Abstract

Game theory is an eminently interesting and flourishing field of study, wherein many situations of conflicts can be efficiently examined and resolved. With the advent of quantum information and computation, the quest to analyse classical game theory in quantum realm received significant interest not only to investigate the foundational aspects of quantum theory but also to inspect conditions where quantum strategies can be beneficial in comparison to classical strategies. The central idea to study and analyse quantum strategies as opposed to classical strategies is to achieve a better payoff or reward well within the settings of a game. The advantages using quantum strategies in a game theoretic framework are mainly attributed to quantum entanglement and nonlocal correlations present in the shared quantum resource. In fact, Bell and Bell-type inequalities- whose violation confirms the presence of nonlocal correlations in a quantum system- have a very strong connection with game theory. The basic framework of the Bell inequality based on locality and realism can be formulated in the game-theoretic realm using the CHSH (Clauser-Horne-Simony-Holt) game. Further the element of incompleteness, present in quantum mechanics and reflected in assumptions of Bell's inequality, is nicely portrayed as games with partial information; also known as Bayesian games. Moreover, quantum game theory also finds its application in analysing security, algorithms, quantum key distribution, and quantum communication protocols by representing these concepts as games between different players.

The Thesis readdresses the role of entanglement and nonlocality in quantum information and computation using different perspectives of quantum game theory. In the initial part, the Thesis addresses and analyses the representation of quantum cryptographic protocols as a game. The Thesis further investigates a multi-party Vaidman-type game using partially entangled states and establishes its connection with quantum secret sharing with the analysis leading to the proposal of an efficient information sharing protocol. In the latter part of the Thesis, Bell-CHSH type inequalities are mathematically represented as Bayesian games to discuss combination of common interest, and common and conflicting interest games. The dissertation aims to study different entangled systems including maximally, non-maximally, and mixed entangled states using interesting aspects of quantum game theory with the aid of different representations. These representations highlight the importance of quantum as well as classical strategies under various conditions, rules, and settings of a game. Furthermore, such analysis provides a better insight on the role of entanglement and nonlocality in quantum information processing and computation, as a whole.

In order to analyse the security of Ping-Pong protocol, which is an asymptotically secure quantum key distribution and a quantum quasi-secure direct communication protocol, we represent and study the protocol in a game-theoretic framework. For this, we demonstrate the evaluation of Nash equilibriums of the game depending on the parameters involved, encoding strategies of the sender, and eavesdropping strategies of an eavesdropper. We further extend out study to another quantum secure direct communication protocol, i.e., LM05 protocol. Our analysis results into establishing a comparison between two protocols from the point of view of a generic two-way key distribution game with or without entanglement. The detailed study provides interesting insights in terms of the security and payoffs of different stakeholders in the protocol. We also extend our investigation for the use of three-qubit maximally and non-maximally entangled states as resources for the three-party Ping-Pong protocol. Our results interestingly indicate that a set of non-orthogonal and non-maximally entangled three-qubit states are more useful for the PP protocol as compared to three-qubit maximally entangled GHZ states. Moreover, we also demonstrate an increased security and enhanced qubit efficiency for the use of non-maximally

entangled non-orthogonal set of states as opposed to the use of two separate maximally entangled two-qubit Bell states with orthogonal basis. In addition to the above, we also propose a mixed state sharing protocol to further enhance the security of Ping-Pong protocol.

Considering that one of the major concerns in implementation of quantum computers is the inevitable presence of noise, which destroys correlations present in an entangled system, we further address issues and nuances of decoherence and protection of nonlocal correlations from local noise in the framework of game theory, portraying the two players as noise and weak measurement reversal operations, respectively. In order to effectively understand the moves of players, we evaluate the maximum payoff and Nash equilibrium strategies for different noisy channels. The results thus obtained, enable comparison of two different situations where payoffs of players are defined using the Bell inequality and discord, respectively. The results shed light on the complexity of nonlocal correlations under real conditions in different situations of a protocol and a game.

In addition, the Thesis also involves study of a game proposed by Vaidman, in which a team of three players always wins the game when the players employ quantum strategies while sharing a three-qubit maximally entangled state. Our analysis of Vaidman game involves two different classes of three-qubit entangled states, namely, GHZ class and W class of states. Precisely, we analyse the role of degree of entanglement for Vaidman's game in a setting where the three players share a set of partially entangled three-qubit states. The analysis further allows us to establish a direct correspondence between Vaidman's game and quantum secret sharing. Furthermore, we suggest an application of the game where the rule-maker itself is entangled with the players participating in a game. Such a game can be deployed in facilitated secret sharing between three parties, where one of the players is a facilitator and also controls the secret sharing protocol. For the purpose of practical applications, we also consider the effects of different noises in the proposed game set-up, and formulate its multi-party extensions using four, five, and six qubit GHZ states.

In the final part of the thesis, we analyse different Bayesian games where payoffs of players have CHSH-dependence on the types of players involved in a two-player game. Considering different combinations of common interest, and conflicting interest coordination and anti-coordination games, we study the effects of sharing an arbitrary two-qubit pure state and different classes of mixed states as quantum resources in those games. We further propose the representation of a special class of the Bell inequality- tilted Bell inequality, as common as well as conflicting interest Bayesian games.

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