Evolution of Strategies in Iterated Prisoner’s Dilemma

Results Summary

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Simulation Setup

A series of simulation experiments were conducted to investigate the emergence of cooperation within the Iterated Prisoner's Dilemma. Each simulation was structured as follows:

- An initial population of strategies, either randomly generated or drawn from a predefined set.

- Evolutionary dynamics proceeding over a fixed number of generations (`numGenerations`) or until a single strategy dominated the population.

- All-versus-all tournament, with each match consisting of numRounds iterations of the game.

- Reproduction based on fitness proportional to total score in the generation

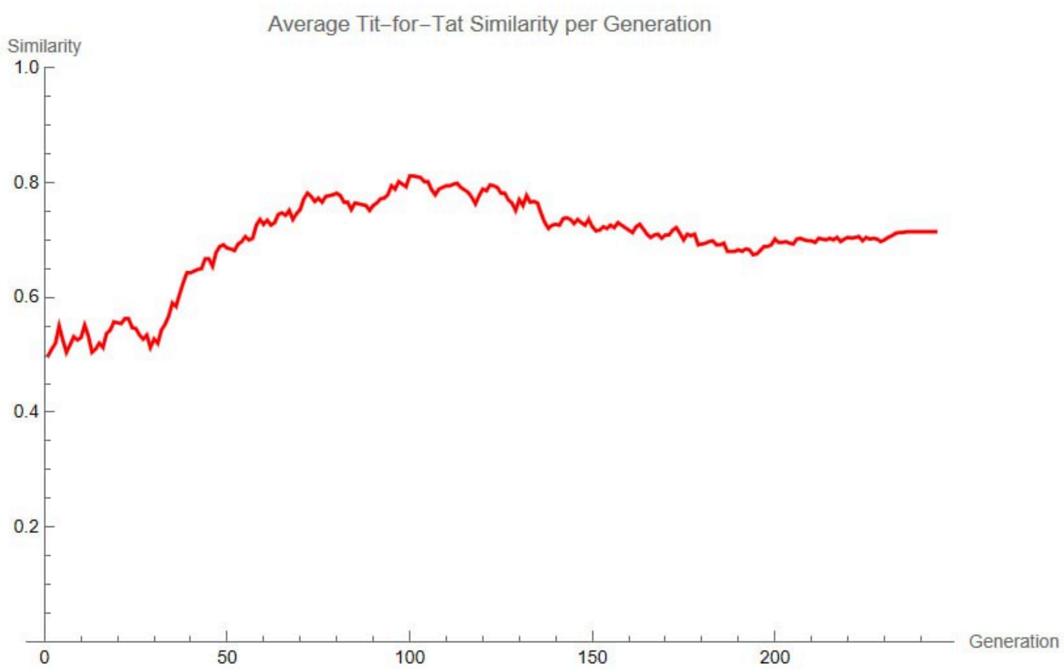
Each strategy was implemented as a deterministic mapping from the preceding n moves of the opponent to a choice of cooperation (C) or defection (D), where n denotes the history length (e.g., for $n = 2$, strategies could condition their actions on patterns such as CC, CD, etc.).

Experiment 1: Evolution from Random Strategies with History Length = 2

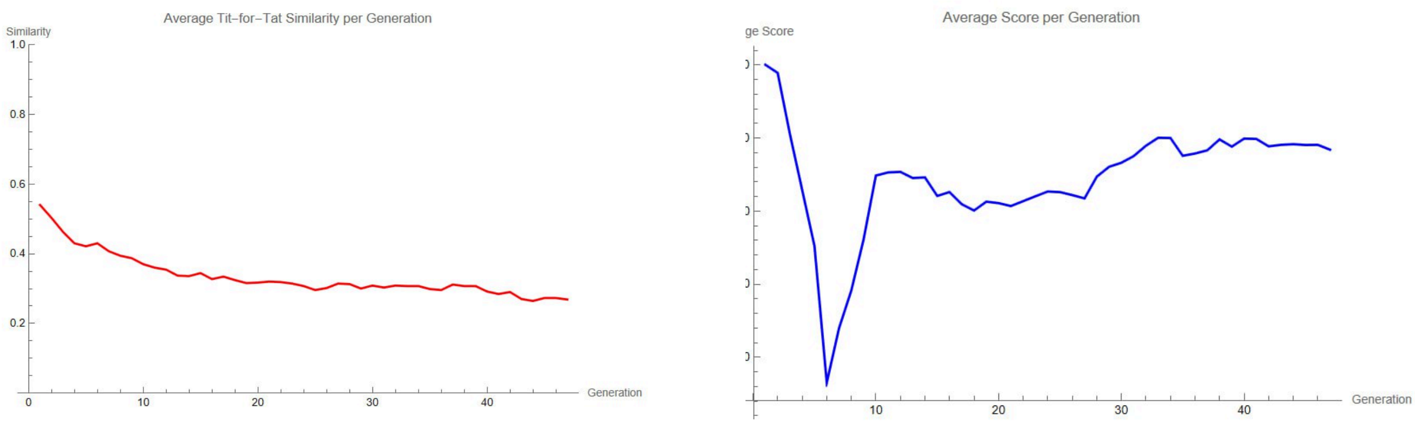
populationSize	numGenerations	historyLength	numRounds
100	300	2	50

