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RESEARCH ARTICLE

Quantum Tant-Fant

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Abstract

Objectives: The Tant-Fant finds its origin in Bengal, India. The original game hereby referred to as the classical game has two players. To develop a basic understanding in the reader's mind, the paper describes the rules and strategies for playing Tant-Fant in detail. The classical game board can be drawn on paper, played on board, or a web reference available. **Methods:** In the classical version, players ought to have three pieces aligned in a row termed as a three-in-a-row either horizontally, vertically, or diagonally but not on the players' initial position also termed as the home row. Alternatively, the players can make specifically a diagonal three-piece alignment also termed a diagonal three-in-a-row. **Findings:** QTF uses the counter-intuitive principles of quantum superposition and collapse to design new moves. The players may choose from either of the two quantum moves, QM1 and QM2 which are equivalent to placing a superposition of pieces in different squares. **Novelty:** The quantization of a given game use fewer steps in comparison to classical computation, bringing out previously non-existing strategies for game playing and for tackling more and more complexities in the game. Quantum computers are finding potential applications in almost every field of life. As the quantization of many classical games has already been achieved, the quantization of a lost traditional game would be an interesting feat to achieve.

Keywords: Quantum Computation; Quantum Gates; Superposition; TantFant Game; Entanglement

1 Introduction

Quantum computers are finding potential applications in almost every field of life. Quantization of many classical games has already been achieved. Quantization of Tant-Fant is an interesting problem to infuse some interest in this game that is waning. It also potentially brings out previously non-existing strategies for game playing and for tackling more and more complexities in the game. This study contains the first-ever quantization of Tant-Fant, so no existing literature is available to cite or develop a research gap.

Cantwell [1] used superposition is used to quantize chess. The superposition has to have an upper limit to ensure the feasible simulation of the game. The paper by Padhi [2] develops quantum circuits for a 3*3 chessboard with only pawns in it. These circuits can be used to play chess on a quantum computer.

Qiao [3] discussed the quantum phenomenon of superposition and entanglement introduced in GO. The experimental demonstration shows a quantum version of GO using correlated photon pairs entangled in polarization degree of freedom. Wu [4] generalized Gomoku and Weiqi (GO) 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. Sahu [5] discusses in his paper, the boxes in the game of GO are shown as a superposition of quantum states and the players have two kinds of moves- classical and quantum. Superposition, collapse, and entanglement are also discussed. Gamification techniques are employed by Kopf et al. [6] to educate students about quantum physics using the quantum card game. The provided game provides several methods and game models for learning new quantum ideas.

2 2. Methodology

2.1 Classical Tant-Fant (CTF)

2.1.1 CTF Game

CTF is a finite, deterministic, perfect information game. The two players alternate in making moves on a 3*3 square board, divided into eight equal parts. It is an alignment game. CTF is related to three men Morris, Nine holes, Achi, Shishima, and Dara, and uses the same board as Tapatan and Achi. The major difference between CTF and these games is that in CTF the pieces are initially placed on each player's side known as the home row. The game uses a 3*3 board. The game occurs at the intersection of lines. The board has three rows formed by three horizontal lines and three columns formed by three vertical lines. The opposite corners of the board are connected using two diagonal lines (Figure 1). The players are given the freedom to select the colors of the pieces to be played. In the classical version, for example, the two players could be given black and white pieces, respectively.

2.1.2 Moves in CTF

Each player is allowed to move only one piece per turn. Players move the pieces to an adjacent unoccupied intersection along the lines. The players ought to move along the pattern on the board, so each piece can move one space at a time only. The pieces can move back and forth along the lines. No other moves are allowed. If a player repeats a position three times, it is considered a draw. The game is declared a draw after 50 moves. A stalemate draw is defined as the condition when a player cannot move, as per the house rules. It has been established that if neither player makes a mistake, the game must end in a draw [7].

The common locations on a CTF board are of two types: starting squares and intermediate squares (Figure 1). A starting square is defined to be a location on the game board where a piece starts from. It is different for each player. An intermediate square is useful while playing the game, the pieces pass through these squares. The number of starting squares is six; three for each player and intermediate squares are three. A blockade to the game involves an adjacent position but without any black solid line drawn and, therefore, no path to move on or a square belonging to the other player.

