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Integration of Quantum Computing in Data Driven Technologies

Prathamesh Pramod Kulkarni
Electronics and Telecommunication Department, Sinhgad Institute of Technology and Science, Savitribai Phule Pune University
kprathamesh67@gmail.com

Abstract

This paper tries to cover the emerging field of quantum computation and its interaction between networking and communication, cloud computing, machine learning, robotics, cognitive science and artificial intelligence. The paper tries to build on various technologies with quantum computing and how this technologies come together to form a base for the future of computation. An overview of each field is described and not detailed implementation is discussed.

I. INTRODUCTION

The goal of this paper is to shed light on the various technologies which can be implemented using quantum computing. Quantum Computing is the use of quantum-mechanical phenomena such as superposition and entanglement to perform computation. Quantum computing is enabling the communication and quantum internet .With the ever increasing demand of cloud services the paper discusses about how quantum computing can help us store, secure and process data using quantum cloud or quantum computer as a service. Due to increased amount of data the classical machine learning algorithm are lagging behind and how quantum algorithms are paving their way in machine learning with increased speeds and more predictive power than before. Quantum computing can be used in robotics and the way it is resolving some of the issues previously addressed in classical robotics. It also shows how each aspect in making of robot is affected by quantum computing. The role of quantum computing is cognitive science is discussed and how artificial intelligence can be scaled to human like performance levels. How some problems related to AI are solved with quantum computing are solved using quantum computing are discussed at the end. The paper tries to make a point on how these various technologies build on top of each other and result in a whole AI ecosystem and how they are improving the computation power compared to classical computation.

II. BACKGROUNG

Quantum computing takes advantage of the strange ability of subatomic particles to exist in more than one state at any time. Due to the way the tiniest of particles behave, operations can be done much more quickly and use less energy than classical computers. Classical computers carry out logical operations using the definite position of a physical state. These are usually binary, meaning its operations are based on one of two positions. A single state - such as on or off, up or down, 1 or 0 - is called a bit. Quantum computing uses quantum bits, or 'qubits' instead. In quantum computing, operations instead use the quantum state of an object to produce what's known as a qubit. These states are the undefined properties of an object before they've been detected, such as the spin of an electron

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or the polarisation of a photon. Because a quantum computer can contain these multiple states simultaneously, it has the potential to be millions of times more powerful than today's most powerful supercomputers. This superposition of qubits is what gives quantum computers their inherent parallelism. this parallelism allows a quantum computer to work on a million computations at once, while your desktop PC works on one.

Some important terms related to quantum computer are mentioned below,

a. Quantum Bits

A qubit (or Quantum bit) is similar in concept to a standard 'bit' - it is a memory element. It can hold not only the states '0' and '1' but a linear superposition of both states.

b. Quantum State

It refers to the state of an isolated quantum system. A quantum state provides the value of the outcome of each possible measurement on the system. It predicts the system behaviour.

c. Quantum Superposition

Quantum Superposition refers to atom that can be at two positions at same time. The superposition of state is applied to any quantum particle in the universe. In fact, quantum superposition is responsible for the exchange of information in quantum bit.

d. Quantum Entanglement

Particle waves are said to be entangled if measuring one of such particles affects the other particle. When a system is entangled, this means that the individual component systems are really linked together as a single entity.

e. Quantum Teleportation

It allows us to send a quantum state from one place to another without that state traversing the space in between.

f. Quantum Decoherence

This describes the process in which a quantum system (or property) loses its wave property of interference. If the waves of the particles are in phase with each other they are said to be quantum coherent. If they are out of phase, they are said to be quantum decoherent.

g. Quantum Circuit

A quantum circuit is a model of quantum computation in which a computation is a sequence of quantum gates, which are reversible transformations on a quantum mechanical analogue of an n-bit register.

III. QUANTUM NETWORKING AND COMMUNICATION

Quantum networks form an important element of quantum computing and quantum communication systems. The transmission of information in physically separated quantum processors happened in the form of quantum bits, also called qubits. By networking multiple quantum devices, the Quantum Web develops a virtual quantum machine ready to give an exponential scale-up of the quantum computing

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power. A new distributed computing era can be envisioned because of quantum internet. Unlike classical networking, quantum networking is governed by quantum mechanics which impose very challenging constraints for network design.