- **Result**: Only one out of several simulations converged to a Tit-for-Tat-like strategy.
- **Observation**: Low number of rounds leads to noisy scoring; strategies that punish defectors may not have enough time to benefit.

The only “successful” simulation:



Example of a “failing” simulation:



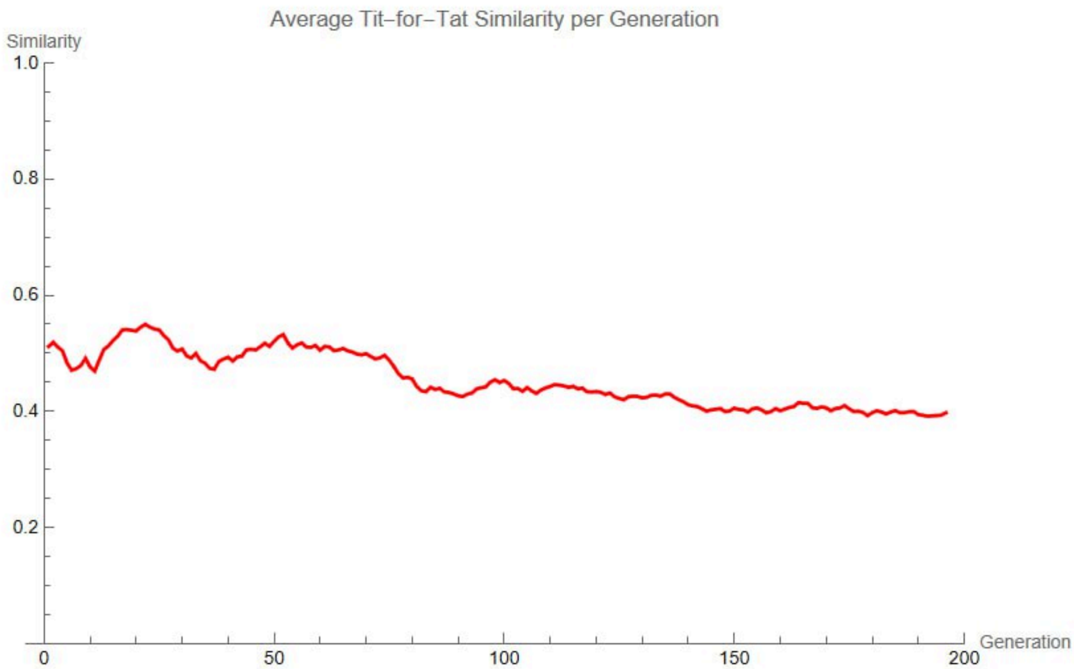
Experiment 2: Random Strategies with History Length = 4

populationSize	numGenerations	historyLength	numRounds
100	300	4	200,400

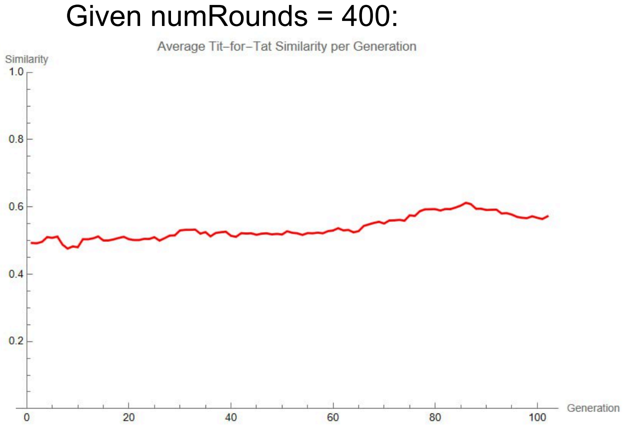
- **Result**:
  - With numRounds = 200: unsuccessful convergence
  - With numRounds = 400: partial convergence to TitForTat-like strategy

