"Catantics: Unraveling the Strategic Mysteries of Settlers of Catan"

Bocock, Elsbecker, O'Connell, Salinas-QSS 30.04

Introduction

Settlers of Catan is a multi-player board game that involves resource gathering, trading, and settlement building. We use evolutionary game theory to explore the effectiveness and evolution of varying degrees of aggression and cooperation. }

We categorize player strategies into four distinct types: very aggressive, moderately aggressive, moderately cooperative, and very cooperative. Each strategy employs a specific approach to resource acquisition, trading, and development within the game.

Understanding the dynamic between competitive and cooperative strategies in multi-agent systems provides meaningful insights into both human behavior and artificial intelligence algorithms. We use Catan, as a model to explore how strategies characterized by varying levels of aggression and cooperation evolve in response to dynamic environments and behaviors from opponents or surrounding people. By systematically analyzing how very aggressive, moderately aggressive, moderately cooperative, and very cooperative strategies perform and adapt through evolutionary game theory, our study highlights the complex adaptive mechanisms that people may use to optimize success in competitive yet potentially collaborative scenarios.

Hypotheses

Null: A moderately aggressive strategy would be the most effective, as it emphasizes the importance of asserting control over the board, trying to gain access to the most resources.

Data and Methods

Our Python simulation code approximated the basic mechanics of Catan, including resource distribution, player actions, and victory points. We supported three to four players. In both cases, we simulated 100 rounds that only ended when one player had accumulated ten victory points. We made these concessions:

Randomized Resource Generation differs from the board game. In our simulation, resources are randomly generated and assigned, but in the game resource distribution is often dependent upon the game leader. As we could not accurately account for this variance, we chose to simply randomize resources.
Terrain Variation is not present in our simulation, as such our strategies ignore the relative advantages of choosing to build towards or away from specific terrain types like hills and forests.

Simplified Resource Trading and Management compared to the board game. We mimic the mechanism behind most resource trades, the decision of which resources are excessive or lacking in the situation of equal counts is inherently random.
Fixed Strategies is inherent to this model and our research focus. While most board game players likely alter their strategy throughout the game, our simulation focuses specifically on the selection of one strategy.

Limited Outside-of-Action Player Interaction might limit the full implications of aggressive and cooperative strategies. It enables players to talk in live-time, players can make decisions to form alliances or block other players. However, we are not able to reliably replicate this in our game model so our strategic code is focused on only within-action player interactions.

Results

1. Very Aggressive Strategy: Players using this strategy initially performed well due to rapid expansion and quick accumulation of resources. But, they often faced resource shortages in the mid to late game due to limited trading and over-expansion. Their win rate was low, with success heavily dependent on early-game resource abundance. This strategy struggled when resource availability became scarce or when opponents employed effective trading strategies to mitigate the aggressive expansion.
2. Moderately Aggressive Strategy: This strategy showed balanced performance, combining expansion with strategic trading. Players employing this strategy had a consistently high win rate, suggesting that a mix of aggression and cooperation allows for sustainable growth and resource management. The ability to trade effectively while still prioritizing expansion helped these players maintain a steady resource flow and adapt to changing game conditions.
3. Moderately Cooperative Strategy: Players with this strategy prioritized trading and gradual expansion. They performed well overall, with a high win rate similar to moderately aggressive players. Their success was attributed to effective resource management and leveraging trades to balance resource shortages. By focusing on cooperation, these players could secure needed resources through trades, ensuring steady development without the aggressive expansion that could lead to resource depletion.
4. Very Cooperative Strategy: This strategy had the lowest win rate. While very cooperative players supported others through trades, they often fell behind in victory points due to slower expansion and reliance on others' cooperation. This strategy was most successful in games where other players were highly aggressive and resource-poor. However, the overall lack of assertiveness in expanding and building infrastructure led to its poor performance in most scenarios.
Evolution of Strategies: Through evolutionary game theory and repeated simulations, we observed that strategies tended to evolve towards a moderate balance of aggression and cooperation. The simulation showed a natural selection process where extremely aggressive or cooperative strategies were less sustainable, leading to a predominance of moderately aggressive and moderately cooperative strategies over time. The adaptive nature of these moderate strategies allowed them to respond better to the dynamic resource availability and trading opportunities presented in the game.

