G2Q AND ALTAIR ENABLE HYBRID CLASSICAL-QUANTUM WORKFLOWS FOR INDUSTRIAL-SCALE PROBLEMS

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Executive Summary

Altair and G2Q, a quantum-ready software company that develops cutting-edge hybrid classical-quantum optimization algorithms, have partnered to develop a feasible, efficient platform for hybrid classical-quantum workloads and perform a fraud-detection proof of concept (POC).

Altair® HPCWorks® is a high-performance computing (HPC) and cloud orchestration platform with scheduling features and integration capabilities that make it a robust, flexible base for hybrid classical-quantum workloads, both real and simulated.

Altair® RapidMiner® is a data analytics and AI platform with data modeling and optimization capabilities that guide effective utilization of computational resources within the larger operational workflow.

Within this project, the Altair® Accelerator™ and Altair® FlowTracer™ components of the Altair HPCWorks platform were adapted to efficiently run a novel hybrid quantum-classical workflow to detect fraudulent credit card transactions and significantly reduce the number of false positives without a precipitous drop in the number of actual fraudulent transactions detected.

The results strongly suggest that quantum computing can be efficiently integrated with HPC to begin solving industrial-scale problems that can't be optimally addressed with classical computation alone, significantly accelerating critical science, engineering, and financial applications.

Compelling Motivation

The costs associated with financial fraud of all types are unsustainably high and growing.

- Consumers lost a total of $27.2 billion in 2024, up 19% over 2023.
- Credit card fraud worldwide is expected to reach $43 billion by 2026.
- The amount of money laundered globally in one year is estimated to be 2-5% of global GDP, or between $800 billion and $2 trillion.
- Total worldwide fraud schemes led to losses of $486 billion in 2023.
- Top 2024 fraud types included investment fraud ($6.5+ billion), business email compromise ($2.7+ billion), tech support fraud ($1.4+ billion), personal data breach ($1.4+ billion), and credit card and check fraud (nearly $200 million).

Classical machine learning and advanced AI approaches are used today to combat fraud. Nevertheless, as shown in the above statistics, fraudulent activity remains a substantial problem for global financial systems.

Attacking Fraud Detection with Quantum Computing

Financial institutions and analysts have found classical approaches problematic because although a high number of fraudulent transactions are detected, they're embedded within a larger set of valid transactions, called false positives. The process of distinguishing true fraud from valid transactions carries significant costs of its own.

There is wide agreement about the underlying reason for this poor performance: Classical computers have inherent limitations when data patterns are complex, hard to detect, or tend to change, or when fraudulent transaction data is very similar to genuine data. This is the case in financial fraud of all types.

Our hybrid quantum-classical platform plays an essential role in overcoming these limitations by efficiently integrating classical and quantum workflows. This is accomplished by components including:

- Employing industrial-scale variational quantum optimization and machine learning algorithms that generate coherent, highly parallelizable classical and quantum tasks; these algorithms have been tuned to run efficiently and effectively on several quantum hardware architectures
- HPC-class infrastructure that can efficiently and precisely execute large sets of related classical and quantum computing tasks, in the right order and at the right time, and track resources consumed during execution
- Management of variability in quantum hardware and noise via a novel compilation technique that reduces noise by automatically adapting execution to the desired quantum topology while managing broken qubits and connections

Empowering Hybrid Classical-Quantum Workflows

Scheduling and Workload Orchestration

- Accelerator efficiently orchestrates hybrid classical-quantum workloads, seamlessly coordinating classical HPC operations with quantum processing units (QPUs) as well as tracking and reporting resources consumed during execution.
- Accelerator invokes QPU jobs or simulators via API or command line as part of the larger workflow.
- FlowTracer efficiently implements the workflow as a series of related classical and quantum tasks, efficiently feeding them to Accelerator in the right order and at the right time.

Hybrid Machine Learning/Quantum Optimization Algorithm

G2Q's algorithm employs important techniques that leverage classical and quantum computational resources in a way that emphasizes their respective strengths and mitigates their weaknesses:

- A quantum distributed optimizer finds meaningful solutions to industrial-scale problems by using circuit approximations that can be parallelized on classical and quantum machines, enabling it to scale problems of virtually any size.
- Classical machine learning is employed to yield highly optimized quantum circuits that reduce the impact of quantum uncertainty and noise, with no need for expensive, time-consuming parameter optimization techniques.
- Machine learning modules are built with embedded quantum layers and nodes to speed up training and improve results.
- Characteristics of the real-world problem being addressed are identified and mapped to an effective, general-purpose framework that can be tuned to the quantum hardware being used.

