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Implementation of Quantum Optimization Algorithm

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Abstract*: Quantum computing is a quickly growing research field. This article introduces the basic concepts of quantum computing, recent developments in quantum searching Quantum computers are computing devices that can theoretically have computed power that is many orders of magnitude greater than that of conventional computers. The quantum bit, or qubit, which is the quantum state of electrons in an atom, is the fundamental data unit in a quantum computer. Qubits have the potential to exist in several superposed states at once, making them capable of carrying much more data than do standard two-state bits. The mathematical basis of the proportionality of qubit states is like that of the input weights of neural networks. The technology of quantum computers has made some progress, but much more work needs to be done in terms of research and development before it can be used in everyday life. There are also views that suggest this outcome is impossible. A recent field of study known as quantum computing (QC) combines components of computing, physics, and mathematics. Interest in quantum computing is rising among academics, technologists, and businesspeople. For the past ten years, it has given researchers in the scientific, technological, and industrial disciplines a place to conduct their work. The fundamentals of QC have been developed using notions from quantum physics. The parallel processing functionality in QC has simplified the currently employed algorithms. Numerous optimization-related challenges and issues were solved with the aid of this function. Intelligent computational techniques that were inspired by quantum mechanics have been applied in a variety of fields. A qubit's ability to be in superposition is one of its characteristics that distinguishes it from a conventional bit. Superposition is one of the fundamental principles. Entanglement is another one of quantum physics' counterintuitive occurrences. When each particle's quantum state cannot be characterized separately from the quantum state of the other particle(s), a pair or group of particles are said to be entangled.*

Keywords: Qbits, QC, Quantum physics, Quantum Mechanics, Parallel Processing, superposition, Entanglement

I. INTRODUCTION

One of the hottest subjects in the IT industry right now is quantum computing. Through the use of technology, people and businesses are now able to tackle computational issues that were once thought to be unsolvable. This technology has had a big impact on chemistry, quantum simulation, optimization, machine learning, and many other domains. While conventional computers used for web browsing won't be quickly replaced by quantum computers, quantum technology is fundamentally altering how society functions. A number of scientific advances have been made in the construction of "gated" quantum computer systems thanks to research being conducted by numerous top technology firms and startups, including Google, IBM, Microsoft, Intel, and Honeywell. Since hardware development for quantum computing is currently the main barrier, many organizations are concentrating on this.

In general, the field of study known as quantum computing is said to be focused on creating computer technology based on the concepts of quantum theory, a branch of physics that describes the atomic and subatomic behavior of matter and energy. The general strategy for creating quantum computers at scale is to construct these quantum systems to interact with one another in specified ways while engineering out undesirable interactions with the environment. Because

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quantum computing is not based on binary bits—that is, bits that can only be either zero or one—it is a special form of computing. Instead, the technology is based on qubits. These are two-state quantum mechanical systems that are capable of simultaneously existing in part zero and part one. When the quantum properties of "superposition" and "entanglement" are coupled, N qubits can work together as a unit rather than separately, resulting in an exponentially higher information density (2N) than that of a conventional computer (N). System integrity is still a weakness even though quantum computers have a huge performance advantage. Qubits are extremely vulnerable to environmental perturbations, which makes them error-prone. Although complex correction codes and redundant qubits are needed to correct these mistakes, the development of practical applications for so-called Noisy Intermediate Scale Quantum devices is progressing quickly.

II. LITERATURE SURVEY

2.1 Quantum Computing

Quantum computing is a type of computation whose operations can harness the phenomena of quantum mechanics, such as superposition, interference, and entanglement. Devices that perform quantum computations are known as quantum computers.

There are several models of quantum computation with the most widely used being quantum circuits. Most models are based on the quantum bit, or "qubit", which is somewhat analogous to the bit in classical computation.

2.2 Qubit

A qubit can be in a 1 or 0 quantum state, or in a superposition of the 1 and 0 states. When it is measured, however, it is always 0 or 1; the probability of either outcome depends on the qubit's quantum state immediately prior to measurement. One model that does not use qubits is continuousvariable quantum computation.

