title: Economic Applications of Quantum Information Processing

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abstract:

The advent of quantum mechanics has brought home curiously counter-intuitive though provably-correct understanding of how physical systems process information. These properties include non-local existence of entangled physical systems and the inability to replicate an unknown quantum system. The quantum-information community has applied these strange quantum mechanical phenomena in designing a remarkable handful of algorithms with computational advantages over their classical counterparts [Shor '94] [Grover '97]. These quantum phenomena can improve data-communication rates over noisy channels [Holevo'98], establish secure distribution of cryptographic keys [Bennett '84], and create a plethora of other computing, sensing, communication, and security applications.

Economic mechanisms and game-theoretic modeling of the interplay of trust, incentives, strategies and payoffs in such mechanisms often involve the reciprocity of economic motivations and available information for each participant. The unique properties of quantum information provide new economic mechanisms in several specialized contexts, such as secure authentication, information hiding, digital property rights and complex auction scenarios. Other examples of quantum economic mechanisms include encouraging cooperation in the context of the prisoner's dilemma [Eisert '99, Du '02], coordination [Huberman '03, Mura '03], the minority game [Flitney '07] and public goods provisioning [Chen '02]. In particular, a quantum public-goods mechanism significantly reduces the free-rider problem without a third-party enforcer or repeated interactions, both in theory and practice [Chen '06].

To date, economic applications of quantum information have received relatively little attention in spite of their being much easier to implement than the computational applications that have received the bulk of research. In this paper we survey numerous avenues for economics applications of quantum information, where quantum bits replace classical bits in representating and processing information. These new economic applications provide security and privacy advantages over their classical counterparts, but require rigorous understanding of the new incentive structures, strategies, equilibria, and cheating mechanisms that are introduced by using quantum information. As a specific example, we elaborate on our recent findings on a quantum protocol for auctions, where the bids are encoded into quantum states and a distributed adiabatic search reveals the payoff-maximizing allocation to the auctioneer. The use of quantum information preserves the privacy of all the losing bidders by destroying all information available to the auctioneer apart from the winning allocation [Hogg '07] [Guha '08]. By introducing entanglement between bid states, participants can arrange for correlations among their bids with the assurance that this entanglement will not be observable by others. We show that even a few qubits give key demonstrable advantages to a quantum auction over existing classical approaches. These advantages include an exponential advantage in the resources needed to represent combinatorial and correlated bids and preserving privacy of losing bidders. The method applies to a variety of auction types, e.g., first or second price, and for auctions involving either a single item or bundled items (combinatorial auctions). We discuss potential avenues for future research on a variety of applications of quantum information to economics. These applications are good candidates for improved algorithms and relatively easier actual implementations with currently available technology.

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