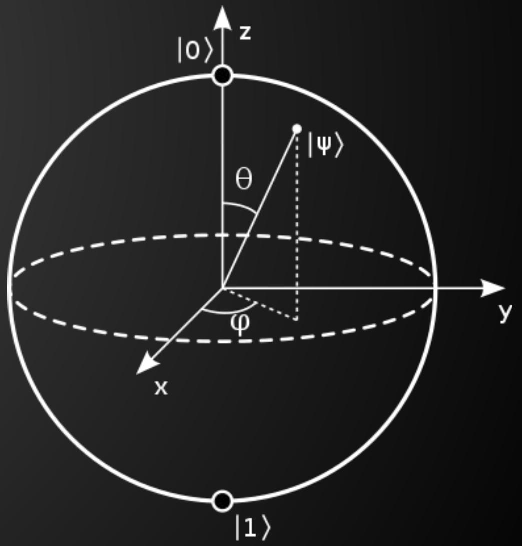
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
School of Professional & Executive Development

Quantum Credit Risk Analysis

Presented by:
Arjun Puppala, Jose Ramon Aleman, Marti Ciurana

Tutor:
Giulio Gasbarri



Outline - Draft

- Introduction
- Problem
  - Description
  - Definition
  - Parameters
- Methods
  - MC (Classical)
  - QAE
    - Grover's Algorithm
    - QFT
  - IQAE
- Results
  - Uncertainty model
    - Loss Distribution
    - Z Distribution
    - Default Probabilities
  - Expected Loss
  - Value at Risk (VaR)
  - Conditional Value at Risk (CVaR)
- Conclusions

Introduction

We introduce and describe an iterative algorithm of the Quantum Amplitude Estimation (QAE), known as the Iterative QAE (IQAE). This is used for estimating credit risk that outperforms Monte Carlo (MC) simulations on traditional computers. We calculate the Economic Capital (EC) required, which is the difference between the Value at Risk (VaR) and the predicted Loss Distribution Value (LDV). The calculation of the EC required is of interest, because it quantifies the amount of capital required to be solvent at a certain level of confidence, making it an important risk statistic. We implement this problem for a realistic LDV and analyze its scaling to a realistic problem size. We present estimates of the overall number of necessary qubits, the expected circuit depth, and how this translates into an expected runtime on future fault-tolerant quantum hardware under acceptable assumptions.

Problem

Description, Definition, and Parameters

Problem Description

We can describe the problem as the simple default risk, that a lender takes on in the chance that a borrower will be unable to make the required payments on their debt obligation. Whenever a lender extends credit to a borrower, there is a chance that the loan amount will not be paid back. The measurement that looks at this probability is the default risk.

The default risk applies to both individuals who borrow money, and companies that issue bonds and due to financial constraints, are not able to make interest payments on those bonds. Whenever a lender extends credit, calculating the default risk of a borrower is crucial as part of its risk management strategy. Whenever an investor is evaluating an investment, determining the financial health

Problem Definition

We analyze the credit risk of a portfolio of

k

assets. The default probability of every asset

k

follows a Gaussian Conditional Independence model, i.e., given a value

z

sampled from a latent random variable

Z

Problem Parameters

The introduced quantum algorithm for estimating the credit at risk, Iterative Quantum Amplitude Estimation (IQAE), does not rely on Quantum Phase Estimation (QPE), and is based on Grover's Algorithm, reducing the required number of qubits and gates needed. We provide a rigorous analysis of IQAE and prove that it achieves a quadratic speedup up to a double-logarithmic factor compared to classical Monte Carlo simulation. We test the algorithm in a two (2) assets portfolio.

Methods

MC, QAE, Grover's Algorithm, QFT, IQAE

Methods

In order to further demonstrate the capabilities of IQAE, we used classical simulations of quantum hardware to show that it can also be applied to speed up the computation of risk measures of a simple two-asset (2) portfolio. Nevertheless, we notice that to achieve quantum advantage in a real-world scenario, the quality of current quantum hardware needs to be improved. Errors arising from the limited coherence time and cross-talk when measuring the states of qubits need to be substantially suppressed. Furthermore, because of this reason, the number of qubits must be increased.