Nash Equilibrium and Payoff Matrix: Our Nash Equilibrium analysis indicated that moderately cooperative strategies were often the most stable, providing a balance between resource accumulation and trading. The payoff matrix showed that moderately aggressive strategies were particularly effective against very aggressive opponents, while moderately cooperative strategies excelled against very cooperative opponents. This balance suggests that while cooperation is crucial, maintaining an element of aggression ensures competitiveness and resource acquisition.

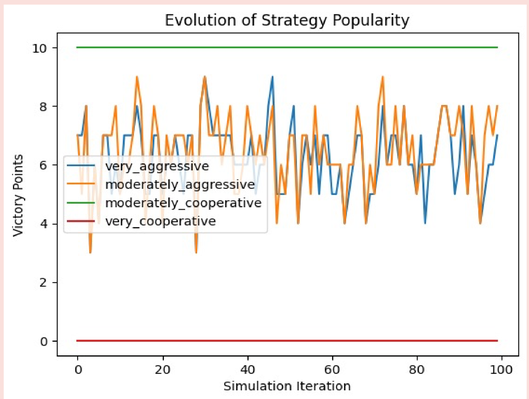


Figure 1. Evolution of Strategy Popularity

Results cont.

Heatmaps and Pairwise Comparisons: Heatmaps of pairwise strategy performance illustrated that mixed-strategy environments (combining moderate aggression and cooperation) resulted in the most competitive and balanced games. These environments allowed for dynamic interactions and adaptive behaviors, highlighting the importance of flexibility in strategy. The heatmaps revealed that games with a diverse mix of strategies tended to be more dynamic and balanced, as players continuously adapted their tactics based on opponents' actions.

Figure 2. Payoff Matrix

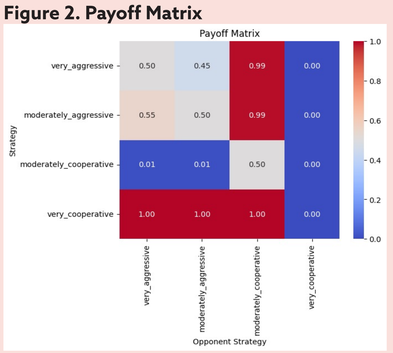
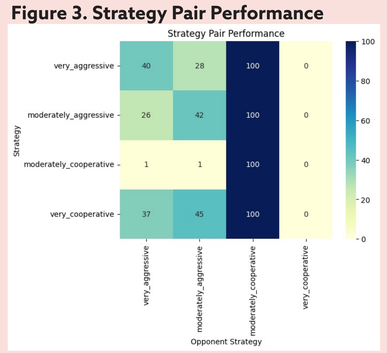


Figure 3. Strategy Pair Performance



Key Findings

1. Moderation is Key: Both moderate strategies outperformed the extreme strategies.
2. Resource Management: Effective resource management and strategic trading are crucial for success.
3. Adaptability: Adapting to changing conditions and opponent strategies is a significant advantage.
4. Strategic Interactions: The interplay between strategies creates a dynamic competitive environment, with no single dominating strategy.

Discussion

Our study demonstrates that in "Settlers of Catan," a balance between aggression and cooperation yields the best results. Moderately aggressive and moderately cooperative strategies consistently outperformed extreme strategies, highlighting the importance of adaptability and strategic trading. These findings align with broader theories in game theory and behavioral economics, suggesting that success in competitive environments often requires a mix of assertiveness and collaboration. The results suggest that while aggressive tactics can lead to short-term gains, sustainable success requires cooperation and resource management mirroring real-world scenarios where individuals and organizations must navigate between competition and collaboration to achieve long-term goals.