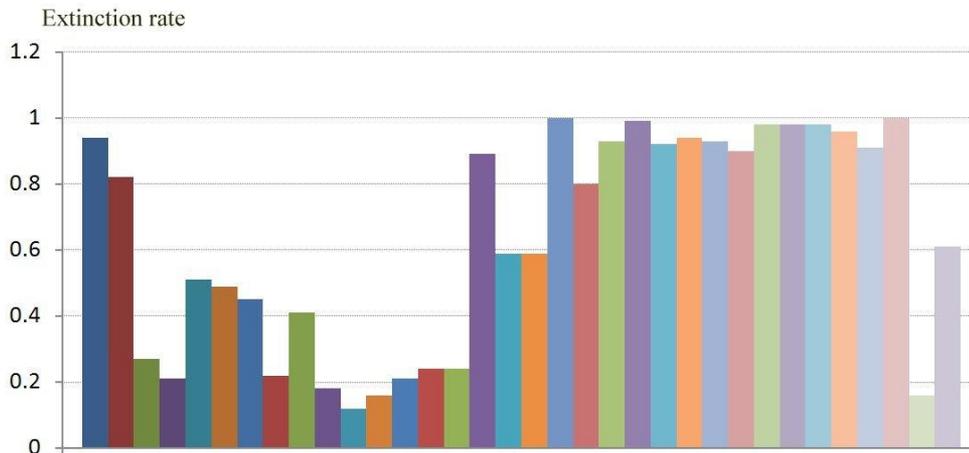
Collective strategies

Invasion barrier: The minimal cluster size for one strategy to invade a population of another strategy.





- We run a series of 10,000 competitions. In each competition, **6** strategies are randomly chosen from a set of **32** strategies. Each strategy has **20** copies in the initial population. **Stochastic universal sampling** is used to select parents for the next generation. The parents simply copy their strategies to produce offspring and no mutation is carried out. The competition is run for **100** generations.



ZD strategies

- Press, William H., and Freeman J. Dyson. “Iterated Prisoner’s Dilemma contains strategies that dominate any evolutionary opponent.” *Proceedings of the National Academy of Sciences* 109.26 (2012): 10409-10413.
- ZD strategies can unilaterally set the payoff of the other player to any fixed value within $[P, R]$.

		Player II	
		C	D
Player I	C	(R, R)	(S, T)
	D	(T, S)	(P, P)

ZD strategies

Let P_I and P_{II} denote the payoffs of two players. ZD strategies are those memory-one strategies that ensure

$$\alpha P_I + \beta P_{II} + \gamma = 0 \quad [1]$$

where α, β, γ are predetermined constants. If player I adopts a ZD strategy (p_R, p_T, p_S, p_P) for example, [1] can be determined no matter which strategy player II uses. The probabilities of ZD strategies satisfy

$$p_R - 1 = \alpha R + \beta R + \gamma \quad [2.a]$$

$$p_S - 1 = \alpha S + \beta T + \gamma \quad [2.b]$$

$$p_T = \alpha T + \beta S + \gamma \quad [2.c]$$

$$p_P = \alpha P + \beta P + \gamma \quad [2.d]$$

ZD strategies

- ZD strategies exist not only in IPD but also in a large variety of repeated games.
- Condition for the existence of ZD strategies in 2x2 repeated games is $T, R > P \geq S$
- (D,D) is minmax solution.
(C,C) is Pareto superior to (D,D).
- Folk theorems

		Player II	
		C	D
Player I	C	(R, R)	(S, T)
	D	(T, S)	(P, P)