We went on to show how IQAE can be applied to the task of pricing an asset using real quantum hardware. However, the current pace of advances in research directed at improving both quantum hardware and quantum algorithms makes us optimistic that real quantum advantage in risk analysis can be achieved in the

Classical Method: Monte Carlo (MC)

The Monte Carlo (MC) method is a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. The underlying concept is to use randomness to solve problems that might be deterministic in principle. MC predicts a set of outcomes based on an estimated range of values versus a set of fixed input values.

In other words, a MC simulation builds a model of possible results by leveraging a probability distribution, such as a uniform or normal distribution, for any variable that has inherent uncertainty. It recalculates the results over and over, each time using a different set of random numbers between the minimum and maximum values. In a typical MC experiment, this exercise can be repeated thousands of

Quantum Amplitude Estimation (QAE)

QAE is one of the algorithms at the basis of the quantum revolution, it can be understood as a combination of Quantum Phase Estimation (QPE) and Grover Algorithm. It is useful to estimate the VaR, and has the potential to achieve a quadratic speed up for most of the application that are nowadays solved through Monte Carlo (MC) simulations, while these simulations scale with

O

(

1

/

Grover’s Algorithm

This algorithm can speed up an unstructured search problem quadratically.

Suppose you are given a large list of

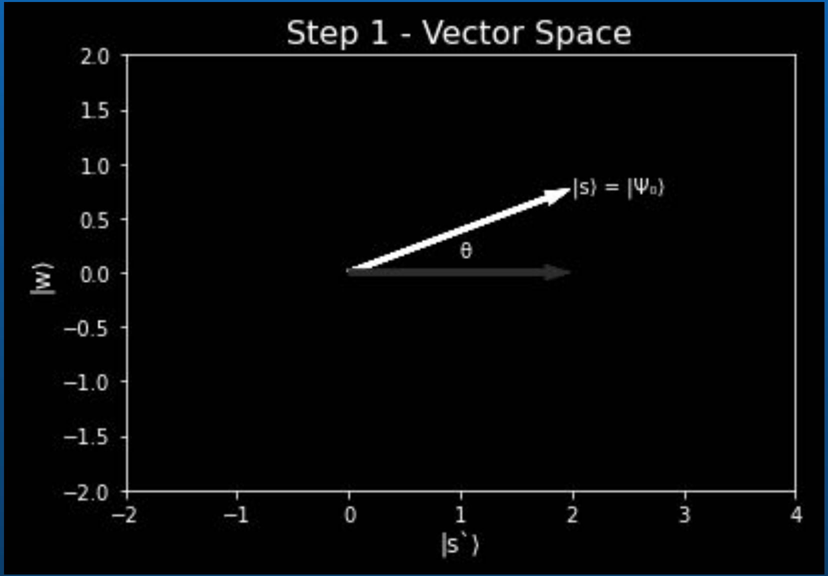
N

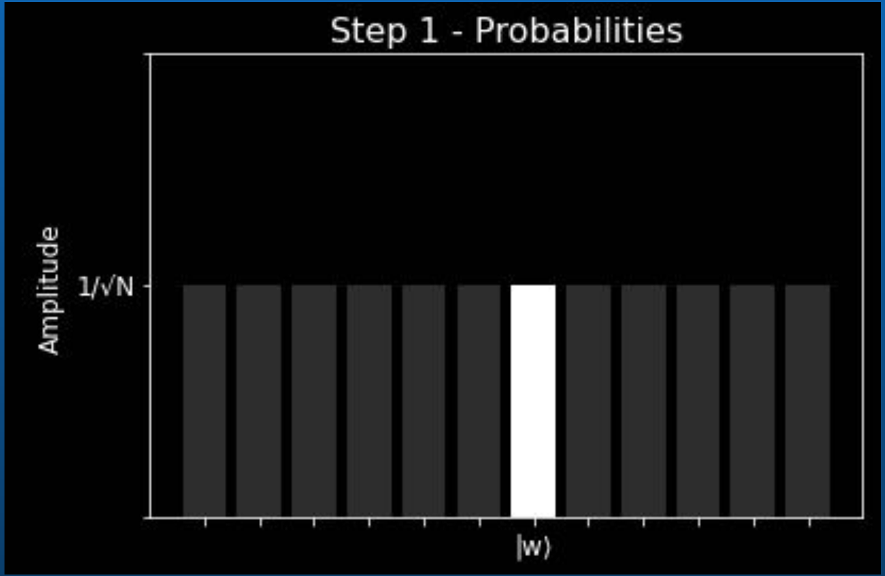
 items. Among these items there is one item with a unique property that we wish to locate; we will call this one the winner

