Quantum game theoretic analysis of Kabaddi

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Abstract

Quantum mechanics is bringing in innovation and change in every aspect of our lives. Quantum game theory has been providing better strategies in problems where earlier game theory was applied. In this paper, an attempt is made to use Quantum game theory in Kabaddi to provide Quantum strategies which have no classical counterpart. For the same, efforts are made to construct the dataset from scratch by observing match videos of Pro Kabaddi league, 2019 season 7 and construct payoff matrices depicting various strategies of raiders and defenders. The payoff matrices are further used to construct utility matrices. A Quantum circuit is used to quantize the Kabaddi. The data suitably adapted from utility matrices is fed into the Quantum circuit. The output contour and mesh plots are obtained. The plots depict the regions where the teams win. This is the first reported attempt to quantize Kabaddi and the initial results provide impetus for further research.

***Keywords**: MATLAB, Kabaddi, Raider, Defender*

Introduction

India has a very rich heritage of culture and traditions, where games and sports have always remained an important part of the society. Many popular games have originated here, and one such game is Kabaddi. It is an outdoor game, which requires a lot of physical stamina, agility, individual proficiency, neuromuscular coordination, lung capacity, quick reflexes, intelligence and presence of mind. It is a team game, requiring seven players in each of the two teams that are pitched against each other. It requires a small playing field measuring 12.5m x 10m (for adults), which is divided by a mid-line into two halves (each measuring 6.25m x 10 m). Each team is assigned one half as its territory. The game of Kabaddi is played in 45 minutes, with an interval of 5 minutes after first 20 minutes of the game. The Game is supervised by a referee, two umpires and a scorer. No equipment is required in this game.

A typical event of the game starts when one player from one of the teams, who is called the raider, enters the territory of the opposite team, called the defenders. The team which wins the toss sends its raiders first. It also gets an opportunity to choose one half of the field. The raider moves from the territory of his/her team into the other side of the field uttering a continuous cant of Kabaddi with the objective of touching one of the defending players without being caught hold of. An important condition is that the raider can remain in the opponent team’s area only until he/she continues to can’t the word kabaddi in one single breath. He/she is turned out from his/her side the moment he/she takes another breath while remaining in the opponents' area, and the opposite team is awarded one point. The defenders try to hold the raider within their area, and the raider tries to force his/her way back to his/her side without discontinuing the chant. If the raider succeeds in returning to his/her part of the field without being caught after touching a defender and without losing his/her breath, a point is credited to his/her team and the player of the opposite team touched by the raider is sent out of his/her team's territory. On the other hand, if the raider is not able to do so and is held by the defending group, then the opposite team gets a point, and the raider has to drop out (Do or die raid). Also, if any player goes out of the marked boundary line during the play, or if any part of his/her body touches the ground outside the marked boundary, he/she is sent out (except during a struggle). When a player is put out from one side, a player of the opposite team, who may have been sent out of his/her team's area earlier, re-joins his/her side. A player from each group alternately raids the opposite side. This process continues until a team succeeds in putting out the entire opposing team from its territory or the stipulated time is up. The victorious side is then credited with two additional points (Lona). The side scoring maximum points at the end of the game is declared as the winner. As per the literature survey, so far only one paper has been published on the analysis for winner prediction in the game of kabaddi [1].

Games are defined as mathematical objects consisting of a set of players, a set of strategies (options or moves) available to them, and a specification of players' pay-offs for each combination of such strategies (possible payoffs of the Game). The pay-offs to players determine the decisions made and the type of the Game being played. A Game consists of strategies (actions taken while interactions), pay-offs (utilities gained), pay-off function (calculates utility against each strategy), and, of course, game rules [2].

The minimax theorem minimizes the loss of a player. The maximin theorem is used to maximize the benefits gained by the player [3]. Conventional optimization methods convert the problem to a single decision maker problem with a single composite objective for the whole system [4]. It is assumed that there is perfect cooperation among decision-makers so they do not prioritize their objectives. The behaviour of involved parties is neglected. Game theory takes these into account and the results obtained are close to the practice. Game theory develops broadly acceptable solutions as it studies the strategic actions of individual decision makers. Game theory can predict how people behave, based on their interests, in conflicts. Game theory problems are often multi-criteria multi-decision-making problems. Each decision-maker plays the Game to optimize his objective, knowing that other players' decisions affect his objective value and that his decision affects others' pay-offs and decisions. The main concern of players is to maximize their benefit in the Game, knowing that the payoff is the product of all the decisions made. If we can analyse agent actions, strategies etc., to predict its moves, we can advise about different moves to agents. It means we can provide a sophisticated model for future decision-making. The framework for game theory consists of formulating predictions, delivering prescriptions and recommendations for decision makers [5].