G2Q implements the workflow as a FlowTracer flow consisting of specific data preparation, configuration, and processing tasks. FlowTracer can substantially reduce computation time by efficiently managing different highly parallelizable quantum and classical workloads as well as compatibility issues.

Data Analytics and AI

Not all use cases have the same costs associated with fraud events or false positives. Additionally, different quantum hardware executes the workload at varying efficiencies, so it's important to evaluate the impact of the hybrid quantum-classical workflow in context on a case-by-case basis.

- Altair RapidMiner develops a data model of the overall business process — using operational costs provided by the end user, knowledge of algorithm structure, and computational costs — to analyze and guide algorithm design and tuning.
- Altair HPCWorks provides confirmatory runtime computational execution data to help validate the generated AI model.

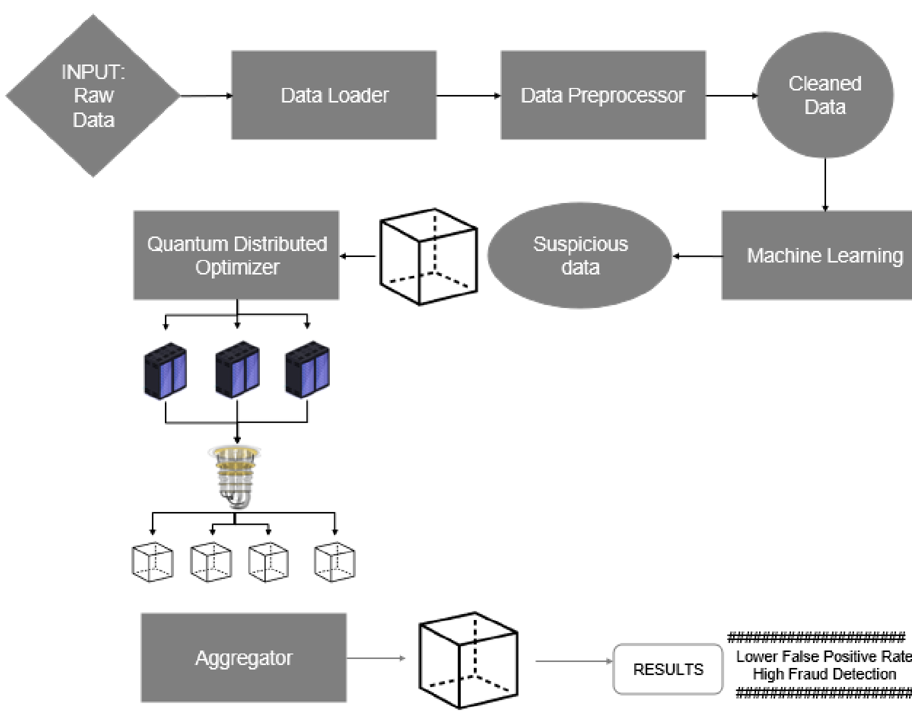
Monitoring, Reporting, and Workflow Visibility

- Altair HPCWorks provides the same confirmatory runtime computational execution data to give users visibility into actual workload behavior and resource usage, which is necessary to ensure consistent performance and cost metrics.

Fraud Detection Use Case

A fraud detection POC was performed on 56,864 real credit card transactions and the following key objectives were demonstrated**:**

- **Efficient management of quantum and classical workloads:** 5,623 workloads were created and efficiently distributed on available quantum and classical machines.
- **Meaningful solutions to problems much larger than the available quantum computer:** Feasible, optimized solutions with 5,623 variables were obtained using only a 20-qubit IQM Resonance quantum computer.
- **Parallelization of computation on multiple quantum computers while maintaining a feasible solution:** Workloads were efficiently distributed on multiple quantum computers without compromising solution quality.
- **Efficient machine-learning integration and optimization tuned to meet business objectives, balancing fraud detection rate and false-positive detection rate:** Integrating machine learning with optimization resulted in obtaining high fraud-detection rates and low false-positive rates.

