THE QUANTUM COMPUTING LEAP IN FINANCIAL RISK MANAGEMENT

Empowering Monte Carlo simulations with quantum computing: our methodology for enhanced financial instrument valuation.

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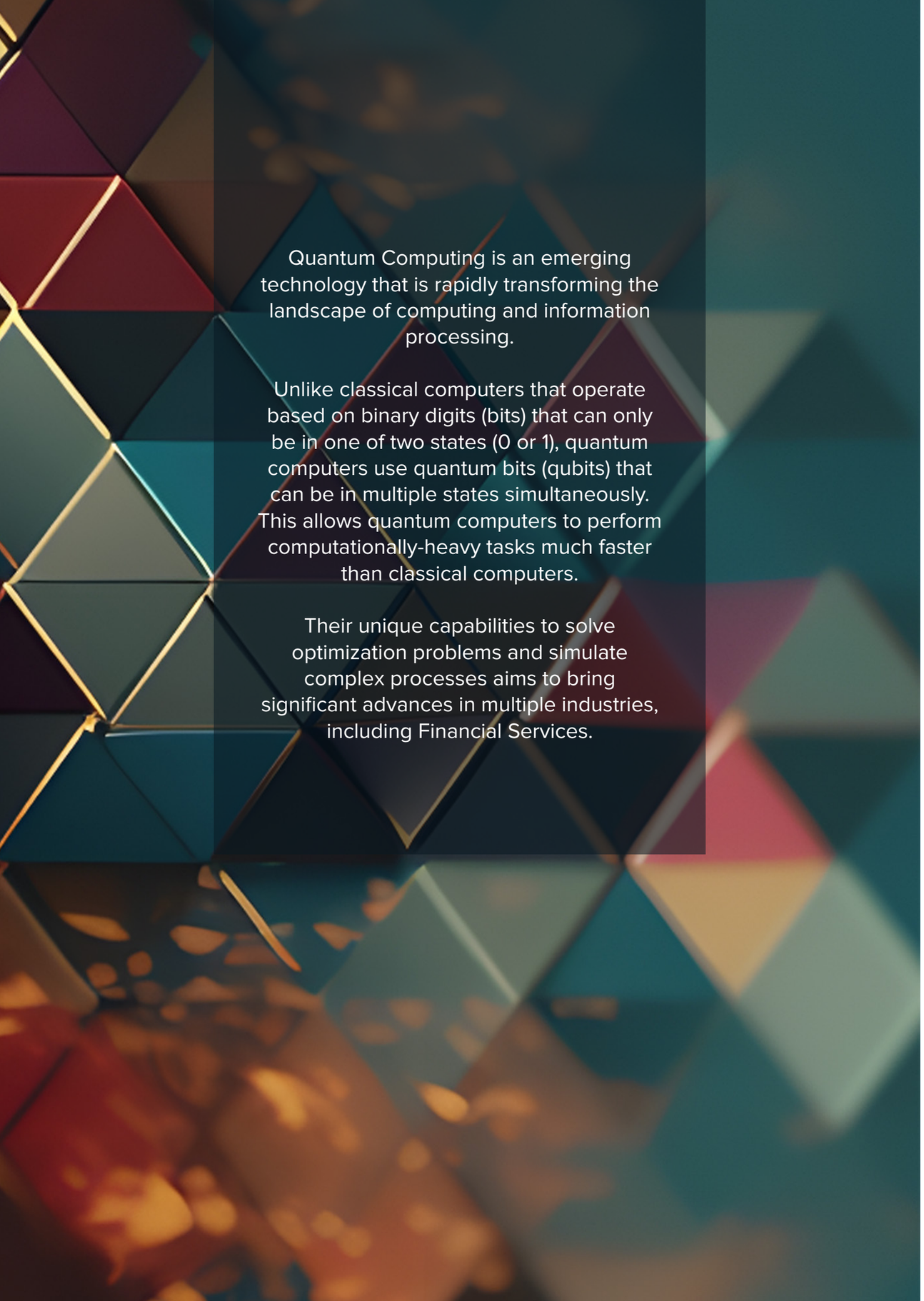

Quantum Computing is an emerging technology that is rapidly transforming the landscape of computing and information processing.

