A Detailed Investigation on Potential Impact of Quantum Computing on Improving Artificial Intelligence

Dr.G. Nagaraj[1*]
[1]Associate Professor,
Department of Mechanical Engineering,
Sethu Institute of Technology, Tamilnadu, India
nagarajsasi@gmail.com

Dr. Niraj Upadhayaya[2]
[2]Professor, Department of CSE,
J.B. Institute of Engineering & Technology, Bhaskar Nagar, Yenkapally, Moinabad, Hyderabad, India
nirajup@gmail.com

Atheer Matroud[3]
[3]Subject Lead, School of Engineering and Computing, De Montfort University, Dubai, United Arab Emirates
atheer.al-mousa@dmu.ac.uk

N Sabitha[4]
[4]Assistant Professor,
Department of Computer Science and Engineering, Maturi Venkata Subba Rao (MVSR) Engineering College, Telangana, India
sabitha_cse@mvsrec.edu.in

Dr.Reshma V.K[5]
[5]Assistant Professor, Department of Computer Science and Engineering, Sri Krishna College of Engineering and Technology, Hyderabad, India
reshmavk@skcet.ac.in

Regonda Nagaraju[6]
[6]Professor and HoD, Department of IT, St.Martin's Engineering College, Dhulapally, Secunderabad, Telangana, India
nagcse01@gmail.com

ABSTRACT

Quantum computing is an emerging technology (QC). Several groups and research institutions are working to make quantum computing applications a reality. Artificial Intelligence (AI) is another emerging field that is becoming more established over time. The main goal of this research is to figure out how the advancement of quantum computing technology will affect AI applications. Computational methods are used to explore the growing influence of quantum computing development for a specific AI application. This study also discusses about the impact and potential of Quantum Computing (QC) on Artificial Intelligence (AI). These can be accomplished by employing cutting-edge methods to deliver usable, economically viable, and scalable technology across a wide range of industries. On the other hand, the risk of committing errors in quantum algorithms, as well as the inability to function without being super-cooled, emerges as a major challenge. Macro-energy systems and the development of sustainable energy materials are just two areas of science and engineering that quantum computing has the potential to completely transform.

***Keywords*: Quantum, Computing, Artificial Intelligence or AI, Application**

1. INTRODUCTION

Quantum computing is a revolutionary concept in digital data processing that is based on the fundamental laws of nature, or quantum mechanics. With the development of observational techniques and material purity in the early twentieth century, a few quantum phenomena became apparent. The most common example is the transistor found in every modern computer or device. It works by using tailored materials and quantum-based techniques to control massive clouds of electrical current carriers (band structure, localized states, etc.). They exhibit behaviour that is rare for naturally occurring materials, including the capacity to absolutely required current using either current or light or current or light. Recently, the ability to operate, view, and most critically, isolate antimatter particles with their essentially quantum features has been made possible by the shrinking of transistors and detectors as well as, concurrently, access to extreme temperatures (such as 273C) [1]. These characteristics are one of the reasons why quantum computers are not much like the laptop or desktop machines we use today.

These characteristics have been theoretically known for more than a century, but they have just lately been observed and confirmed over a wide spectrum of particles and environments. Despite appearing absurd in our day-to-day lives, quantum mechanics has so far produced several remarkable medical breakthroughs (such as MRI and laser surgery) that have the potential to completely change the way that medical research and patient care are conducted. Quantum computing, if realised, is the most potential technology for significant breakthroughs in processes now beyond the grasp of present computing power when modern computers have fully exhausted computational capacity and no longer develop geometrically as transpired in the last century [2].

Among others, Honeywell has begun to invest in this technology. Quantum computing is similar to classical computing in many aspects, storing information as bits, or 0 or 1. However, quantum computing allows for the simultaneous storage of many states of data by encoding information in a quantum bit, or qubit. This is when quantum physics ideas like entangling and superposition come into play. In order to manipulate information, quantum computing uses the same physical principles that apply to atoms, which makes it different from ordinary computing [3]. The processing of enormous, complicated datasets and the evolution of algorithms to enable improved learning, reasoning, and thinking are just a few of the ways that quantum computing is reportedly helping artificial intelligence.

