Quantum Algorithms For Tail Risk In Loan Portfolios

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STEVENS INSTITUTE OF TECHNOLOGY 1870 School of Business

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NSF

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MOTIVATION AND GOALS

MOTIVATIONS:

While we await large-scale stable quantum computers, it is imperative to develop natively quantum algorithms and investigate the scope of these algorithms. We propose to study quantum advantage within the context of risk estimation in large loan portfolios, and more generally financial Monte Carlo.

GOALS:

Establish feasibility and quantum advantage for computing risk in large portfolios of correlated loans.

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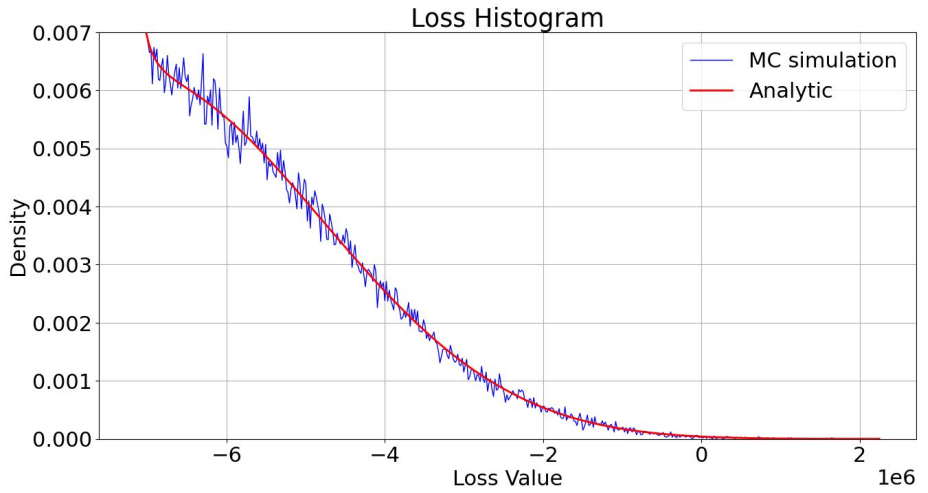
PROGRESS ON TASKS

Task 1 Progress

- **Classical benchmark on lognormal Merton Model.**
- Monte Carlo implemented.
- Fast analytic approximation developed.
- Can solve:
  - VAR.
  - Conditional VAR, CVAR.
  - VAR conditioned on big defaults.



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PROGRESS ON TASKS

Task 2 Progress

- **Developed Quantum Algorithm:**
  - Convert floating point risk calculation to fixed precision (low bit).
  - Reformulated Financial Monte Carlo as Quantum Counting.
  - Use Grover Operator, Phase Estimation and QFFT giving PAC-algorithm for quantum counting (theory + quantum simulation).
  - Benchmark implemented on RPI IBM Quantum System.

ACCOMPLISHMENTS & RESULTS

Method	VAR	and-VAR	or-VAR	CVAR	and-CVAR	or-CVAR
Monte Carlo	[$59K, $72K] 10,000 sec	[$2.43M, $2.47M] 3,000 sec	[$857K, $905K] 1,000 sec	[$534K, $549K] 10,000 sec	[$2.71M, $2.79M] 3,000 sec	[$1.26M, $1.33M] 1,000 sec
Approx Analytic	$68K 1 sec	$2.45M 1 sec	$882K 1 sec	$540K 1 sec	$2.75M 1 sec	$1.30M 1 sec
Quantum (Theory)	XXX 100sec	XXX 55sec	XXX 33sec	XXX 100sec	XXX 55sec	XXX 33sec

Analytic fastest, specialized model.
MC is general but slow.
Quantum algorithm is general and quadratically faster in theory.
Practice: Circuit too deep, can't execute. Fewer loans, less precision → noisy output, useless.