Physicists as well as non-physicists have been interested since a long time in the weird phenomenon seen in subatomic particles studied using Quantum mechanics. Due to existence of various dilemmas in classical game theory, people have tried, for example replacing classical probabilities with the respective Quantum counterparts. An obvious next step to which is studying the effects of Quantum superposition, interference and entanglement on the agents' optimal strategies. Quantum strategies have been shown to be more efficient in terms of output compared to their respective classical counterparts [6-24]. On the other hand, Quantum game theory also could be used to solve some of the problems yet unsolved in Quantum computation and Quantum information [25].

Meyer [26] and Eisert et al independently (1999) proposed to apply Quantum mechanics to game theory. Meyer showed that the player implementing quantum strategies always wins over the one implementing classical strategies in zero-sum games while Eisert et al. studied Prisoner's dilemma which is a non-zero-sum game.

Eisert et al. [27] study two player two strategy games like prisoners' dilemma. They replace classical strategies with Quantum strategies. They give a generalized quantization technique for two player two strategy game. Although the generalized quantization technique presented is for two player games, it can be conveniently extended to N player games. For a two player Quantum game, they define (1) the two player Quantum game D (H; i; S_A; S_B; P_A; P_B) (2) a Hilbert space H of the Quantum system, to specify the game (3) a density matrix is used to give the initial state i that is contained in the game (4) associated state space S(H), i ∈ S(H), (5) moves or strategies of the players represented by sets S_A and S_B, which are a collection of entirely trace preserving maps of state space onto itself (6) the pay-off (utility) functions P_A and P_B, which tell the payoff after the final state f [27]. Eisert et al. show that Quantum strategies give better outcomes than classical ones. Similar results are shown in several other reported works [6-24].

Quantum Football has been discussed by taking the analogy of ball as the occupied state that can be shared between many energy levels (players). The major analogies used in this study are, the two players are depicted as two energy levels that form qubit, |0> (ball is with player |0>) and |1> (ball is with player |1>) and thus the state of football (a quantum system can be written as a|0>+b|1>, where a, b are time dependent complex numbers satisfying $|a|^2+|b|^2=1$. The quantum ball is a superposition, which is shared among both the players. In multiplayer case, it can be firmly stated that all the players have some of the ball [28]. The possibility of using Quantum physics in football training is also discussed. The professional football players were given to do some exercises as per their choices. The 'left ankle injury' of a player was treated by "quantum touch at a distance" DK2 method. The vibratory connections were used to strengthen the physical, mental and spiritual capacity of the players [29].

In the Chinese Go, the single stones are replaced by the pairs of entangled stones. The collapse occurs when such an entangled pair comes directly in contact with one more stone [30]. The Quantum phenomenon of superposition and entanglement are introduced in GO. The experimental demonstration shows a Quantum version of GO using correlated photon pairs entangled in polarization degree of freedom [31]. The games Gomoku and Weiqi (GO) are generalized to be playable on Quantum computers. It is to be ensured that standard classical games are the subsets of the Quantum game. The three options for playing the game are: (1) between two Quantum computers (2) two classical computers playing on a Quantum computer (3) two classical computers [32]. The boxes in the game of GO are shown as a superposition of Quantum states and the players have two kind of moves- classical and Quantum. The superposition, collapse and entanglement are also discussed [33].

Quantum chess uses uncertainties of Quantum physics to make chess random. Cantwell [34] uses the principle of superposition to quantize chess. The superposition must have an upper limit to ensure the feasible simulation of the game. In quantum chess, due to the elements of randomization, the computer chess player need not always win against the human player [35-36]. Padhi et al. [37] develop Quantum circuits for a 3*3 chess board with only pawns in it. These circuits can be used to play chess on a Quantum computer.

The Quantization technique used in the present work is adapted from Eisert et al. [27]. The quantization scheme uses the phenomenon of Quantum entanglement to create novel strategies that have no classical counterpart and thus, are called entangled. The quantized game is bound to obey the correspondence principle, due to which every Quantum game has to collapse to the classical game when there is no entanglement. An entanglement factor is used to determine the degree of entanglement, which lies between zero (the minimum value) and $\pi/2$ (the maximum value). Jiang et al. [38] discuss the multiplayer and multichoice quantum games while Benjamin et al. discuss the multiplayer quantum games [39].

Piotrowski et al. [40] explain that as any measurement of the entangled strategies would result in decoherence so the existence of entangled strategies can only be ensured if the players have no clue about their possible strategies. Due to quantum entanglement, the quantum state of systems undergoing interactions cannot be described independently until the collapse occurs because of the way they interact [30].

