Topic: Risk-Management Strategies from an Evolutionary Game Theory Perspective

Risk-taking is an important part of strategic interactions; objective is to incorporate the study of risk-taking behavior into the game theory framework. Consider the case of the iterated Prisoner's Dilemma, where players choose their desired risk level for each individual encounter. Categorize resulting strategies and determine Nash equilibria. This model generalizes the current IPD framework: the standard model can be viewed as a special subcase where there is only 1 risk-level choice for each individual encounter.

Model

Consider a binary option of a high-risk Game 1 enviroment or a low-risk ("regular") Game 2 environment. If both players opt for a high-risk environment, they play Game 1 where the reward structure magnifies the benefit of cooperation - higher rewards for mutual cooperation, higher temptation to defect. Otherwise, the environment is the default low-risk environment, with the standard benefit of cooperation/temptation to defect.

Additional avenues of investigation:

- high-risk environment by default (instead of low-risk default environment)
- limit case of continuous risk-preference level (not just binary high/low risk)
- interplay between the players' risk environment preference and stochastic nature

Prospective Research Outline

- Categorize successful memory 1 strategies in $\mathbb{R}^{16}$.
  - first: pure strategies
  - second: epsilon-noisy
  - stretch: fully mixed strategies
- Prove Nash equilibria conditions for the successful strategies.
- Check robustness of top strategies to different initial conditions. Initial conditions include parameters (e.g. imitation probability β) and initial population, e.g. (starting with uniform ALL-D population, ALL-C population, or a mix of strategies).
- Check robustness of convergence time to different initial conditions. Convergence time can be defined as the number of timesteps to when a stable cooperative strategy takes root (e.g. first reaches more than 10% of the population). Given "worse" initial conditions, does it take polynomial or exponentially more time for a stable cooperative strategy to take root?

- Stretch: develop visualizations for how the strategies evolve over time as a function of the parameters.
- Repeat analysis in $\mathbb{R}^{12}$, looking at whether a stable cooperative strategy in $\mathbb{R}^{16}$ implies a stable cooperative strategy in $\mathbb{R}^{12}$.
- Compare the conditions for the emergence of stable cooperative strategies in the two risk level environment vs. single risk environment (i.e. the standard IPD framework).

Feasability

To make it computationally tractable to handle strategies in $\mathbb{R}^{16}$, perhaps use Monte-Carlo to approximate average payoff between two strategies. Since new strategies are invented relatively rarely, I only need to do MC to compute the sample average payoff of the newly invented strategy vs. the other strategies in the population (at most 99) for a fraction of the timesteps.