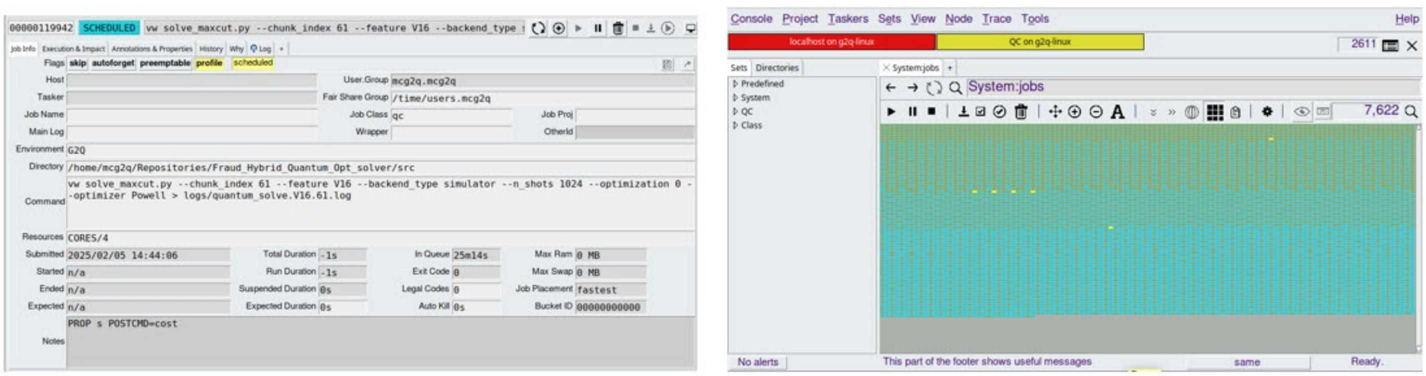


Hybrid Quantum-Classical Platform Workflow

Performance Indicators

The algorithm and workflows were executed on an IQM Resonance 20-qubit quantum computer and Altair's Sunnyvale/Santa Clara compute farm.

Connections were established via APIs, and jobs and workloads were created, managed, and monitored in real time and in batch mode on FlowTracer. All process logs could be downloaded, stored, and accessed for analysis.



The Interface Used to Manage the Hybrid Classical-Quantum Jobs and Workflows

After the job queue successfully executed, the following fraud detection results were achieved:

	Hybrid Quantum Platform	SOTA Machine Learning Algorithm
Fraud detection rate	89%	78%
False positive rate	2.5%	0.1%
False positive reduction due to high true positive detection	77%	N/A*

Although the state-of-the-art (SOTA) machine learning algorithm achieved a good reduction in false positives, the true-fraud capture rate was too high. By using the hybrid quantum platform, the fraud detection rate increased significantly and the false positive rate was controlled. Using the optimizer, false positives due to a high recall rate were reduced by 77%. **For this POC, since the dataset is small, there were not enough false positives arising from the SOTA machine learning algorithm to run through the quantum distributed optimizer. However, even a 0.1% false positive rate could be valuable to send to the optimizer.*

The results indicate that it's possible to use noisy intermediate-scale quantum (NISQ) computers for industrial-scale problems without compromising the quality of the solution, and in certain instances quality may increase. In terms of speedup, the current POC could not be run in time to verify the execution of multiple circuits on a single quantum job, so performance in terms of execution time could not verified.

Specific Advantages of Quantum-Based Fraud Detection

- Increases fraud detection rate and reduces false positives compared to a machine-learning solution
- Reduces operational and frictional costs associated with managing false positives

General Advantages of a Managed Hybrid Workload

- Utilizes operational and computational experience to optimize usage of hybrid classical-quantum workloads for overall business processes
- Provides data-driven flexibility in the face of changing quantum computational capabilities and costs, both in the algorithm and in workflow management
- Enables continued process improvement as quantum capabilities mature
- Provides a platform for accelerating critical science, engineering, and financial applications that cannot be easily addressed using only classical resources

Conclusion

Integrating quantum computing with classical HPC enables us to begin solving industrial-scale problems that classical computing alone can't handle. Because quantum computing — unlike classical computing — excels when data patterns are complex, hard to detect, or tend to change, it complements HPC and has the potential to significantly accelerate problem-solving in science, engineering, and finance.

Altair HPCWorks efficiently supports hybrid classical-quantum programs by leveraging proven scheduling, reporting, and workflow orchestration capabilities and adapting them for quantum computing. By combining these features with the powerful G2Q hybrid classical-quantum optimization algorithmic framework, Altair HPCWorks supports verifiable, scalable, optimized execution of quantum-accelerated workloads on HPC and quantum infrastructures.

The G2Q-Altair platform gives users a unique combination of infrastructure and quantum-ready algorithms that yields meaningful solutions and takes advantage of small NISQ quantum computers to reduce the amount of classical computation required, potentially saving time, money, and energy. Quantum computers use substantially less time and computational energy resources than classical HPC for the complex problems they're designed to solve.

Quantum computing has the potential to dramatically improve energy efficiency in real-world applications including climate modeling, material science, and grid optimization — in which technologies including AI and the Internet of Things (IoT) help to efficiently manage supply and demand in complex electrical power grids, reducing energy waste and streamlining power distribution. Quantum computing can also be used to design efficient, cost-effective energy storage solutions and optimize manufacturing processes and supply chains to reduce energy waste and minimize costs.