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THE APPLICATION OF THE GAME THEORY IN SOCCER SHOT-MAKING USING NASH EQUILIBRIUM

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ABSTRACT

The aim of my paper is to discuss the role of the game theory in taking a shot in soccer. I will use this theory to illustrate a common scenario - whether to beat the goal keeper by shooting the ball in the right or left side of the goal - in the game of soccer. Game Theory is an area of applied mathematics that studies the strategic interactions between objects, situations, outcomes etc and their resulting payoffs. It helps to find anoptimum strategy using the Nash equilibrium.

The objectives of this study are:

1) ***To show that penalty kicks is a very common type of game and one that the game theory can help predict***
2) ***The players behave similar to the prediction***
3) ***A striker more accurate on one side, makes him less likely to shoot the ball on that side***

***KEYWORDS**: applied mathematics, strategic interactions, optimum strategy, Nash equilibrium.*

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INTRODUCTION

Game Theory: Game theory, is a branch of applied mathematics that provides tools for analyzing situations in which parties, called players, make decisions that are interdependent. This interdependence causes each player to consider the other player's possible decisions, or strategies, in formulating strategy. A solution to a game describes the optimal decisions of the players, who may have similar, opposed, or mixed interests, and the outcomes that may result from these decisions.

Game: A series of situations where the outcome depends on the actions of two or more decision makers (players).

Player: A strategic decision maker in the context of the game.

Strategy**:** A complete action plan that players follow, taking into account the situations that may occur in the game.

Pay-out**:** The pay-out you receive when a player achieves a particular result. Payments can be in a quantifiable format, from dollars to profits.

Information set**:** Information available at a particular point in the game. The term information set is most commonly used when the game has sequential components.

Equilibrium: The point of the game when both players make a decision and reach a result.

TYPES OF GAMES

1) **Cooperative and non-cooperative games:** Cooperative game theory focuses on how well players can do, given the value that each coalition of players can create, while non-cooperative game theory is a move that players should reasonably do. Focuses on.

2) **Normal form and extensive form games**: A standard game is a description of a matrix-style game. In other words, if the game's rewards and strategies are presented in tabular form, it is said to be a standard game. Standard games help identify dominance strategies and Nash equilibrium. In a normal form of the game, the Matrix shows the strategies adopted by the various players in the game and their possible outcomes. Extensive-form games, on the other hand, are games in which the game is described in the form of a decision tree. Extensive shape games help you depict events that can occur randomly. These games have a tree-like structure with different node names for the players. Possible actions and pay-outs for each player are also specified in this structure.

3) **Simultaneous move games and sequential move games**: A simultaneous game is a game in which the movements of two players (strategies adopted by two players) are performed at the same time. With simultaneous movement, the player does not know the movements of other players. In contrast, a sequential game is a game in which the player is aware of the movements of the player who has already adopted the strategy. However, in a sequential game, the player does not have a deep knowledge of the strategies of other players. For example, a player knows that other players do not use a single strategy, but

does not know how many strategies other players can use. Simultaneous games are displayed in normal format, and sequential games are displayed in rich formats.

4) **Constant sum, zero-sum and non-zero-sum games**: A constant sum game is a game in which the total score of all players remains constant, even if the scores are different. A zero-sum game is a type of constant-sum game in which the sum of the results of all players is zero. In zero-sum games, different player strategies cannot affect the available resources. Also, in a zero-sum game, the gain of one player is always equal to the loss of the other player. A non-zero-sum game, on the other hand, is a game in which the total score of all players is non-zero. You can turn a non-zero-sum game into a zero-sum game by adding a dummy player. Dummy player losses are overwritten by the player's net profit. Examples of zero-sum games are chess and gambling. In these games, if one player wins, the other player loses. However, cooperative games are examples of non-zero games. In cooperative games, all players win or lose.

5) **Symmetric and Asymmetric games:** In symmetric games, all players have the same strategy. Symmetry can only exist in short-term games. This is because in long-term games, players have more options. The decision in a symmetric game depends not on the player in the game, but on the strategy used. Even if you change players, the decision is the same in a symmetric game. The prisoner's dilemma is an example of a symmetric game. On the other hand, an asymmetric game is a game in which the player's strategy is different. In asymmetric games, a strategy that benefits one player may not benefit the other player equally. However, decisions in asymmetric games depend on the different types of strategies and decisions the player makes. An example of asymmetric play is when a new organization enters the market. This is because different organizations use different strategies to enter the same market. Bottom of Form

TYPES OF EQUILIBRIA

1) **Correlated equilibrium**- In game theory, correlated equilibrium is a more general solution concept than the well-known Nash equilibrium. The idea is that each player chooses an action according to a private observation of the same public signal value. The strategy assigns an action to each possible observation that the player can make. If no player wants to deviate from the strategy (assuming no other player deviates), the distribution from which the signal is drawn is called the correlated equilibrium.

2) **Symmetric equilibrium**- In game theory, symmetric equilibrium is an equilibrium in which all players use the same (possibly mixed) strategy in equilibrium. The balance is symmetrical because both players use the same strategy. Symmetrical equilibrium has important properties. In a single population model, only symmetric equilibrium is evolutionarily stable.

3) **Trembling hand perfect equilibrium**- In game theory, the perfect equilibrium of the trembling hand is an improvement on Nash equilibrium. Perfect equilibrium of a trembling hand describes the possibility of out-of-balance play by assuming that a "slip" or tremble allows the player to choose an unintended strategy, but with a probability is very small.