Quantum communication means sending of qubits from one quantum processor to another over long distances. This way local quantum networks can be intra connected into a quantum internet. Quantum communications have been widely restricted to a synonymous of a specific application, e.g. Quantum Key Distribution (QKD).QKD is a cryptographic protocol enabling two parties to produce a shared random secret key by relying on the principles of quantum mechanics, either quantum measurement or entanglement. Only the creation of encryption key is done by QKD but the encrypted information is transmitted in a classical way. The communication protocol enabling two parties to enhance the transmission of classical information through a quantum channel is called superdence coding. Both QKD and superdense coding exploit quantum mechanics to convey classical information. The Quantum Internet relies on the ability to share quantum states among remote nodes. However, quantum mechanics restricts a qubit from being copied or safely measured. Hence, although a photon can encode a qubit and it can be directly transmitted to a remote node, e.g., via a fiber link, if the traveling photon is lost due to attenuation or corrupted by noise, the quantum information is definitely destroyed.

IV. QUANTUM CLOUD COMPUTATION

Combining quantum computing and cloud computing can shape the future of computing. Quantum computing focuses on creating super-fast computers using the concepts of quantum physics whereas Cloud computing allows the computing power to be provided as a service. Hence a quantum cloud system or quantum cloud will provide quantum computing as a service. Quantum emulators, simulators or processors can be accessed through the cloud in cloud based quantum computing. Increasingly, cloud services are being looked on as the method for providing access to quantum processing. The massive processing power of quantum computers can be accessed by the users over internet is called quantum computing within the cloud. Problems faced by classical cloud computing such as security, processing, backup and vicinity can be overcome by quantum computing. Thus quantum cloud can prove to be a better and reliable place to store and process data.

Currently, deploying public key infrastructure (PKI) is one of the most elegant solutions for securing clouds. PKI works by exchanging keys using certificate via the public channel for authentication purposes. PKI based architecture works on public key cryptography. Another method for secure authentication on Cloud is using Kerberos. Many researchers have proposed a Kerberos-based model for secure data storage and secure authentication on the cloud. Third model is that it uses ease of deployment of a Kerberos Model along with the security benefits of Quantum Cryptography. Kerberos allows the nodes to connection points of the various cloud networks to communicate with each other which in turns helps in providing Single Sign-On solution for using various cloud networks by signing on only once. Any Encryption Algorithm AES, DES et al. can be used for encrypting data. This new method builds on top of the pre-existing architecture of using Kerberos for Single Sign-On authentication for flexibility and scalability but gives a workaround for the limitation of classical cryptographic algorithms by using QKD inside the KDC for key distribution and using Quantum

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Channel for transmission. Thus quantum cloud can prove to be a better and reliable place to to store, secure and process data.

V. QUANTUM MACHINE LEARNING

Quantum machine learning explores the interaction between quantum computing and machine learning, investigating how results and techniques from one field can be used to solve the problems of the other. With an ever-developing measure of information, current machine learning frameworks are quickly moving toward the breaking points of traditional computational models. Right now, quantum computation can offer focal points in such machine learning undertakings. The field of quantum machine learning explores how to devise and implement quantum software that could enable machine learning that is faster than that of classical computers. Machine learning is used to find patterns in the data and quantum systems produce atypical patterns that classical systems are thought not to produce efficiently, hence using quantum computers for machine learning prove to be very useful. Quantum machine learning aims to implement machine learning algorithms in quantum systems, by using the quantum properties such as superposition and entanglement to solve these problems efficiently. This results in increased speed of functioning and data handling. To operate the classical algorithms we develop quantum algorithms to perform various machine learning techniques.

Quantum machine learning can be used to minimize loss function with quantum tunnelling, dimensionality reduction can be achieved by using a support vector machine implementation that is suited for quantum gates and quantum computing, very large datasets can be handled by combining small scale quantum computing and powerful classical computing, When it comes to executing linear algebra computations, quantum computers can exponentially speed up the prospects, Quantum machine learning can have a strong footprint in optimization, Quantum machine learning can be used to perform kernel evaluation by feeding estimates from a quantum computer can be fed into the standard kernel method, Quantum computers could make deep learning a whole lot more profound by solving complex problems that are intractable on classical computers.

VI. QUANTUM COMPUTING IN ROBOTICS

Computer vision and image processing algorithms are computationally expensive as they have to compute results on millions of pixels. Quantum properties, like entanglement and parallelism can help us understand the nature of visual information and to secure, store and process them efficiently. This study has resulted in a sub-discipline called Quantum Image Processing(QIMP).AI-applications are frequently used in robotics, like path planning, the deduction of goal-oriented action plans, system diagnosis, the coordination of multiple agents, or reasoning and deduction of new knowledge . Quantum algorithms for these applications are already formulated which replace the classical definitions of probability with quantum probability. Approaches to tackle challenges like robot

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trajectory planning can be solved by simulated annealing as well as genetic algorithm which take a quantum route.