w

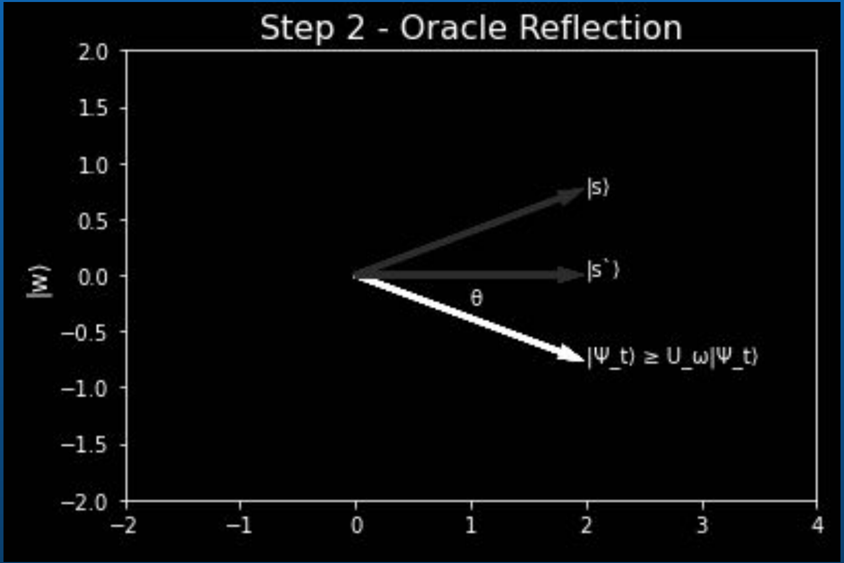
. To find the marked item using classical computation, one would have to check on average