2. LITERATURE REVIEW

The fields of computer programming and information science are paying more and more attention to quantum computing (QC). It has motivated physicists, engineers, and computer scientists, and the potential for its use is definitely changing the landscape of information technology (IT). QC, a quantum mechanics-based technology, can process and transfer data while concurrently executing complex calculations. For instance, the Google Sycamore nuclear machine can do a work which might take a machine 10,000 years to accomplish in just 200 seconds [4]. The technology, thus according Arute et al., is excellent for many commercial transactions since it allows companies to understand data-driven trends and discover new opportunities. It also efficiently analyses data sets with significant expertise and little processing effort. The promise of QCs has been acknowledged by numerous organisations, including IT behemoths like Google, Intel, and IBM as well as start-ups like Rigetti and IonQ. Although the use of QC is well-established in some corporate sectors, such as medicines and industrial goods, an increasing number of other companies and sectors have just recently realized the significance of its real-world uses. For instance, the financial industry is coming to appreciate the advantages of QC's quick data processing capability more and more [5]. Thus, it is anticipated that the number of QC applications will rapidly rise as more businesses recognise and utilise QC's significant advantages in the transition of technology.

Given the promise that this access to specialty, academic and commercial researchers are looking into ways to increase its reliability. Thus, QC research has expanded, although it has mainly concentrated on creating technological elements, like software tools, technologies, and quantum hardware. Research efforts aimed at determining the difficulties and opportunities for expanding QC knowledge are still insufficient when comparison to the technical elements [6]. For instance, scholars know little about prospective QC applications for project planning, quality improvement, and delivery management in a variety of industrial sectors. The potential for QC applications to improve business process efficiency and effectiveness in industries including healthcare, finance, and energy makes this a crucial research gap. Quantum technologies (QTs), for instance, could be utilised to create novel medicines, materials, or manufacturing methods. Therefore, it is crucial to look into the main difficulties that QC apps run into in real-world situations [7]. Quantum computing can allow AI researchers to integrate more data than usually it incorporates. This allows the quantum computers to achieve more accurate conclusions than conventional computers.

To overcome these obstacles, nevertheless, it's necessary to assimilate the QC field's fragmented knowledge and pinpoint its limitations. Furthermore, because the use of QC in everyday factories is less well known, knowing the obstacles that stand in the way of QC applications is necessary for determining the field's future agenda. Our study utilised a two-method strategy to fill up these gaps. To give a thorough picture of the difficulties in adopting QC, researchers first carried out a comprehensive literature review (LR) of 103 papers. Then, researchers used the fuzzy hierarchy procedure F-AHP to assess and pinpoint the significant challenges in the application of QC. Recent research works have used F-AHP to assess the challenges in improving software process. Studies that have already been conducted claim that with the widely used Multi Criteria Decision Making (MCDM) procedure, F-AHP can systematically classify and rank elements. MCDM method is used to identify and rank the significant challenges for QC implementation [8]. This research study makes two significant contributions to the field: (a) identify a potential scope for expanding scientific studies on QC adoption and (b) highlight current research gaps in the field.

3. RESEARCH METHODOLOGY

Secondary method of data collection has been considered to gather theory based information. This study can therefore be used as a starting point for practitioners and academics who want to learn more about the specifics of QC implementation in the software industry or other fields. Second, by highlighting the biggest obstacles to QC implementation, this report's utilisation F-AHP has the power to educate and advance public discourse and policy. Our categorization and ranking of the main obstacles to QC adoption can influence the trajectory of the digital transformation of QC technology, especially as the found obstacles might also apply to related technological sectors. Last but not least, our two main research methodology is a fresh method for QC research. All currently understood and useful quantum procedures that can operate on quantum systems are predicated on the quantum system's capacity to act in unison upon specific reconfiguration. A feature based on what is known as quantum entanglement causes a system of very many (quantum) components, each containing a bit of data to behave as one. Because of this, vast amounts of data can be handled simultaneously while just using a small number of particles, or in massively parallel.

4. ANALYSIS AND DISCUSSION

The ability to create and maintain individual quantum particles' (qubits') isolation is a major challenge for quantum computers, as seen in the image below. In the computation process, wire electronics (or circuits built of other materials) cannot behave in a quantum way without extremely steady cooling. To develop computational quantum particles, superconducting systems must be cooled to a temperature that is roughly ten thousandths of a degree above zero temperature (qubits). These systems, which are controlled by electrical signals from conventional computers, require a sizable refrigeration system that uses the rare helium-3 isotope to keep them at these extremely low temperatures [10]. For around 0.1 ms, or a millionth of a second, quantum particles (qubits) stay sufficiently isolated or coherent under these severe circumstances. Similar insulation and operability have been attained by certain other systems that use man-made and natural atoms instead of metal wires. To find the gradient, it is necessary to take the derivative of the function in respect to x and later substitute it with x-coordinate of the "point of interest" in respect for the x-values within the derivative. Quantum data plane, control and measurement plane, qubit technology and control processor plane appears to be key parameters to evaluate quantum computers.