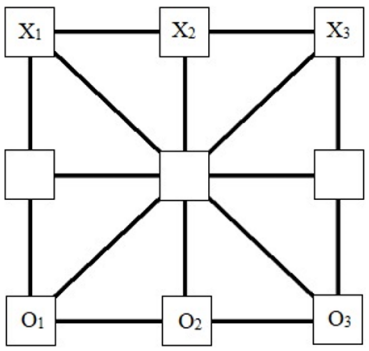

Fig 1. The game board for Tant-Fant showing pieces

2.2 Quantum Tant-Fant (QTF)

Some important quantum principles that are utilized for the development of QTF include superposition, entanglement, and measurement or collapse. The quantum mechanical principles introduce non-determinism and complexity into Tant-Fant and make brute-force strategies considerably more difficult to implement. In the CTF a piece is in exactly one square out of the nine available on board. In the QTF, a piece can be placed by a player in a superposition state between two squares i.e., it can be in both squares simultaneously with probability $\frac{1}{2}$ each. Entangled states in quantum Mechanics are those states which cannot be expressed independently of each other and exhibit very strong correlations that cannot be found in the classical domain at all. In QTF, pieces that share squares in their superposition states are said to be entangled. When a player places a piece such that the pieces in superposition states form a cycle, the opponent is permitted to choose a collapse. There are two possible choices for the collapse and all the superposition states that are part of the cycle attain appropriate classical states as soon as the opponent makes the choice (Figure 2). Apart from the pieces in the cycle, there could be other pieces that share one superposition piece with some pieces in the cycle. These pieces also get the appropriate value on the collapse of the pieces in the cycle. After initiating the collapse, the opponent also gets to place pieces as usual. These concepts are illustrated in Figure 3.

The motivation is two-fold. The addition of quantum moves adds an element of uncertainty to the game mechanics and thus makes the game more interesting. This is important because it is well known that there exist optimal gameplay strategies such that the game is bound to end in a draw if both players adhere to these strategies. The other motivation is to utilize gameplay as a tool to illustrate the concepts of quantum mechanics to students that are otherwise quite counter-intuitive and hard to comprehend. It is envisaged that playing QTF would make this task relatively simpler.

The rest of the paper is organized as follows. In section 1 (Introduction), the CTF game and the applicable moves within the framework of the game are described. Also, the detail of the QTF and quantum moves is given. Some illustrations of gameplay are given in this section for the reader's understanding. In section 3, concluding remarks are made and future scope is also discussed.

The board is set up. QTF uses novel quantum moves. Each piece can be played as a superposition of two classical moves, called the quantum move. Some legal quantum moves are allowed. The counter-intuitive principles of quantum superposition and collapse are utilized to design new quantum moves for the QTF. QTF has two players. To develop a basic understanding in the reader's mind, the rules and strategies are described in detail below (version 1: QM1 and version 2: QM2).

The players may choose from the following options.

A quantum move that places a superposition of pieces in different squares as long as they are not occupied by any classical piece. The two quantum moves that can be chosen by the players during gameplay in QTF are as follows. They are designated as QM1 and QM2.

Unitary Matrix

The unitary matrix that is applicable for the quantum move is the Hadamard unitary matrix that will put the cells under consideration in equal superposition of $\frac{1}{2}$ and $\frac{1}{2}$.

2.2.1 Version 1

QM1: Out of the two superposed pieces produced in this move, one remains at its current position and the other is placed at some adjacent position according to the pathways provided on the board. The superposed pieces of player X, produced through move 3, are designated as X_{31}* and X_{32}*.

2.2.2 Version 2

QM2: The two superposed pieces are placed in two adjacent squares. Again, the super-positioned pieces of player X, produced through move 3, are designated as X_{31}* and X_{32}*.

Only QM1 and QM2 as above are permitted. There are no classical moves.

(i) The two superposed classical pieces are moved to any two available adjacent positions.

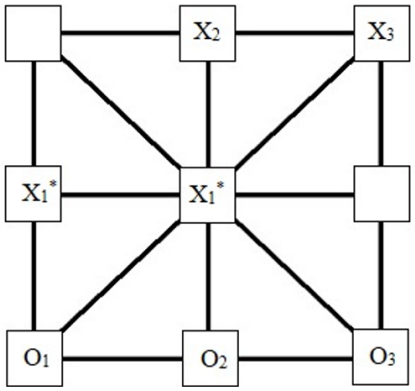

Fig 2. The game board for Tant-Fant depicting QM2

(ii) One piece is moved to an adjacent position and one stays in its position.

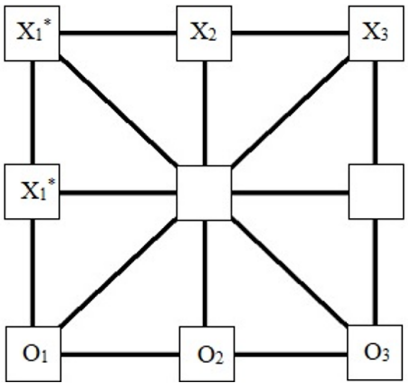

Fig 3. The game board for Tant-Fant depicting QM1

(iii) The players may create cyclic entanglement. The player who creates the cyclic entanglement does not get to choose the collapse. The opponent gets to choose the collapse (Figure 4).