Vlachos, P., & Karafyllidis, I. G. [41] develop a Quantum circuit based on the formalism of [27]. They illustrate its working for the case of Prisoners' dilemma, the Battle of sexes and the game of chicken. The Quantum circuit is developed for two-player Quantum games described by 2*2 payoff matrices, for games with two strategies. The user can specify (1) The payoff matrix for both the teams, (2) the strategies (3) the amount of entanglement between initial strategies. The output of the game is as follows: (1) expected payoff of each team as a function of the other team's strategy parameters and the amount of entanglement. (2) Contour plots- divide the strategy space into regions in which teams can get larger payoffs if they choose to use a Quantum strategy against classical. In the case of the Prisoner's dilemma, the user enters the entanglement factors Υ, θ_B and Φ_B (angles for team B). Then the payoff matrix for B is calculated and stored. Υ, θ_B and Φ_B determine the strategy that team B will follow. After this, the Quantum circuit calculates all possible strategies for team A by gradually increasing θ_A and Φ_A. In our work, payoff matrices with mixed Nash equilibria have been quantized.

Model

The quantization of many physical phenomenon has been achieved as explained vividly in the Introduction (literature review) section. The quantization of Kabaddi is attempted in this paper to provide some novel and improved strategies and outcomes for improving the strategic decision making by coaches and players. The dataset was written down by observing the match videos of pro kabaddi league 2019 season 7, in the form of 2*2 payoff and utility matrices. The strategies of the teams are given as input to the Quantum circuit in the form of the qubits, which are known to both the teams. There are two, two-qubit Quantum circuits that are used to entangle the Quantum register. There are unitary operators that modify the initial strategies of the teams along with entangling operators. The measurement of qubits is conducted at the end to obtain the resultant payoff matrices.

The method employs the circuit model of quantum computation. The two strategies are entered as input to the model in the form of two qubits. These qubits are defined in the beginning of the game and are known to both the players. Apart from this, there are two two-qubit quantum circuits which happen to be unitary operators and utilized for the entanglement and two one-qubit gates which are the operators that change the initial strategy of the players. The measurement involves calculating the payoffs matrices of the players by operating on the qubits. The angle Υ is the degree of entanglement and θ and Φ determine strategies that each of the teams will follow.

For mesh plot, first of all, the variables θ_B and Φ_B are used which determine the strategy that team B will follow which helps in calculating and storing the matrix of player B’s strategy. Then the possible strategies for team A are calculated by gradually increasing the θ_A and Φ_A. The payoffs depend on Υ, θ_B, Φ_B, θ_A and Φ_A.

For contour plot, the angle Υ is not modified instead the Φ_A is altered.

The MATLAB contour plot and mesh plot are drawn for each 2*2 matrix. Figures 1 and 2 show payoffs (payoffs) for a Quantum game theoretic analysis of Kabaddi for team A, taking angles (θ_A, Φ_A) as a varying quantity. The angles Υ (a measure of degree of entanglement in the game), θ_B and Φ_B (θ and Φ are the constituents of the unitary gate) can be determined. The following payoff matrix represents the game

		Raider	
		TH	Dash
Defender	FK	(a, a’)	(b, b’)
	D	(c, c’)	(d, d’)

Table 1: Kabaddi utility matrix for the cumulative match points of the tournament

		Raider	
		ANKLE-HOLD	BLOCK
Defender	HAND-TOUCH	(0.135, 0.135)	(0.246, 0.214)
	BACK-KICK	(0.123, 0.123)	(0.175, 0.193)

Table 2: Rounded off kabaddi utility matrix for the cumulative match points of the tournament

		Raider	
		ANKLE-HOLD	BLOCK
Defender	HAND-TOUCH	(1, 1)	(3, 2)
	BACK-KICK	(1, 1)	(2, 2)

Table 3: Rounded off kabaddi utility matrix for the cumulative match points of the tournament

Results

This paper attempts an analysis of the Quantum Game Theoretic analysis of Kabaddi, using the dataset consisting 2*2 payoff matrices. The contour and mesh plots (Figure 1 and 2) show team B can modify the angles θ_B and Φ_B. This can further demarcate the regions where A is the winner in the strategy space, it can be in the upper, middle or lower region of the strategy space. The contour plot (Figure 1) shows the strategy space, demarcated into separate regions where individual teams can get larger payoffs if a quantum strategy is used instead of classical strategy.