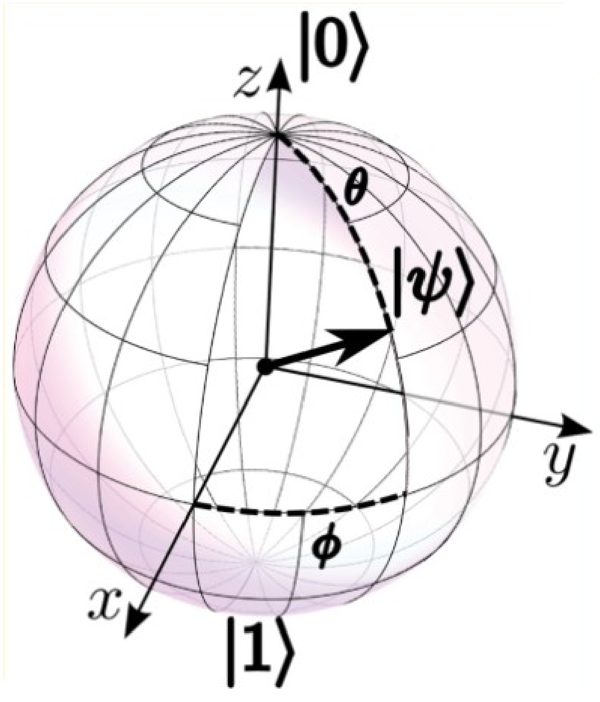

Figure 1: Computational quantum model [3]

The usage of "IBM Q" to acquire and run programmes on the cloud allows people to access quantum computing, which is currently a research-focused field. Commercially available quantum computing systems are getting bigger and bigger, and they can work with a limited percentage of quantum systems to complete a small number of tasks (qubits). These systems can hold up to 100 qubits and are mostly based on superconducting technology. The scientific community has even been given access to some quantum computing machines so they can test and study small quantum programmes using web - based applications (e.g., IBM Q). But because they cannot yet execute complicated programmes or handle "big data," all currently existing quantum computational devices are still a long way from being a fully functional quantum computer [11]. Quantum cryptography, one use of quantum computing, is a significant exception. Quantum cryptography is already being utilised to safeguard communications thanks to large government funding (NSA, DOD, DOE). To access encrypted data, many encryption techniques require a keycode from the user. The key must still be shared, though, and it can be cracked by intruders trying to 'hack' a system. The key and the contents can be permanently protected with assuredly untraceable encryption thanks to quantum computing. Because quantum encryption is based on the principles of nature (quantum mechanics), it can provide such great security [12]. As a result, it is anticipated that the initial use of quantum computing in medicine will be to safeguard communications and records of medical procedures.

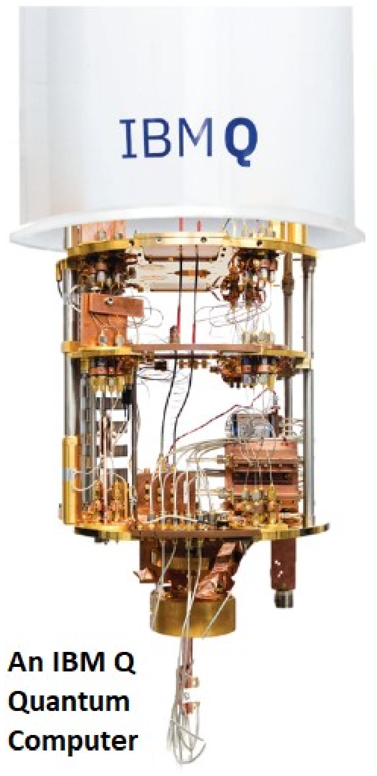

Figure 2: IBM Q Quantum computer[3]

Quantum computing opens up a number of opportunities for machine deep learning and processing natural language. For instance, a "meaning aware" algorithm was recently created by running a natural-language processing algorithm on quantum computing. Currently, search problems, quantum annealing, machine learning, simulation of quantum analysis and post-quantum cryptography are some major techniques used for quantum computing, however, the proposed model integrates different aspects. Meaning awareness means that the computer can now comprehend both the single letters and the entire sentence. The state-of-the-art today allows for the extension of this awareness to whole phrases that produce real-time speech without the need for guesswork. It is also capable of running deep learning and machine-learning algorithms quicker than its classical computers with the aid of quantum computing. The findings produced by quantum mechanics using quantum physics are more accurate than those of conventional computers. AI and quantum computing will be combined to create an optimum system that can produce higher accuracy. With quantum AI, many possibilities exist. Numerous academic studies are emerging to demonstrate the importance of this combination. The following outcomes are possible with quantum AI. To facilitate this innovation for developers, various libraries are in development.

