Research Statement

Faisal Shah Khan, Ph.D.

Quantum algorithms exploit entanglement — a fundamental form of quantum correlation — to achieve computational advantages over classical methods; I study how related quantum correlations, including entanglement, discord, and order-dependent effects, behave as quantum systems interact with classical processes, shaping inference, coordination, and learning across finance, protocol security, and AI.

Quantum Correlations in Finance and Trading

Financial systems rely on correlations that are typically modeled as classical in origin. I examine how inference and strategic behavior change if market-relevant information is generated through quantum processes, a modeling question motivated by the gradual integration of quantum communication and computation into existing information systems.

Focusing on entanglement, quantum discord, and order-dependent effects induced by measurement, I analyze how non-classical correlation structures manifest in trading contexts. Order dependence introduces directionality and information flow, linking naturally to concepts such as Granger causation in time-series analysis.

Because such correlations are not directly observable after measurement, they must be inferred from post-measurement data. The emphasis is therefore on detecting latent non-classical structure that yields predictive or strategic advantage, rather than on formal certification of quantumness. This work includes the development of a quantum correlation index for diagnosing non-classical dependence in networked systems, in collaboration with the QLAB team at the University of Maryland.

Security of Quantum Protocols

Many quantum protocols rely on fixed measurement and reset procedures to produce reliable classical outcomes. In my work, this structural issue first became apparent in the Eisert–Wilkens–Lewenstein (EWL) protocol, where a publicly known disentangling operation is required to recover the classical limit. These same design choices, however, can introduce blind spots that allow correlations to influence global behavior without leaving detectable local signatures.

I examine structural vulnerabilities that arise from publicly known measurement procedures, reset operations, and quantum-to-classical interfaces. In such settings, correlations can alter joint outcomes while remaining locally indistinguishable, revealing forms of influence that are globally effective yet locally undetectable.

The aim is not merely to catalog exploits, but to understand how protocol architecture itself can render certain effects unattributable. By treating these vulnerabilities as structural consequences of protocol design rather than incidental weaknesses, this work seeks to inform principles for constructing quantum protocols whose failure modes are explicit rather than implicit. This work is conducted in collaboration with colleagues at the University of Dubai and Khalifa University.

Quantum Correlations as Memory Resources

In systems with imperfect recall, coordination can fail. I study how quantum correlations can compensate for imperfect recall, enabling coordinated or equilibrium behavior despite restricted access to past information. In such settings, quantum discord can substitute for strategic memory: coordination can be restored using only local measurements on appropriately correlated quantum states.

This result establishes discord as a minimal sufficient resource for equilibrium restoration under memory constraints, providing a quantum analogue to classical results such as Kuhn's theorem and extending equilibrium analysis beyond purely classical information structures.

This perspective also connects to machine learning models in which memory is represented through finite internal states. Viewing correlation structure as a resource suggests alternative mechanisms for encoding temporal dependence in neural architectures, particularly in settings where explicit memory is constrained.