4) **Nash equilibrium-** In game theory, the Nash Equilibrium, is the most common way to define a solution for non-cooperative games involving two or more players. Nash equilibrium assumes that each player knows the other player's equilibrium strategy, and simply changing one's strategy will not yield anything. The principle of Nash equilibrium dates back to the era in 1838, when it was applied to competitors who chose output. Each player chooses a strategy (an action plan based on what has happened so far in the game), and other players can change their strategy without changing it to get their expected rewards. If it cannot be increased, the current strategy choices form a Nash equilibrium.

CONDITIONS TO GUARANTEE THAT THE NASH EQUILIBRIUM IS PLAYED:

1) The players will do their greatest possible to maximise their expected payoff as described by the game.
2) The players are perfect in their execution
3) The players must have sufficient intelligence to reach the solution
4) The players should know the planned equilibrium strategy of all other players
5) The players believe that a change in their own strategy will not cause a change by other players
6) Common knowledge that all players meet these conditions

APPLICATION OF GAME THEORY IN PENALTY KICKS:

The penalty is not complicated. The striker places the ball in front of him and positions him. He runs forward and shoots the ball at the net. The goalkeeper tries to stop him. Despite the above order, players basically move at the same time. The goalkeeper dives after the striker kicks the ball, but can't really wait for the ball to decide where to dive away from the foot-the ball is moving so fast that the goalkeeper is already Hiding behind him his jump. Therefore, the goalkeeper should choose his strategy before observing the relevant information from the striker. This is when and where the game theory comes into play. This type of game is actually very common. Both players select the side. One player wants to match the side (goalkeeper), but the other doesn't want to match (forward). So, from the forward's point of view, the goalkeeper wants to jump left when the forward kicks to the left and jump to the right when the forward kicks to the right. The striker steps to the left if the goalkeeper jumps to the right and to the right if the goalkeeper jumps to the left.

I will represent the outcomes of each case using a 2 by 2 playoff matrix between the kicker and goalie matchup.

Strategies:

1) The kicker can kick left or right
2) The goalie can dive left or right

Assumptions:

- Goalie jumps left= q
- Goalie jumps right= (1-q)
- Kicker kicks left= p
- Kicker kicks right= (1-p)
- The kicker never kicks in the centre

- The kicker is good, so they will never miss the goal if the goalie didn't dive that side
- The goalie is good, so they will never let the ball go into the goal if he guesses the correct side

Case 1:

If both, the goalie and kicker pick the same side.

KICKER/GOALIE	JUMPS LEFT	JUMPS RIGHT
KICKS LEFT	(-1,+1)	(+1,-1)
KICKS RIGHT	(+1,-1)	(-1,+1)

[+1= WIN ; -1= LOSS]

If the goalie jumps to the left side, then the shooter will get a payoff of:

$p\cdot(-1)+(1-p)\cdot(1) = 1-2p.$

If the goalie jumps to the right side, then the shooter will get a payoff of:

$p\cdot(1)+(1-p)\cdot(-1) = 2p-1.$

In both the cases, the maximum achieved p is 0.5

Therefore, this is an example of a balanced game.

Case 2:

If the goalie is weaker on the left side

Asymmetric goalie example

KICKER/GOALIE	JUMPS LEFT	JUMPS RIGHT
KICKS LEFT	(-0.5,+0.5)	(+1,-1)
KICKS RIGHT	(+1,-1)	(-1,+1)

For the goalie:

If the goalie jumps to the left side, then the kicker will get a payoff of:

$p\cdot(-1/2)+(1-p)\cdot(1) = 1-(3/2)p.$

If the goalie jumps to the right side, then the kicker will get a payoff of:

$p\cdot(1)+(1-p)\cdot(-1) = 2p-1.$

In this case, the maximum achieved p is 4/7. The minimax-optimal expected payoff to the shooter is 1/7. The goalie being weaker means the kicker's payoff increases.

For the kicker:

If the kicker kicks the ball to the left side, then the kicker will get a payoff of:

$q \cdot (-1/2) + (1 - q) \cdot (1) = 1 - (3/2)q.$

Again, the shooter guarantees a payoff of 1/7, and the goalie can guarantee that the shooter's payoff is never more than 1/7. In this case the value of the game is said to be 1/7.

CONCLUSION

Above, I have illustrated two situations in soccer, specifically penalty kicks, in which the game theory is applied. I first explained the common terms used in this branch of mathematics. After that, I explained the types of games that can be possible. Next, I explained the possible equilibria that are possible in different games. To end my paper, I have shown the application of this theory in two cases.

REFERENCES

1) https://williamspaniel.com/2014/06/12/the-game-theory-of-soccer-penalty-kicks/
2) https://www.youtube.com/watch?v=OTs5JX6Tut4
3) https://www.britannica.com/science/game-theory
4) https://en.wikipedia.org/wiki/Game_theory
5) https://blogs.cornell.edu/info2040/2016/10/17/game-theory-in-penalty-kicks/
6) http://www.econ.ucla.edu/riley/Coloma.pdf
7) https://en.wikipedia.org/wiki/List_of_types_of_equilibrium
8) https://www.economicsdiscussion.net/game-theory/5-types-of-games-in-game-theory-with-diagram/3827