The state $|\psi\rangle$ of a single qubit can always be expressed in Dirac notation as

$|\psi\rangle=\alpha|0\rangle+\beta|1\rangle$, $|\psi\rangle=\alpha|0\rangle+\beta|1\rangle$,

Where $\alpha\alpha$ and $\beta\beta$ are complex numbers, and the state is normalized, i.e., $|\alpha|2+|\beta|2=1|\alpha|2+|\beta|2=1$.

The qubit is in the following state:

$$|\psi\rangle = 0.6\,|0\rangle + 0.8\,|1\rangle \equiv \begin{bmatrix} 0.6 \\ 0.8 \end{bmatrix}.$$

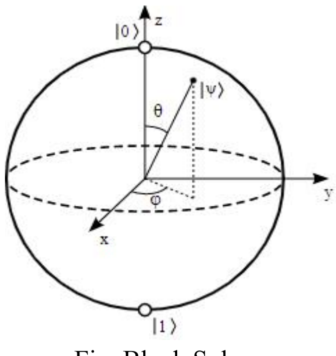

Fig. Bloch Sphere

Single qubit states that are not entangled and lack global phase can be represented as points on the surface of the Bloch sphere, written as{\displaystyle |\psi \rangle =\cos \left(\theta /2\right)|0\rangle +e^{i\varphi }\sin \left(\theta /2\right)|1\rangle .} :

$$|\psi\rangle = \cos(\theta/2)|0\rangle + e^{i\varphi}\sin(\theta/2)|1\rangle.$$

Rotations about the x, y, and z axes of the Bloch sphere are represented by the rotation operator gates.

2.3 Quantum Mechanics

Quantum mechanics is a fundamental theory in physics that provides a description of the physical properties of nature at the scale of atoms and subatomic particles. It is the foundation of all quantum physics including quantum chemistry, quantum field theory, quantum technology, and quantum information science.

While classical physics, a set of ideas that predated the invention of quantum mechanics, adequately describes many aspects of nature at vast (macroscopic) scales, it falls short at microscopic (atomic and subatomic) scales. The majority of classical physics theories can be derived from quantum mechanics as a large-scale (macroscopic) approximation.

Quantum mechanics differs from classical physics in that the energy, momentum, angular momentum, and other properties of a bound system are restricted to discrete numbers (quantization). objects exhibit wave-like and particle-like properties (wave-particle duality), and the uncertainty principle places restrictions on how accurately physical quantities can be predicted before being measured

2.4 Quantum Physics

Many parts of nature are described by classical physics, a body of theories that predated the development of quantum mechanics, at a large (macroscopic) scale, but not well enough at microscopic (atomic and subatomic) sizes. The majority of classical physics theories can be derived from quantum mechanics as a large-scale (macroscopic) approximation.

The most basic level of the study of matter and energy is called quantum physics. It tries to learn more about the characteristics and actions of nature's fundamental building blocks. One of the fundamental breakthroughs was the understanding that matter and energy may be seen as discrete packets, or quanta, each of which has a minimum value. For instance, light with a set frequency will disperse energy into quanta known as "photons." The energy of each photon at this frequency will remain constant, and it cannot be divided into smaller pieces. In actuality, the word "quantum" derives from Latin and meaning "how much." Other key ideas played a role in laying the groundwork for quantum physics:

- Wave-particle duality
- Superposition
- Uncertainty principle
- Entanglement

2.5 Quantum Logic Gates

In traditional computing, logic gates that produce specific binary outputs from specific binary inputs are used to process binary values as they are stored in registers. Boolean algebra is used to mathematically describe classical logic gates. Similar to conventional logic gates, quantum logic gates work by mapping one quantum superposition to another. This allows the system to evolve to the desired ultimate state, which is the right response. A quantum logic gate (or simply quantum gate) is a fundamental quantum circuit that uses a few qubits in quantum computing, more especially the quantum circuit model of computation. Similar to how classical logic gates are the building blocks of traditional digital circuits, they are the building blocks of quantum circuits.As unitary matrices with relation to some basis, quantum gates are unitary operators. The computational basis is what we typically use, which, until we compare it to something, basically implies that for a d-level quantum system, we have labeled the orthogonal basis vectors or use binary notation.