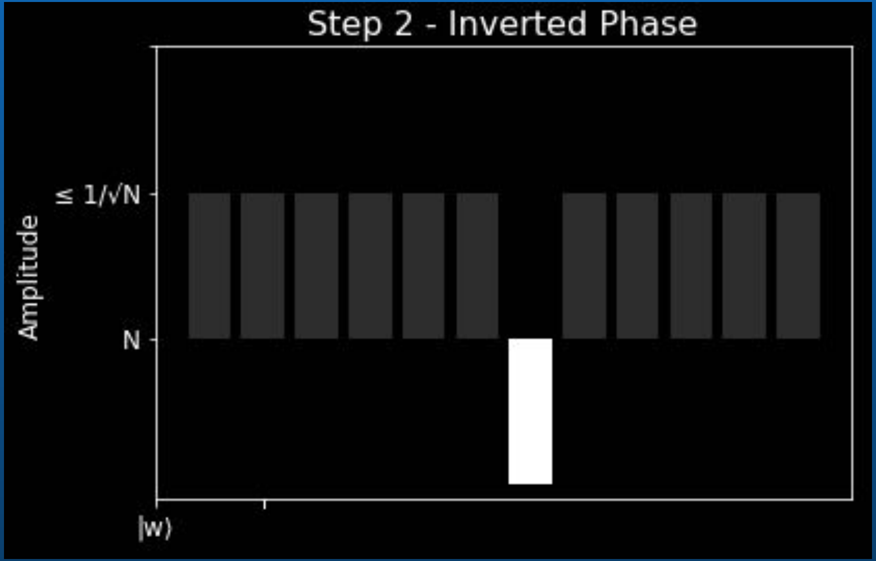
Step 1 - Initialize System



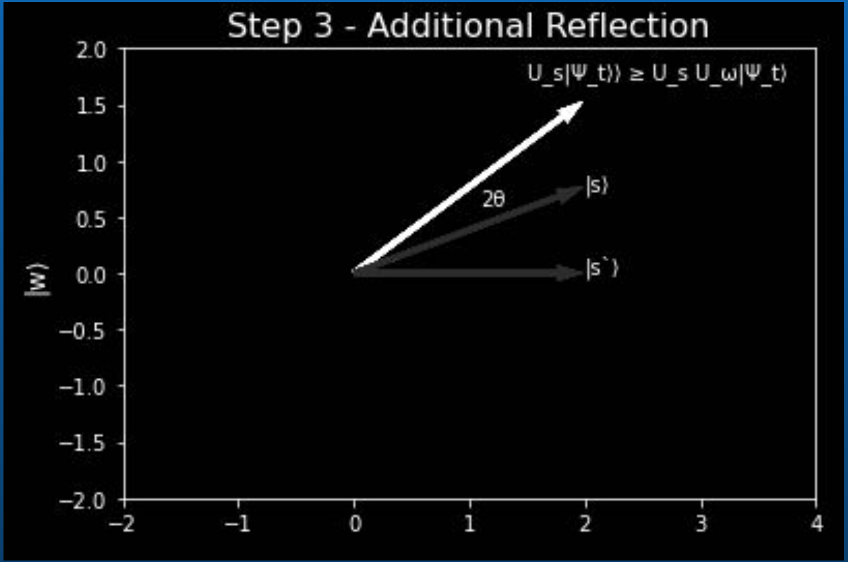


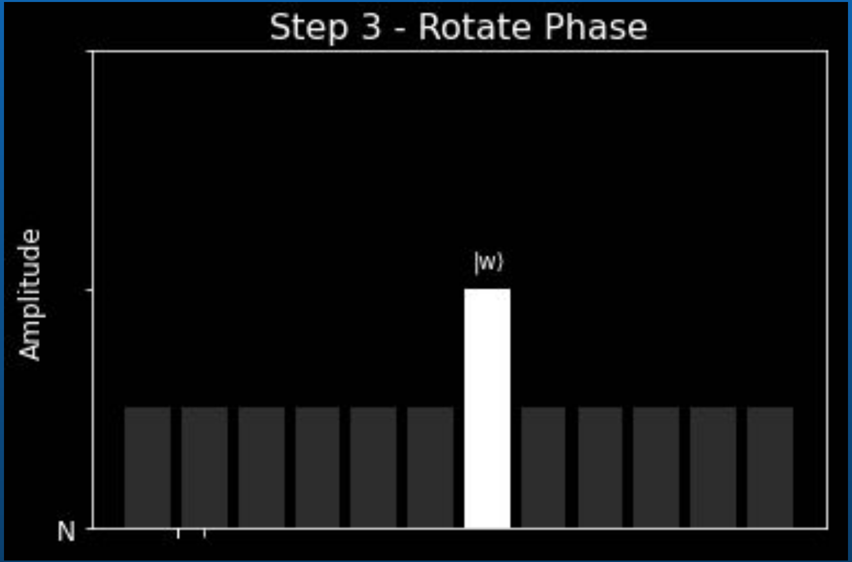
Step 2 - Oracle Reflection and Inverted Phase



