Wells Fargo Challenge: Quantum Evolution with Measurement and Reset

A Challenge with Real-World Relevance in Finance

Introduction

In the financial industry—particularly in areas such as algorithmic trading, real-time risk management, optimal order execution, and dynamic stochastic optimization—the ability to model and predict complex, non-linear stochastic processes is of critical importance. In many of these settings, agents interact with a partially observable system: they observe noisy or incomplete signals from the market and take actions based on these observations. These actions, in turn, affect the underlying latent state of the system, creating a feedback loop between observation and system evolution.

This interaction paradigm bears a striking resemblance to the dynamics of open quantum systems, where the act of measurement on a subsystem leads to the collapse of its state, and—due to entanglement—alters the state of the larger system. Just as a quantum measurement provides partial information and simultaneously perturbs the quantum system, financial agents gather information from the market (e.g., price ticks, order book movements) and their subsequent actions (e.g., placing orders) modify the system itself. This analogy offers a compelling metaphor for thinking about financial systems in terms of quantum channels: evolving probabilistic structures where observation, memory, and intervention are deeply intertwined.

This challenge simulates a class of quantum protocols where measurement outcomes influence future evolution, similar to how new market data or customer behavior influences financial models in real time. Developing accurate and efficient methods to reconstruct or simulate final system states based on partial measurements is an essential capability in applying quantum computing to financial workflows.

While early approaches in quantum computing have focused on static problems like ground-state estimation or optimization, this challenge highlights a dynamic and realistic scenario, pushing participants to think about quantum workflows that evolve step by step, influenced by measurements and resets—just like real-world systems.

Problem Statement: Quantum Evolution with Measurement and Reset

System Setup

You are given a unitary operator U acting on three qubits, where U entangles all three qubits. The system evolves through repeated applications of U, with intermediate measurements and resets on the third qubit.

- The initial state of the first two qubits is a known state $|x_0\rangle$.
- The third qubit starts in the ground state $|0\rangle$.
- The unitary operator $U \in \mathbb{C}^{8\times 8}$ is applied to all three qubits.
- After each application of U, the third qubit is measured in the computational basis. The result $y_i \in \{0,1\}$ is recorded.
- The third qubit is then reset to $|0\rangle$, and the process is repeated n times.
- The final state of the first two qubits after n rounds is $|x_n\rangle$, which depends on the original state $|x_0\rangle$, the unitary U, and the observed measurement outcomes $y_1, \dots, y_n$.

Your Task

Given:

- The initial state $|x_0\rangle$,
- The unitary operator U,
- The number of iterations n,
- The sequence of binary outcomes $y_1, \dots, y_n$,

Construct a quantum circuit that prepares the corresponding final state $|x_n\rangle$ on the first two qubits.

This circuit must reproduce the conditional evolution resulting from the measurement-reset loop, using only the given inputs and without performing actual intermediate measurements.