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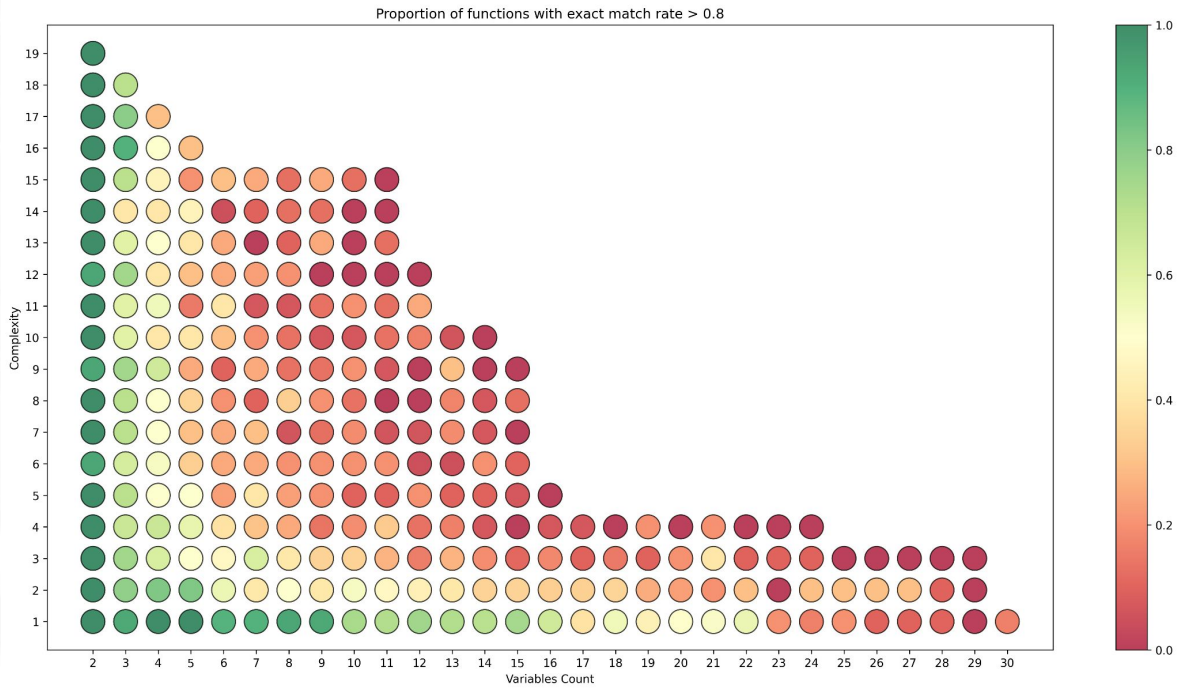
ACCOMPLISHMENTS & RESULTS



Example: 10 loans, 5 bit accuracy: 55 qubits.

Challenges:

- Python-2-Qiskit Compiler
  - Added for-loops
- Quantum bloat
- Hardware capabilities.

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ACCOMPLISHMENTS & RESULTS

- **Quantum Benchmarking - far away from what is needed.**
- **Reformulated Financial MC as Quantum Counting.**
- **Large/deep circuit (counting circuit), many qubits (higher fixed precision)**
  - Theory: quadratic speedup advantage established (general algorithm built).
  - Quantum simulation: results accurate.
  - Quantum computer (**hot off the press):** Doesn't work (implementation), but will work (theory)**.**

Capabilities/Challenges:

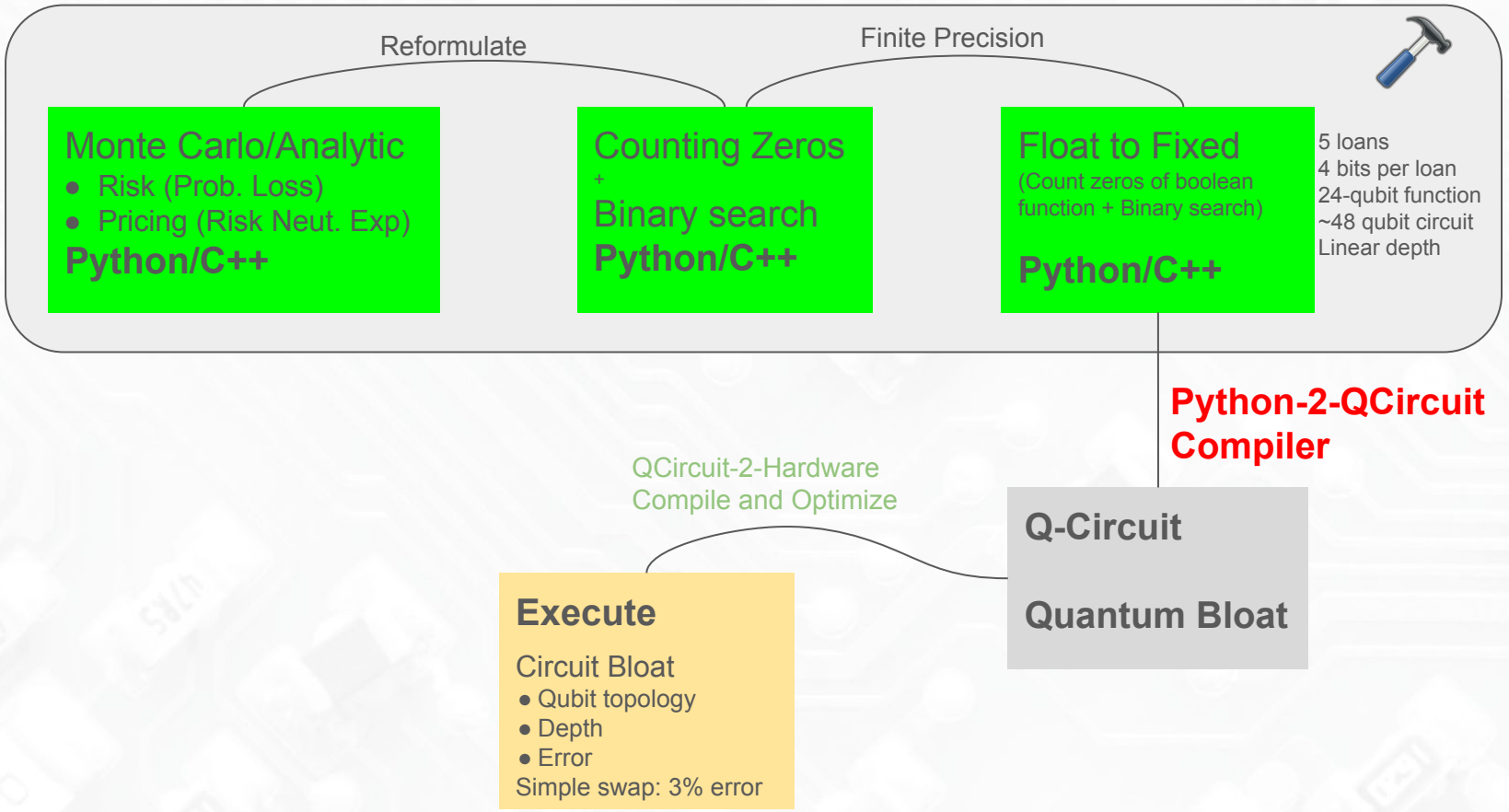
Can apply to any risk estimation (financial, insurance, etc.).

Apply general algorithm to specific application needs python-2-Qcircuit compiler.

More precision needs more qubits. More loans needs more qubits.

Hardware needs to run deep circuits noiselessly.

ACCOMPLISHMENTS & RESULTS



Hammer built

Realizes quadratic speedup
- e.g. 10000 vs 100 cores
- When hardware catches up

Execution:
- Many loans; More precision
  - More qubits
  - More depth
- Noise/instability
  - Not accurate
  - Not viable

Hardware will get there.

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DELIVERABLE COMPLETION

Deliverables for Task 1

- Complete

Deliverables for Task 2

- Complete.
- Understood challenges.
- Working on challenges + full report.

Deliverables for Task 3

- None

PLAN FOR FUTURE MILESTONES

- Building Python-2-Qcircuit compiler: can program in python and run on QC.
- Benchmarking different problems on QC.
- Full report and publication.

RISKS, CHALLENGES, AND ROADBLOCKS

Risks

- QC is a marathon.
- QC algorithms may not work.
- Not enough physical q-bits for real implementation.

Challenges

- Formulate problem in way appropriate for constructing an efficient quantum circuit.

Mitigation Plan

- Important problem.
- Fast classical algorithms important on own right.
- Simulation of QC algorithm.

Roadblocks

- May not find efficient quantum circuit. Need Python-2-Qcircuit compiler.
- Quantum bloat, too few qubits, too deep circuits – noise corrupts results.

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QUESTIONS & DISCUSSION

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