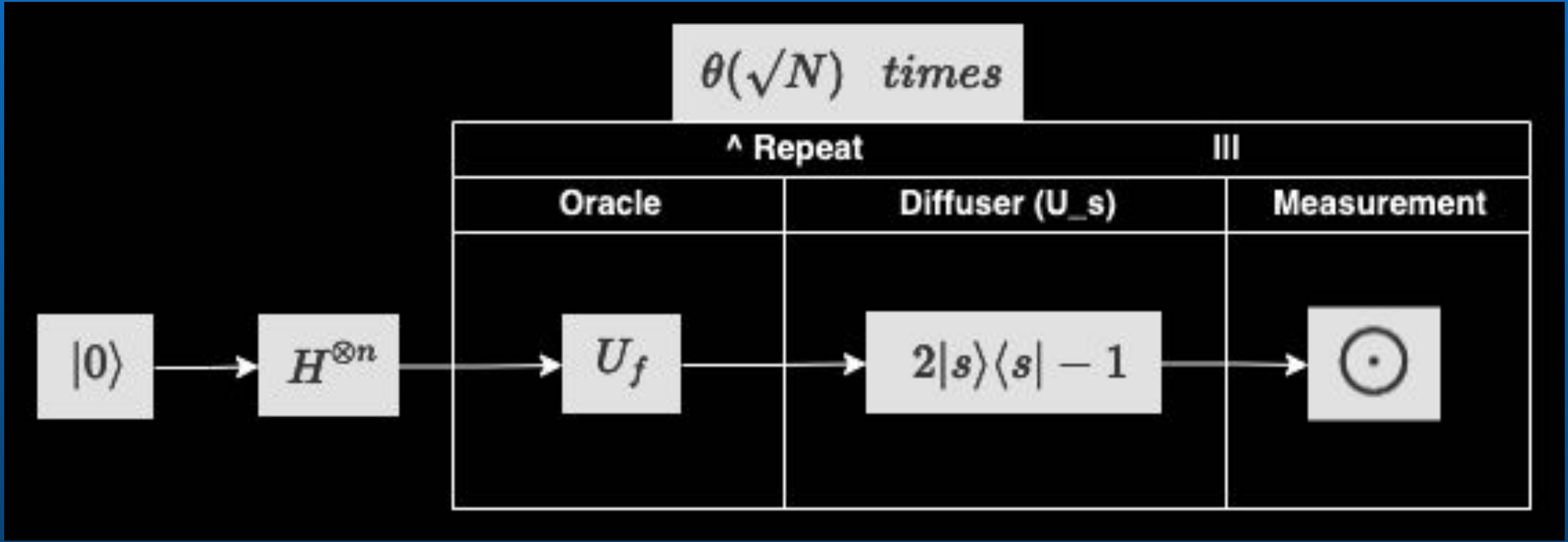


Step 3 - Additional Reflection and Rotate Phase





Grover’s Algorithm Diagram

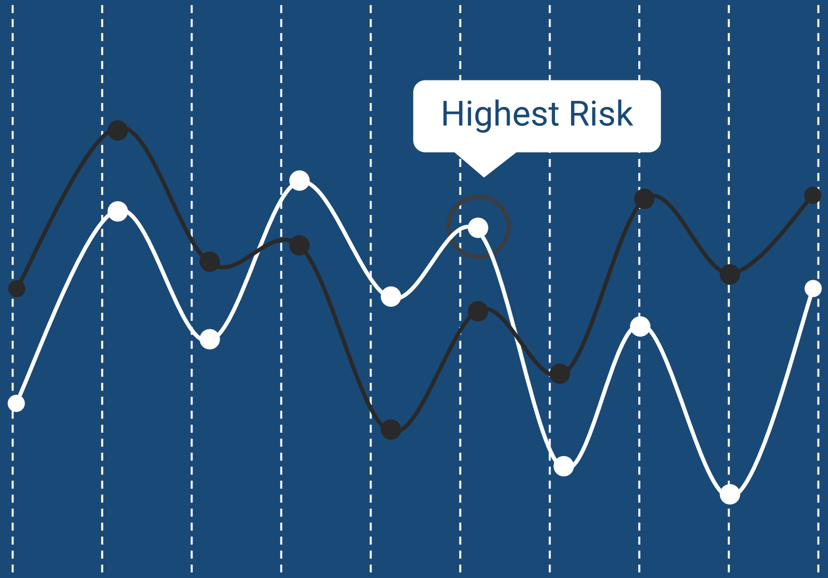


Quantum Fourier Transform (QFT)

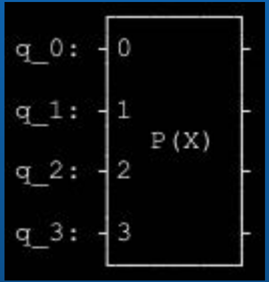
Iterative QAE (IQAE)