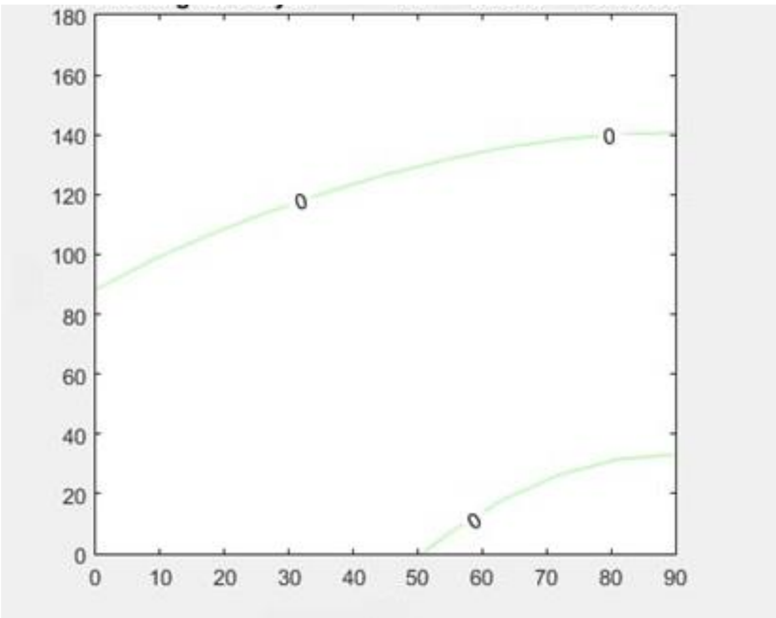

Figure 1: The mesh plot and payoffs for both the teams

The mesh plots show the expected payoffs for each team as a function of the other team's strategy parameters and the amount of entanglement.

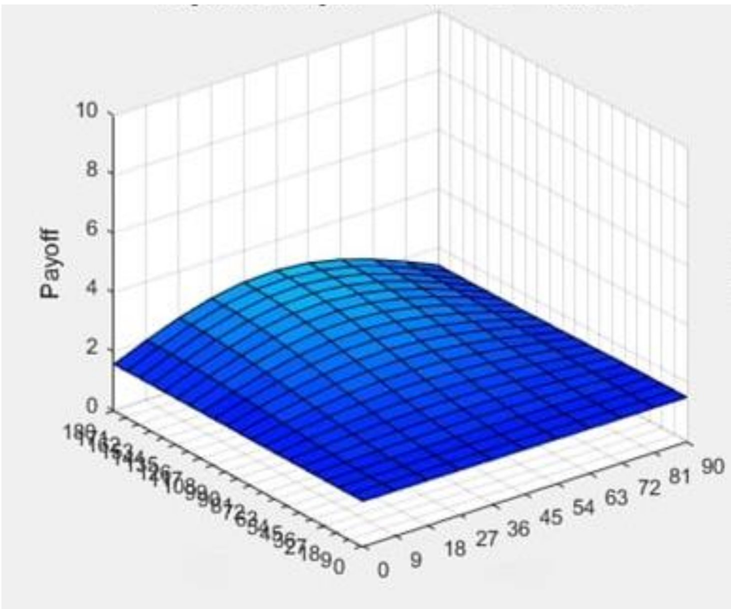

Figure 2: The contour plot and winning for team A

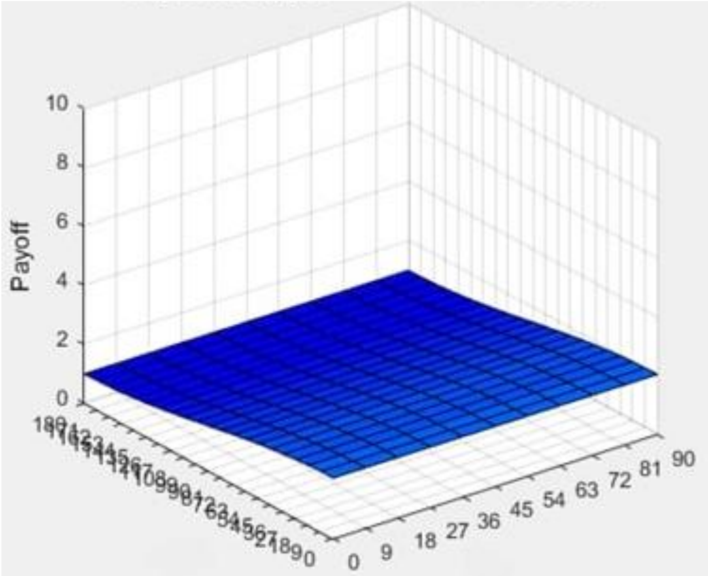

Figure 3: The contour plot and winning for team B

Discussion

In this study, the authors have quantized Kabaddi. The dataset obtained by observing the match videos of the pro kabaddi league 2019 season 7, depicting various strategies of the raider and the defender. The payoff matrices constructed using the dataset were used to make utility matrices. The data in the utility matrices was fed into the Quantum circuit. The authors have taken 2*2 matrices as input to the model. The Quantum circuit gives contour and mesh plots as the output. The plots obtained show the regions where each of the teams win.

The strategies are considered to be entangled by using the entanglement factor ϒ while quantization. The pictorial representation of the Quantum Game Theoretics analysis is shown in figures below for various cases, obtained from the MATLAB contour and mesh plots. The input information corresponds to Quantum game theoretic analysis of Kabaddi.

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