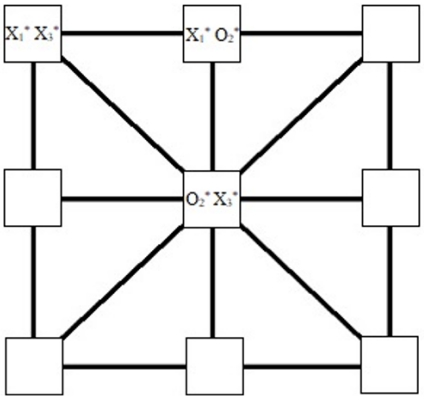

Fig 4. The game board for Tant-Fant depicting cyclic entanglement

2.3 Examples of Gameplay

2.3.1 Depiction of QM1

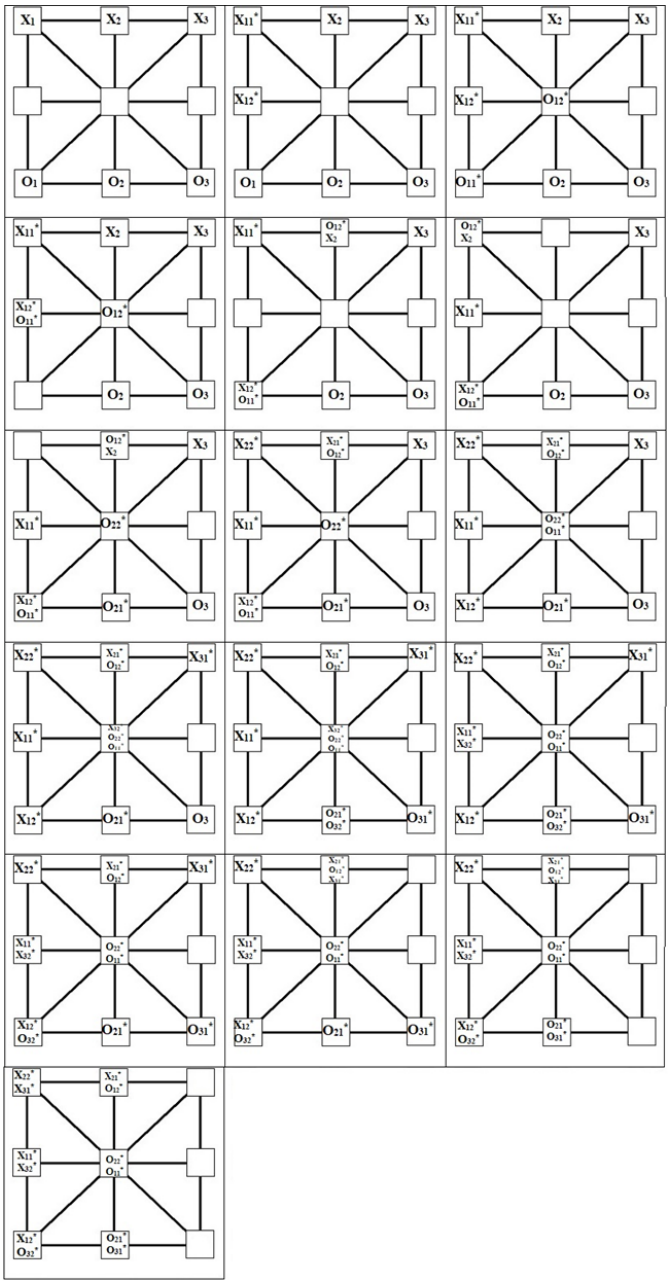

Fig 5. The game board for Tant-Fant depicting QM1

2.3.2 Depiction of QM2

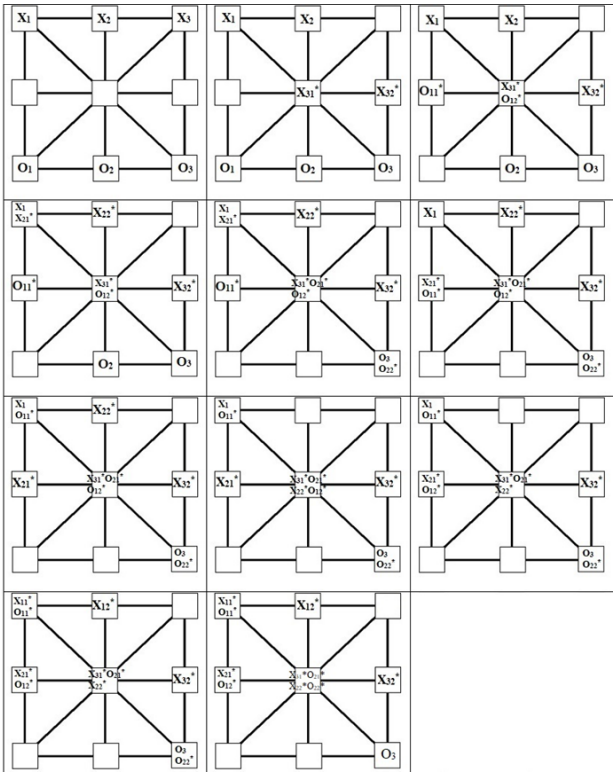

Fig 6. The game board for Tant-Fant depicting QM2

3 Results and Discussion

This study contains the first-ever quantization of Tant-Fant, so no existing literature is available to cite or develop a research gap. Tant-Fant is a traditional Indian board game that originated in Bengal. The game board and moves are discussed in depth to help the reader obtain a basic grasp of the game. The traditional form of the game aims to obtain three pieces lined in a row- horizontally, vertically, or diagonally- dubbed a 'three in a row.' The 'three in a row' cannot be achieved on either player's home row. In another variant of the game, the challenge is to get the 'three in a row' just diagonally. Tant-Fant can be played by drawing the board on paper, on a physical board, or over the internet. Quantum computers are finding major and novel applications in every sphere of civilization. Many games, such as Chess, Tic Tac Toe, Chinese GO, and others, already have their classical versions turned into quantum versions. The quantization of a game has various advantages. Here are a few examples: (a) The quantized version of the game employs fewer strategies than the classical version, and (b) it may discover novel, previously unknown strategies that may eventually aid in resolving the game's problems. This research also illustrates gameplay using quantum moves. The inclusion of quantum moves allows a variety of new game possibilities.

Figure 5 depicts the use of QM1, in fifteen steps the game ends. The X plays the last move and therefore O chooses the collapse. Thus, O is the first winner and gets 1 point, while X is the second winner and gets $\frac{1}{2}$ point (Figure 7).