Results

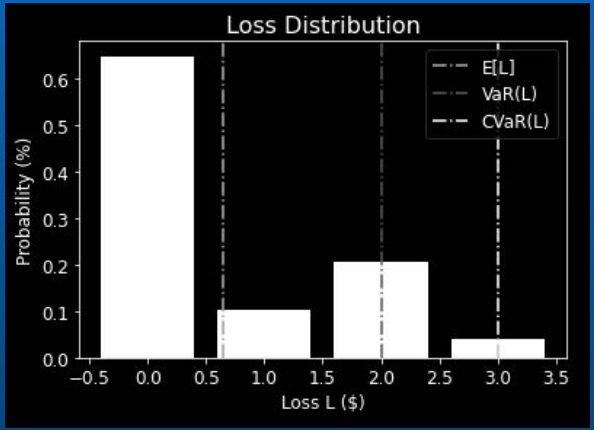
UM, EL, VaR, CVaR

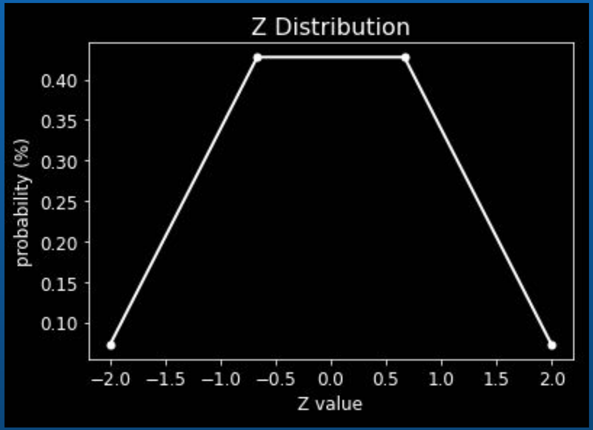


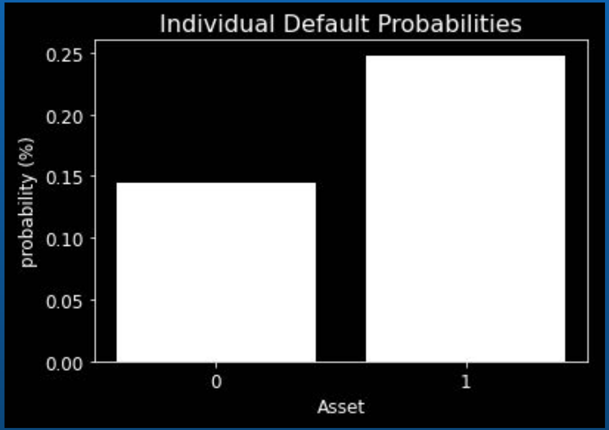
Uncertainty Model (UM)



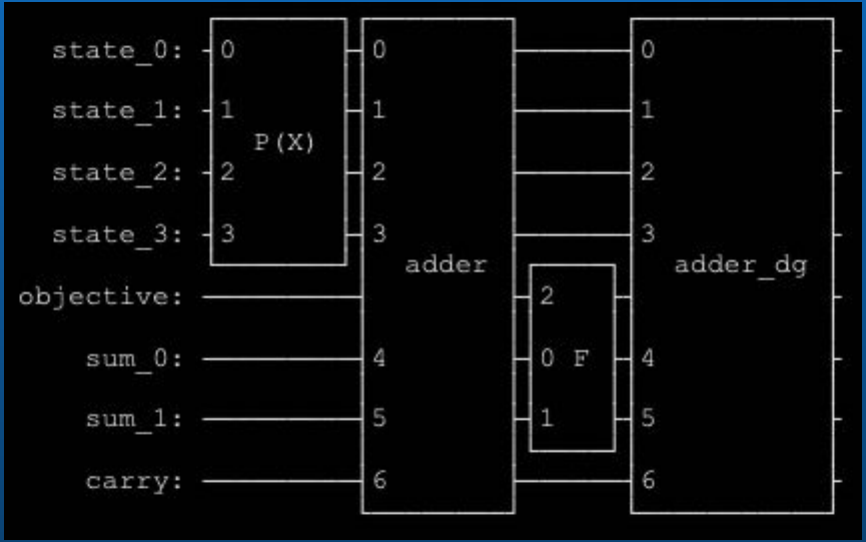
Loss Distribution, Z Distribution, Individual Probs







