Special Issue of International Journal of Linguistics and Computational Applications ISSN 2394-6393 (Online) ISSN 2394-6385 (Print)
Proceedings of the UGC Sponsored - National Conference on "Recent Statistical Computing Techniques and their Applications"
Department of Statistics and Department of Computer Science, Ramanujan College,University of Delhi, Delhi.
March 11-12, 2016. *Published on January 2017*

Comparison between the Strategies used to Solve Stochastic Iterated Prisoner's Dilemma

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***Abstract*—** Stochastic Iterated Prisoner's dilemma is a form of iterated Prisoner Dilemma. Prisoner's dilemma is the problem to show why two completely "rational" individuals might not cooperate even if it appears that it is in their best interests to do so. Strategies are specified by in terms of "Co-Operation Probabilities". The purpose of the paper is to discuss the two strategies to combat the problem namely, Memory-one and Zero determinant and to find strategies that perform better in the iterated game.
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***Keywords*—** Stochastic Iterated Prisoner Dilemma; Memory One; Zero Determinant; Nash Equilibrium.

1. Introduction

Themainrole Game theory is "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers." Game theory is mainly used in economics, political science, and psychology, as well as logic, computer science, biology and poker.Originally, it addressed zero-sum games, in which one person's gains result in losses for the other participants. Today, game theory applies to a wide range of behavioural relations, and is now an umbrella term for the science of logical decision making in humans, animals, and computers.

2. Prisoner's Dilemma

In game theory, there is a typical model, called prisoner's dilemma (PD), which gives a mathematical description of many situations in real life. Prisoner's dilemma is a two-person general-sum game with following rules.

Evolutionary game theory has focused on prisoner's dilemma, which incorporates the essence of conflict.

Now prisoner can take two action either Co-operation or Defection

- A and B both cooperates, then 1 year of imprisonment or an arbitrary payoff R.
- A betrays and B cooperate or vice versa, 3year of imprisonment to one and 1 Year to the other or arbitrary T and S payoff respectively.
- A and B betrays each other, then both will have imprisonment of 2year or arbitrary payoff P.

Such that T>R>P>S and 2R>T+S

- T>R>P>S: Mutual defection is most standard solution or the Nash equilibrium for the problem.
- 2R>T+S: Mutual co-operation is globally optimum.

If game is played for one or for fixed number of times, there is no room of emergence for co-operation, that's why Iterated Prisoner dilemma gains so much attention.

2.1 Stochastic Iterated Prisoner's Dilemma

Stochastic game is generalization of repeated game. Strategies are defined by in terms of "Co –operation Probabilities" X: set of probabilities P of cooperating with Y -> P= $\{P_{CC}, P_{CD}, P_{DC}, P_{DD}\}$. C= cooperated and D= defected , P= function of the outcomes of their previous encounter (Only n-recent encounters: Memory n). An extension of the iterated prisoner dilemma, in which the relative abundance of particular strategies is allowed to change, with more successful strategies relatively increasing.

3. Memory n

In an encounter between X and Y player, X's strategy is specified by a set of probabilities P of cooperating with Y. P is the function of the outcomes of their previous or some subset thereof.

If P is function of the outcomes of only their n- recent encounters, it's called memory n strategy.

3.1 Memory -1

A memory one strategy for the case is defined as P = P= $\{P_{CC}, P_{CD}, P_{DC}, P_{DD}\}$.

Where, P_{ab}= the probability that X will cooperate in present given that the previous was characterize by "ab".

- It has been shown that for any memory n strategy there is a corresponding memory-1 strategy that gives the same statically result s, so that only memory -1 needs to be considered

4. Zero Determinant

Traditionally there is no belief that there is no ultimatum strategy for a player to unilaterally claim an unfair share of rewards. *ASSUMPTIONS are,*

- Player cares for long run expected payoff per round.
- Each player can only remember the outcome of single previous round and thus uses the "Memory -one" Strategies.

It is possible to for both players to choose some strategies to unilaterally enforce a linear relation between there payoffs. Then regardless of a linear relation between the expected payoffs of two players in the limiting state will hold: αSx+βSy+ϒ=0. Where, α, β, ϒ precise values of payoffs and Sx and Sy are short term payoff vector. This is known as *Zero-Determinant Strategy.*

5. Nash Equilibrium

Fact, in a stochastic iterated prisoner's dilemma where, by definition, the strategies are specified in terms of cooperation probabilities, as long as both players use finite-memory strategies, then the game can be modelled by a Markov process and the idea of zero-determinant strategies applies Informally, a set of strategies is a Nash equilibrium if no player can do better by unilaterally changing their strategy. Or in lay man language it is termed as most standard solution, where each player gives his best response to other in game.

- A pure strategy provides a complete definition of how a player will play a game. In particular, it determines the move a player will make for any situation he or she could face. A player's strategy set is the set of pure strategies available to that player.
- A mixed strategy is an assignment of a probability to each pure strategy. This allows for a player to randomly select a pure strategy. Since probabilities are continuous, there are infinitely many mixed strategies available to a player.

Of course, one can regard a pure strategy as a degenerate case of a mixed strategy, in which that particular pure strategy is selected with probability *1* and every other strategy with probability *0.*

5.1 Nash Existence Theorem

Nash proves that if we allow mixed strategies, then every game with a finite number of players in which each player can choose from finitely many pure strategies has at least one Nash equilibrium.

6. Stability

Somehow it's been shown in a study that unfair Zero Determinant strategies are not evolutionary stable. The key intuition is that an evolutionarily stable strategy must not be able to invade other population but must also perform well against other players of same type. Theory and simulations confirm that beyond critical population size, zero determinant loses out in evolutionary competition against more co-operative strategies. Thus not stable for large population.

Whereas the A Nash equilibrium for a mixed strategy game is stable if a small change (specifically, an infinitesimal change) in probabilities for one player leads to a situation where two conditions hold:

- The player who did not change has no better strategy in the new circumstance
- The player who did change is now playing with a strictly worse strategy.

If these cases are both met, then a player with the small change in their mixed strategy will return immediately to the Nash equilibrium. The equilibrium is said to be stable. If condition one does not hold then the equilibrium is unstable. If only condition one holds then there are likely to be an infinite number of optimal strategies for the player who changed.

Stability is crucial in practical applications of Nash equilibria, since the mixed-strategy of each player is not perfectly known, but has to be inferred from statistical distribution of their actions in the game. In this case unstable equilibrium are very unlikely to arise in practice, since any minute change in the proportions of each strategy seen will lead to a change in strategy and the breakdown of the equilibrium.

7. Conclusion

Thus, from the above discussion on the stability, it's pretty clear that mixed strategies cater to most of the stochastic iterated dilemma problems thus making it not optimal yet better solution for the problem.

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