2.6 Algorithms

The type of speedup observed over equivalent classical algorithms can generally classify quantum algorithms. Shor's algorithm for factoring and the associated quantum algorithms for computing discrete logarithms, resolving Pell's equation, and more broadly resolving the hidden subgroup problem for abelian finite groups are examples of quantum algorithms that outperform the most well-known classical algorithm by more than a polynomial factor. These algorithms rely on the quantum Fourier transforms' fundamental building blocks. Although it is implausible, no mathematical proof has been established that demonstrates the impossibility of creating a classical algorithm that is equally quick.

• Algorithm Based on the quantum Fourier transform

1. Deutsch–Jozsa algorithm
2. Bernstein–Vazirani algorithm
3. Simon's algorithm
4. Quantum phase estimation algorithm

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5. Shor's algorithm
6. Hidden subgroup problem
7. Boson sampling problem
• Algorithm Based on amplitude amplification
1. Grover's algorithm
2. Quantum counting
• Algorithm Based on quantum walks
• BQP-complete problems
• Hybrid quantum /classical algorithms

III. PROPOSED WORK

3.1 Objective and Scope

The objective of this project is to increase the speed efficiency of the algorithm than running in the classical computer. With the use of two quantum computation paradigms—the gate-based model and adiabatic quantum computation—this brief work aims to offer various solutions to the Traveling Salesman issue.

1. To increase computational speed.
2. It used for the optimization problem.
3. It used for data analysis and simulation.
4. Quantum computations have great promise for analyses and simulations of extremely complicated processes involving vast volumes of data.
5. Advanced cryptography is the application that most people relate quantum computing with.

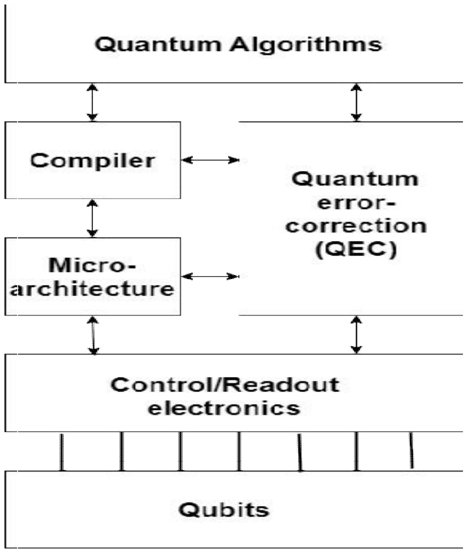

Fig. Proposed Workflow

There are numerous physical configurations for quantum computers. This FAQ will go over a few of those options. The three key ideas of qubits, Hamiltonians, and decoherence are crucial when addressing various methods for quantum computing. Quantum computing begins with qubits. A qubits digital bit can represent either 1 or 0 , but not both at once. A qubit is a two-level quantum system where the two basic qubits states are |0> and |1> is the Dirac notation for the quantum state that will always give the result 0 when converted to classical logic by a measurement, and |1> is the state that will always convert to A qubit can be in state |0> or |1>.or in a linear combination of both states. In a traditional computer, two bits can exist in one of four configurations—00, 01, 10, or 11—but only one configuration at a time. However, with a quantum computer, all four configurations are feasible can be encoded simultaneously into the state of the two qubits using superposition of the four quantum basis states|00>, |01>, |10>, and |11>.The computation could be executed using a single quantum gate, concurrently acting on each state in parallel

IV. CONCLUSION

Finding the shortest path between a number of points and places that must be visited is the goal of the algorithmic problem known as the "traveling salesman problem" (TSP). Utilizing quantum computing technology, it is simpler, faster than a traditional computer, and more effective. The use of quantum computers has the potential to transform computation by solving some types of issues that were previously insoluble. Despite the fact that no quantum computer is now sophisticated enough to perform calculations that a classical computer cannot, significant development is taking place.

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