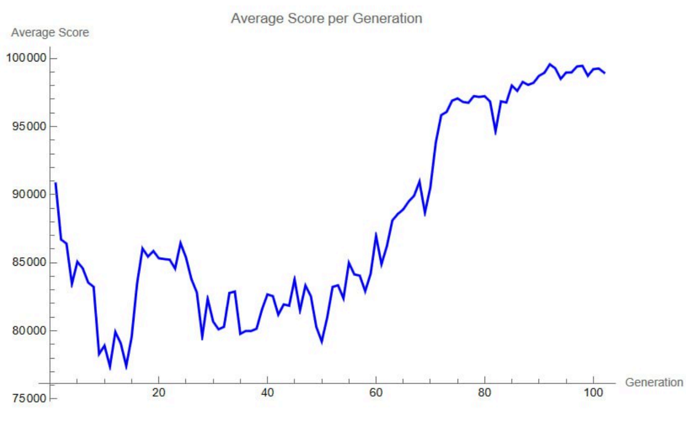
- **Observation**: With a longer memory, the number of possible input histories increases exponentially, making the strategy space significantly larger. This complexity means that not only must each game contain a sufficient number of rounds to reward consistent behavior, but the evolutionary process itself also requires more generations to explore and refine effective strategies.

Given numRounds = 200:



Given numRounds = 400:





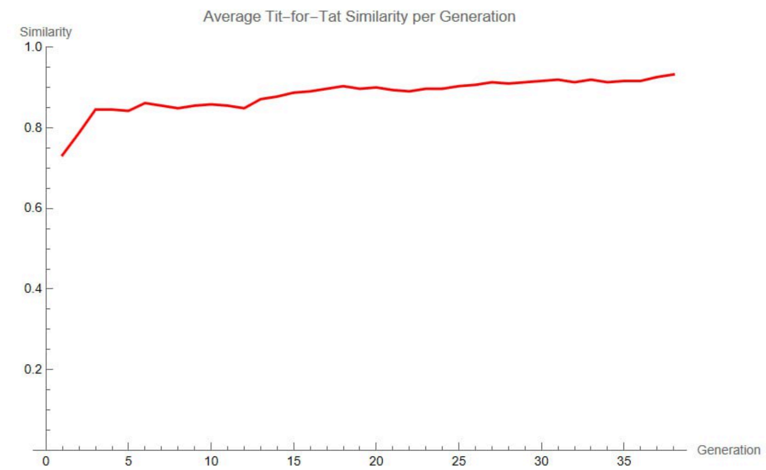
Experiment 3: Fixed Strategy Set (Axelrod Tournament Strategies)

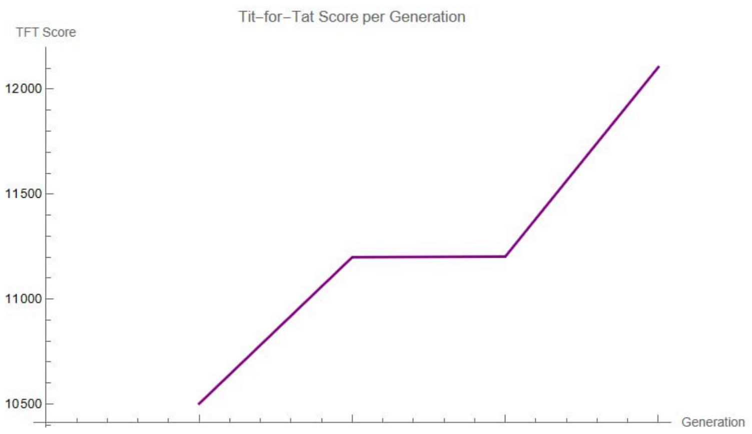
populationSize	numGenerations	historyLength	numRounds
10 (predefined strategies)	100	2,4	50,200,400