Unlike classical computers that operate based on binary digits (bits) that can only be in one of two states (0 or 1), quantum computers use quantum bits (qubits) that can be in multiple states simultaneously. This allows quantum computers to perform computationally-heavy tasks much faster than classical computers.

Their unique capabilities to solve optimization problems and simulate complex processes aims to bring significant advances in multiple industries, including Financial Services.

EXPLORING THE BENEFITS OF QUANTUM COMPUTING FOR MONTE CARLO SIMULATIONS

A financial application where quantum computing is already showing promise is in **Monte Carlo simulations** that are involved in different processes in risk management and hedging strategies, such as option pricing. Options are financial contracts that give the holder the right, but not the obligation, to buy or sell an underlying asset at a predetermined price within a specified time period.

The Monte Carlo method

The Monte Carlo method is a statistical technique that consists of using a large number of random samples to estimate the value of a certain function such as options' expected payoffs. Monte Carlo simulations are a popular method because they can take into account the stochastic nature of the underlying asset's price movement.

These simulations can be computationally expensive, especially for **large and complex models**. In the simplest model (path-independent) the option value depends only on a single time instant in the future, e.g. a specified date next month, next year, and so on, while the value of exotic variants depends on the evolution of the underlying asset (path-dependent) until a predetermined date in the future. Moreover, they can be defined on a multitude of assets. Especially in these last cases, quantum computing has the potential to significantly improve the efficiency of Monte Carlo simulations and enable more accurate estimates of financial instruments' values.

Reply has implemented a methodology to price options and portfolios of options on a gate-based quantum computer using the **Quantum Amplitude Estimation (QAE)**, a quantum computing algorithm that provides a **quadratic speedup** compared to classical Monte Carlo methods. The options subject to the work include vanilla options and complex path-dependent options such as compositions of barrier options.

Quantum Amplitude Estimation

QAE (Quantum Amplitude Estimation) is a quantum algorithm that can be used to estimate the expectation value of a given function and it is based on the Amplitude Amplification algorithm, which is used to amplify the amplitude of the solution state in a quantum search algorithm. This technique allows to detect the most probable solution among all potential scenarios. It is a powerful tool for option pricing because it can be used to estimate the value of complex financial instruments, like the options' expected payoff, with a ***higher degree of accuracy than classical Monte Carlo*** *methods, even when using fewer samples.*

Other financial areas can benefit from this algorithm: QAE can also be used to estimate the expected return of a portfolio, which can help investors make better investment decisions.

QUANTUM COMPUTING FOR OPTION PRICING

There are three main steps involved in using Quantum Amplitude Estimation for option pricing in finance.

The data needs to be encoded in qubits states

Quantum operations simulate financial options and encode expected payoffs in qubits.

The QAE algorithm is applied to produce an estimate the option's payoff.

One key advantage of QAE over classical Monte Carlo simulations is that QAE can provide a speedup because of its ability to **simultaneously evaluate multiple scenarios** of the underlying price.

On the other hand, QAE requires a large number of qubits and a high degree of maturity of Quantum hardware in terms of noise tolerance in order to achieve an accurate estimate. However, advances in quantum hardware and error-correction techniques are making it increasingly feasible to perform QAE on larger and more complex problems.

In the meantime, classical technology capable of parallelizing computations, such as **Graphics Processing Units** (GPUs), comes in handy to **obtain computational speedup** and consequently increased precision in the estimation of financial instruments' values. By computing multiple scenarios for, e.g., the payoff of a financial option, the time-to-solution is reduced by orders of magnitude when compared with approaches based on CPU, allowing to tackle much more efficiently the task of pricing complex, exotic options.

THE PROMISING FUTURE OF QUANTUM OPTION PRICING IN FINANCE

Quantum Amplitude Estimation is a powerful tool that has the potential to revolutionize option pricing in finance. By providing a speedup over classical Monte Carlo simulations, QAE can enable more accurate and efficient pricing of options with multiple underlying assets or complex payoff structures. While there are still challenges to be overcome in terms of hardware, **Quantum Option Pricing** is a promising area of research that could have significant implications for the future of **finance** and, in the meantime, the **use of GPUs** can already help bringing business value with today's commercially-available technology.

Quantum Computing will become an increasingly important tool for **financial institutions**, allowing them to better manage risk, develop more accurate pricing models, and make more informed investment decisions.