Zero-Determinant Strategies and Their Relation to Agent-Based Modelling

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Abstract

In game theory, Zero-Determinant (ZD) strategies are novel strategies discovered in 2012 by Press & Dyson. They have attracted much attention because they include unbeatable strategies called Extortion in a one-to-one competition as a subset. However, Extortion is weak in a large evolving population because cooperative groups are more successful than the groups of Extortioners. Even in the situation, Extortion can still act as a catalyst for cooperation when structured populations are considered. Structured populations are implemented by agent-based modelling. Thus, Extortion meets agent-based modelling in this scenario. In this talk, I first introduce our discoveries in ZD strategies and review some prominent ZD studies in agent-based modelling. Finally, I discuss the role of agent-based modelling in future ZD studies.

Cooperation plays a key role in building a society among unrelated individuals. In evolutionary game theory, the Prisoner's Dilemma (PD) game and other related games are used to consider whether cooperation can evolve. In the Repeated Prisoner's Dilemma (RPD) game, much progress has been done recently after the discovery of Zero-Determinant (ZD) strategies by Press and Dyson (Press and Dyson, 2012). ZD strategies can enforce a linear payoff relationship to their opponent regardless of the strategy that the opponent implements. In other words, when a strategy faces a ZD strategy, his payoff is strictly limited on a straight line even if he changes the strategy to a different one. When Press and Dyson first discovered ZD strategies, that was simplest version (e.g., no noise, no discount factor and so on). Inspired by their work, many extensions have been done including their evolution, multiplayer games, continuous action spaces, alternating games, animal contest, human reactions to computerized ZD strategies, and human-human experiments. For further information, see the references in our recent paper (Mamiya and Ichinose, 2019). We have also extended ZD strategies to cover a discount factor (Ichinose and Masuda, 2018) and noise (Mamiya and Ichinose, 2019) so that they can be more easily applicable to the real world. We also developed a graphical tool to show the payoff relationship between two players in the infinite RPD game. Figure 1 shows one example, which corresponds to an Extortion strategy; $\boldsymbol{p} = (0.86, 0.77, 0.09, 0)$.

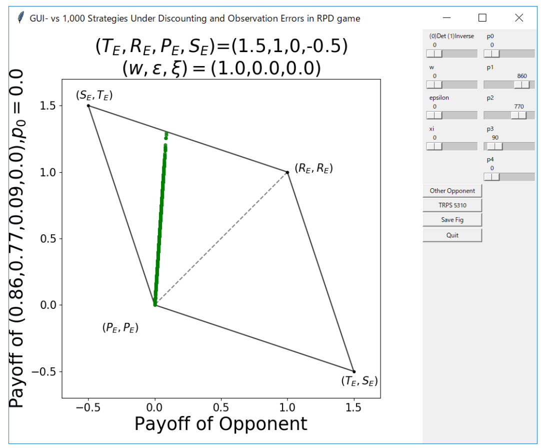

Figure 1: Visualization of the payoff relationship between two players in the infinite RPD game. Extortion vs. random 1000 strategies.

On the other hand, three prominent ZD strategies, Extortion, Equalizer, and Generous, have attracted much attention. Among them, Extortion has interesting features. When Extortion faces their opponent, not only it enforces a linear payoff relationship to the opponent but also its payoff is always higher (except for some special cases) than the opponent's. In other words, Extortion is unbeatable against any opponent in a one-to-one competition. However, Extortion is weak in a large evolving population because cooperative groups are more successful than the groups of Extortioners. Thus, evolution leads from Extortion to Generous strategies, which are cooperative and another subset of ZD strategies.

The above situation assumes a well-mixed population. In a well-mixed population, every player interacts with the other players with equal probability, which means that there is no population structure. On the other hand, when a structured population such as a square lattice or complex networks is considered, the situation dramatically changes. Using agent-based modelling, some researchers have investigated the evolution of Extortion in structured populations (Szolnoki and Perc, 2014a,b; Xu et al., 2017). Extortion ties defective strategies such as ALLD. Thus, Extortion can invade the sea of defectors. After the groups of Extortion are formed, ALLC behaves best against Extortion in the sea of Extortioners although Extortion still obtains higher payoffs than ALLC. In this way, cooperation-Extortion alliances emerge (Xu et al., 2017). This is one of the hot topics in ZD studies with agent-based modelling.

These studies used static networks (structured populations). We do not know what happens to the cooperation-Extortion alliances when dynamic networks are assumed. Dynamic networks can be realized by, for instance, link rewiring in a network or migration on a square lattice. Therefore, including these effects in ZD studies with agent-based modelling is one of the possible directions for future research.

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