- **Result**:
  - For numRounds = 50: No convergence to cooperative behavior
  - For numRounds = 200 and 400: Strong convergence to Tit-for-Tat behavior across all trials

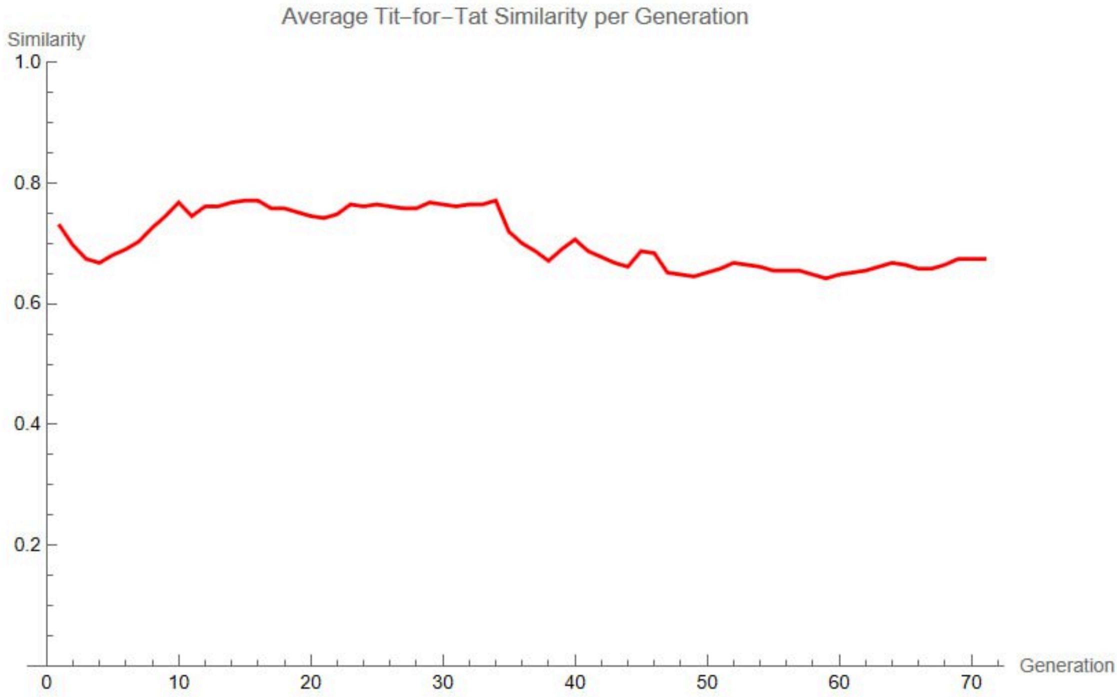
- **Observation**: Low number of rounds leads to noisy scoring; higher number of rounds allows TitForTat to “shine”

Given numRounds = 400:





Given numRounds = 50:



Strategies included:

Strategy	Description
Tit For Tat	Cooperates on the first move, then mimics the opponent's last move
Always Defect	Always defects regardless of history
Always Cooperate	Always cooperates regardless of history
Tit For Two Tats	Defects only if the opponent defects two times in a row
Suspicious Tit For Tat	Starts with a defection, then mimics opponent’s last move
Joss	Mostly behaves like Tit For Tat but sometimes defects at random
Soft Majority	Cooperates if the opponent has cooperated at least as much as they have defected (within given historyLength)
Hard Majority	Defects if the opponent has defected at least once more than cooperated (within given historyLength)
Tester	Starts with defection, then probes to see if the opponent retaliates; may try to exploit naive strategies
Random	Randomly generated mapping of all possible histories to C/D

Summary

When the historyLength parameter gets larger, the number of possible move patterns grows exponentially. This means there are many more possible strategies, so the simulation needs more generations to find and improve good ones.

As for Tit-for-Tat, the simulations show that it becomes dominant only when the number of rounds per game (numRounds) is sufficiently large. This suggests that Tit-for-Tat is evolutionarily optimal in long-term interactions, where its ability to reward cooperation and punish defection has time to yield payoff advantages. However, in shorter games, this advantage is diminished, and convergence to Tit-for-Tat behavior is not observed.