In challenges like pick and place, pick and place poses are defined, but not the way in between. Optimizing the sequence of subtasks (or atomic tasks) within a given problem can be solved efficiently by the use of a quantum computer. Task like abstract task-planning and specific movement planning are currently solved separately due to their complexity, this can be solved with the help of quantum computing in a more integrative way, task such as control schemes ,dynamic programming formulation can be handled more efficiently by quantum computers. Faults may occur in a carefully designed robots also, Therefore, methods to detect and specify these faults are essential. Data mining is a valuable tool for knowledge discovery in order to diagnose systems .Data mining involves machine learning, statistics, and database systems, which are more suited for quantum algorithmic approaches.

With quantum computing these challenges are get easier, hence it can be safe to assume that there will be robots that are entirely quantum powered.

VII. QUANTUM COMPUTING IN COGNITION SYSTEMS

The interdisciplinary study of decision making, intelligence including artificial intelligence and also human memory linguistics and anthropology is called cognitive science. In past decade efforts are made more towards cognitive computation. The ability to learn and implementing decisive processes of computers is growing day-by-day. Hence, efforts are made to unify machine learning algorithms with quantum computing to develop quantum versions of artificial neural network.

The quantum cognition is based on the observation that various cognitive phenomena are more adequately described by quantum information theory and quantum probability than by the corresponding classical theories. Thus the quantum formalism is considered as an operational formalism describing non classical processing of probabilistic data. Recent derivations of the complete quantum formalism from simple operational principles for representation of information supports the foundations of quantum cognition.

Task like decision making, probability judgement, knowledge representation, memory, analysis and information retrieval, perception are expected to carried out in quantum cognition. The capacity of quantum registers with valuable quantum resources makes quantum cognitive systems a promising candidate to strengthen the capacity of cognitive systems.

VIII. QUANTUM ARTIFICIAL INTELLIGENCE

Quantum computing shows the ability to perform parallel information processing and rapid search over unordered sets of data promises significant advances to the whole scientific field of information processing.

Quantum computing is helping the field of AI in

Production of truly random numbers. True randomness has been reported to cause measurable performance improvement to genetic programming and other automatic program induction methods.

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Quantum algorithms for learning. Quantum machine learning shows that we have created quantum algorithms that out performs the classical learning algorithms.

Early AI was much concerned with search techniques as AI problems can be reduced to searching; for example, planning, scheduling, theorem proving and information retrieval. Grover's algorithm and its variations are ideal for efficient content addressable search and information retrieval from large collections of raw data. The principle of probability amplitude amplification that guides these processes can be relaxed for approximate pattern matching as well, thus facilitating applications like face, fingerprint, and voice recognition, corpus search, and data-mining. The Grover algorithm shows that quantum computers can do it even faster than classical computers.

Using QC all the states of the search space can be first superimposed on a quantum register and then a search can be performed using a variance of Grover's algorithm. It is evident that many problems in search, planning, scheduling, game-playing, and other analogous fields can utilize the parallel processing of a quantum register's contents and reduce their processing times by several orders of magnitude.

Speech and language preparing have likewise a lot to pick up from quantum computing. Approximate pattern matching input signal and the conspicuous fast quantum search in colossal lexical databases,

The representation problem can be illuminated exquisitely in a quantum register and more proficiently.

IX. CONCLUSION

This paper attempted to present the application of quantum computing the fields of networking and communication, cloud computing, machine learning, robotics, cognition systems and artificial intelligence. We can see how quantum computing affects the classical fields and help them solve some of the problems previously faces and improve the overall speed of computation. Starting from networking we can see how each fields affects others, the increase in transfer speed of data in networking and communication results in quantum internet, this quantum internet then facilitates the use of quantum cloud where we can store, and process huge amount of data, deploying quantum machine learning algorithms on cloud can make the 'learning' process much more powerful than before. With increase in learning, quantum cognition and artificial intelligence, robots of the future will have more decision making power, memory and ability to analyse and retrieve information. This will in turn help us carry out the currently difficult task with much more ease. All this in total adds to create an ecosystem for quantum artificial intelligence.

Though we have made great progress in the field of quantum computing we are still haven't fully understood and implemented the above technologies completely and a lot of work and efforts are to made. But judging by the current rate of progress we will be completely changing from classical computing to quantum computing in a few years.

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