1. Improvement of quantum algorithms for AI learning.

2. Quantum techniques improve AI neural search.

3. AI for handling stochastic scenarios touches on quantum computation and game theory.

Figure 3: “Quantum computing”

[Source: 7]

Researchers will be able to handle common problems more quickly in the future thanks to the development of quantum-based AI learning algorithms, which will also speed up work in fields like fraud analysis, pattern recognition, and AI training. The IBM Quantum community created the open-source quantum computing methods will allow as Qiskit. The goal is to put quantum computing and AI to the test. Inputs for QiskAqua programs can be decoded from machine learning scenarios, and the algorithms can then be run on actual quantum machines.

```
# A hybrid quantum-classical model.
model = tf.keras.Sequential([
    # Quantum circuit data comes in inside of tensors.
    tf.keras.Input(shape=(), dtype=tf.dtypes.string),

    # Parametrized Quantum Circuit (PQC) provides output
    # data from the input circuits run on a quantum computer.
    tfq.layers.PQC(my_circuit, [cirq.Z(q1), cirq.X(q0)]),

    # Output data from quantum computer passed through model.
    tf.keras.layers.Dense(50)
])
```

Figure 4: "TensorFlow Quantum Library"

It is well knowledge that sophisticated machine learning issues cannot be effectively solved using classical or traditional computer techniques. Quantum computing has entered the scene as a solution to this problem. It has been reported that utilising traditional processors, machine learning techniques dealing with a database of high vector space perform less well. Quantum parallelization and quantum associative memory are two crucial methods that come from quantum computing. They are supposed to improve performance or shorten computation times and can be applied to difficult machine learning problems for both learning and optimization. It is important to note that higher-dimensional tensor and dot vectors can be handled effectively by quantum computers. This feature proves to be very helpful in cutting down on the amount of time that machine learning algorithms use. According to one of the claims, quantum computers can divide numbers in polynomial time, something that classical computers are typically unable to do. There are a number of intractable problems in machine learning that cannot be resolved in the allotted time. When there are limited resources available, heuristic strategies are utilised to address such intractable situations. Here, the computation time can be sped up using quantum computing.

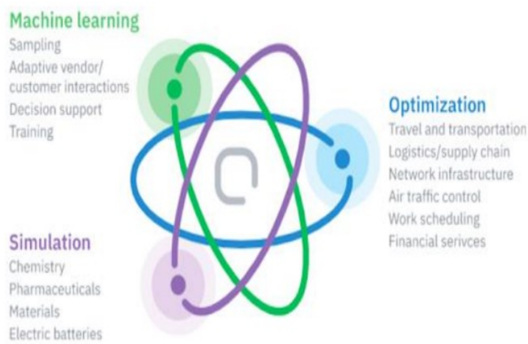

Figure 5: Quantum Computing [13]

The possibility of running and testing quantum programmes in a setting that foretells how qubits will respond to various operations is made feasible by quantum simulators, which are software applications that run on computers. Very effective quantum algorithms have really been created for a number of issues, from the emulation of materials or biochemical processes to optimization, so they may be solved by quantum mechanics far more quickly than by any other standard one. They have numerous uses, including data processing, medication development, material design, and industrial processes. Quantum computing, also known as computing as a product of qubits, can produce tremendous speed for a select few issues while only producing moderate results for other problems.

5. CONCLUSION

The most significant local barriers to the software computer industry are a lack of funds for design and initiative, while the most significant organizational barrier is a lack of organizational motivation in implementing the new method. This study highlights the evolving nature of QC and the growing demand for cross-disciplinary research to address the identified challenges. These findings are important for both academia and industrial practitioners. Most patients visit their doctor expecting more than just a prescription. Especially if the patient is required to follow complicated regimens in order for the therapy to be effective, as is the case with surgery. Quantum computing does not replace the doctor-patient relationship, flexibility, and trust required for collaborative decision-making.

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