Expected Loss (EL)

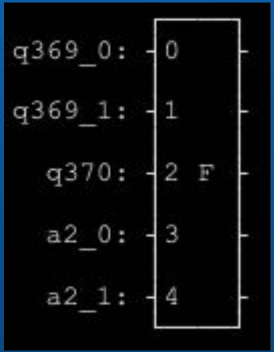


Value at Risk (VaR)

```
..........................................................................
 Start bisection search for target value: 0.950
..........................................................................
low_level     low_value     level     value     high_level     high_value
..........................................................................
-1            0.000         1         0.752      3             1.000
 1            0.752         2         0.959      3             1.000
..........................................................................
 Finished bisection search
..........................................................................


Estimated Value at Risk:   2
Exact Value at Risk:       2
Estimated Probability:     0.959
Exact Probability:         0.959
```

Conditional Value at Risk (CVaR)

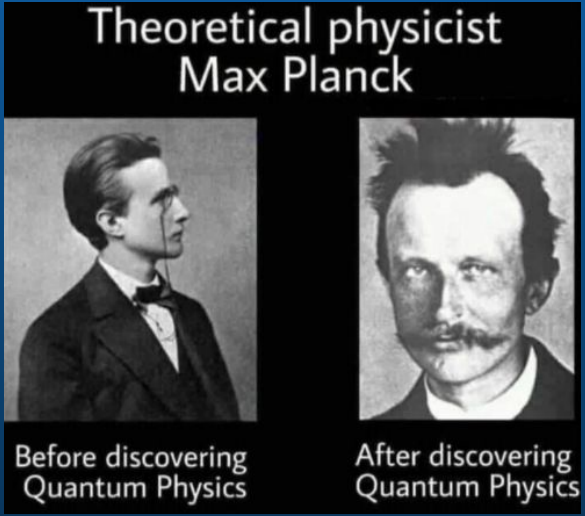


Conclusions

By now, most people have heard that quantum computing is a revolutionary technology that leverages the bizarre characteristics of quantum mechanics to solve certain problems faster than regular computers can. Those problems range from the worlds of mathematics to retail business, and physics to finance. But, as we have seen recently, quantum computers (QC) are exceedingly difficult to engineer, build and program. As a result, they are crippled by errors in the form of noise, faults and loss of quantum coherence.

While classical computers (CC) are also affected by various sources of errors, these errors can be corrected with a modest amount of extra storage and logic. Quantum error correction schemes do exist but consume such a large number of

Thank you for your time



The problem

Company

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

Ut enim ad minim veniam, quis nostrud

Context

Ut enim ad minim veniam, quis nostrud exercitation

- Duis aute irure dolor in reprehenderit in voluptate velit

Problem statement

Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Challenges deep-dive

Challenge 1

Expand audience

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

Challenge 2

Up 30-day actives

Ut enim ad minim veniam, quis nostrud exercitation

- Duis aute irure dolor in reprehenderit in voluptate velit

Challenge 3

Increase conversion

Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

09.05.XX

Lorem ipsum dolor sit amet, consectetur adipiscing elit

09.17.XX

Lorem ipsum dolor sit amet, consectetur adipiscing elit

10.13.XX

Lorem ipsum dolor sit amet, consectetur adipiscing elit

10.20.XX

Lorem ipsum dolor sit amet, consectetur adipiscing elit

11.01.XX

Lorem ipsum dolor sit amet, consectetur adipiscing elit

The team


CEO
Wendy Writer
Dir. of Sales
Ronny Reader
Dir. of Engineering
Abby Author
North America Lead
Perry Presenter
Asia Lead
Vinny Viewer
Europe Lead
Molly Maker
Front End Lead
Casey Creator
Back End Lead
Berry Books