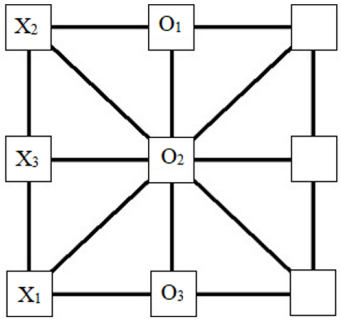

Fig 7. The game board for Tant-Fant depicting QM2 (post-collapse)

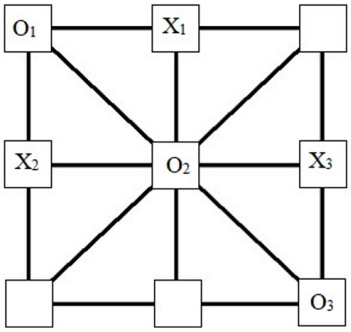

Fig 8. The game board for Tant-Fant depicting QM2 (post-collapse)

Figure 6 depicts the use of QM2, in ten steps the game ends. O plays the last move, so X gets to choose the collapse. O is the winner (Figure 8).

4 Conclusion

Given that many classical games have already been quantized, quantizing a lost traditional game is an interesting challenge. QTF introduces unique moves by utilizing the counter-intuitive principles of quantum superposition, entanglement, and collapse. The Tant Fant originated in Bengal, India. The original game, known as the classical game, had two players. The work describes the rules and methods for playing Tant-Fant in detail to help the reader obtain a basic understanding. The classical game board can be drawn on paper, played on board, or accessed via an online reference. The objective of the classical version is to place three pieces in a row termed a 'three-in-a-row' either horizontally, vertically, or diagonally but not on the players' starting position, also known as the home row. A diagonal 'three-in-a-row' must be constructed in another version. The QTF allows players to select one of two quantum moves. QM1 and QM2 are both equivalents to placing a superposition of pieces in multiple squares.

Exploring the optimal play strategy for the two variants of the QTF presented in this article will be an exciting endeavor in the future. It will also be a wonderful feat to investigate the magnitude of the first mover advantage in both versions of the games presented. The analysis performed here utilizing the quantum mechanical principles of superposition, entanglement, and collapse may also be used to help students grasp the ideas of quantum mechanics.

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