

Real-time big data processing using quantum computing to enhance speed and efficiency

Tareq Abed Mohammed^{1,✉}, Ahmed K. Abbas², Rasha Qays Aswad³

¹ College of Computer Science and Information Technology, University of Kirkuk, Iraq

² Collage of Education for Pure Science, University of Diyala, Iraq

³ Collage of Education Al-Muqdad, University of Diyala, Iraq

ABSTRACT

In the era of big data, classical computing techniques face challenges in handling large and complex datasets. Quantum computing offers a transformative solution, especially in terms of real-time data processing speed. This study compares the performance of quantum and classical algorithms for large-scale data tasks. Results show that quantum algorithms achieve up to 70% faster processing and 30% greater computational efficiency, with scalability and an accuracy rate of 95% outperforming classical methods. Despite current limitations such as decoherence and error rates, ongoing advancements in quantum hardware and error correction highlight the potential of quantum computing to revolutionize data processing.

Keywords: big data, quantum computing, quantum algorithms, real-time analysis, quantum devices, error correction, quantum supremacy

1. Introduction

The modern world is characterized by an explosion of the amount of data, and computing technologies have been developed to address this challenge. Most of the conventional classical computing techniques fail at scale and fail powerfully when faced with the size of data and the required processing power, where eventually it becomes almost impossible to process big data in real time. Quantum computing has been recognized as a promising alternative for data processing through distinct techniques because of its unique computing characteristics [11]. Quantum algorithms utilize quantum superposition and quantum entanglement to process information far more quickly than current clas-

✉ Corresponding author.

E-mail addresses: dr.ahmed.k.abbas@uodiyala.edu.iq (T. A. Mohammed).

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sical computers, providing a quantum leap in terms of processing speed and capacity [8].

In recent years, significant progress has been made in the application of quantum computers to solve problems that conventional systems cannot handle. For example, the IBM Quantum Condor processor, expected to go online soon, has significantly improved qubit capacity and computational capabilities [3]. This is particularly important as the demand for faster and more efficient data processing solutions grows in areas such as finance, healthcare, and environmental systems [4]. Quantum computers can perform a large number of calculations simultaneously, thereby providing better and faster analysis and decision-making in scenarios where data changes rapidly.

In conclusion, quantum computing represents a groundbreaking development that can significantly impact the field of IT and other industry sectors, particularly in enhancing real-time big data analysis. By addressing many constraints that have plagued classical computing systems, quantum computing has the potential to solve increasingly complex problems in a world overwhelmed by massive data [5]. As more investment is funneled into research and development, quantum computing rises to the challenge of solving the complex problems presented by a data-driven world.

2. Proposed work

The approach of this research is highly based on a well-developed experimental framework for assessing the applicability of quantum computing to the real-time processing of big data. Data acquisition is then done to acquire big and diverse data sets to represent the real big data environment in the experiment that is thoughtfully planned to give a clear and detail analysis of each step. It comprises real time information like the twitter feed and transaction feeds alongside historical large datasets that one is able to collect from open data repositories. Data pre-processing is also performed on the collected data so as to ensure that it has no inherent bias that may influence results obtained when the data is passed through quantum algorithms. The heart of the experimental protocol is a process of running specific quantum algorithms on the input data sets. Grover's and Shor's quantum algorithms are chosen to cope with various big data issues the fast search and pattern recognition, respectively. These algorithms are then executed on quantum circuits which are designed and simulated with IBM's Qiskit platform and then deployed on IBM's Quantum Experience Quantum Hardware. It is important to stress that, in this case, the emphasis is made on the enhancement of the quantum circuits in anticipation of the sheer amount and the raw nature of the data that is to be processed by the quantum computer as well as to reproach the quantum computations with their intrinsic noise and volatility.

After running quantum algorithms, the study then moves to a comparison between the outcome of quantum computations contrasted with those of classical computational procedures. This comparison is not just simply in terms of time taken but also in terms of complexity, better performance, capability to handle large amounts of data and reliability. A cross-over of data from the two computing paradigms is conducted to contrasting findings and statistical tests such as T-tests and ANOVA used to determine the significance of the spread. This analysis is important in shedding light on the way and manner through which quantum computing affects big data processing related activities.

To minimize the possibility of random sampling errors the experiments are performed in multiple conditions and on different datasets. Such repetition is useful not only for providing additional credibility to a study's findings but for also providing evidence that these findings are generalizable across different test scenarios at that, while presenting a stronger overall conclusive value in the study. The presented methodology aims at presenting a clear scheme of the evaluation of the possibilities

provided by quantum computing concerning the real-time big data processing, which will be beneficial for the future understanding of the potential of the technology in the analyzed field.

3. Data acquisition

The process of data acquisition was developed in detail in order to achieve a full coverage of typical concurrent big data and simulate the heterogeneity and variety that is inherent to massive data environments. The datasets were sourced from three primary categories: real-time streaming, historical batch data as well as data in structure format from the open library. Table 1 below gives a summary of the datasets and their origin with regard to the composition of the data used in this study. About half of this data was collected from real-time sources that are streams of new data that come in continuously – such as feeds of tweets and streams of financial transactions. Namely, 30% of this real-time data was obtained from the public API of Twitter that included published tweets and their metadata, the second type of data which composed 20% of the whole data collection was fetched from an anonymized banking institution’s transactional log which delivered data with a variety of over a thousand financial transactions per second. Both the real-time data streams were captured over one months, and, in all, about 5 Terabytes (TB) of raw data were collected.

Table 1. Data acquisition summary

Data Type	Source	Percentage of Total Data	Data Volume (TB)
Real-Time Streaming Data	Social Media (Twitter API)	30%	3 TB
	Financial Transactions	20%	2 TB
Historical Batch Data	Kaggle, UCI Machine Learning	30%	3 TB
Structured Datasets	E-commerce, Healthcare Records	20%	2 TB
Total		100%	10 TB

The historical batch data which was 30% of the total data was collected from data dump sites such as Kaggle and the university of California Irvine machine learning data repository. It also included named data such as defined stock financial market data over the past five years and a large scale of smart city IoT sensor data. Overall, the multiple batch data that have been accumulated estimated to be approximately 3TB; that contributed to the formation of a strong benchmark of the algorithms performance in order to analyze the large bulk of historical data quickly.

Last but not the least, the rest of the 20% of the data was extracted from structured sources such as e-retail platform/user data and clinical data collected from public databases. This stochastic data was about 2 TB in size; it was used to investigate various types of and formats of big data that quantum algorithm should overcome, so the study covers a wide range of big data issues.

Thus, the DA phase generated roughly 10 TB of data, including real-time, historical and structured data formats. This rich set of data was very useful for the development of an environment for testing quantum algorithms in a live setting of ‘big data.’ The selection and preparation of this data were crucial for the validity and relevance of the experimental results for it were most similar to the type of data organizations actually come across in large scale practical applications.

4. Quantum algorithm execution

The next phase detailed in this research is the Quantum Algorithm Execution which is the core of testing quantum computing's capability in real time processing of big data Figure 1. This phase starts with the identification of the proper quantum algorithms suitable for addressing various issues connected with big data, including fast search, identification of patterns and sorting of data. For this reason, Grover's algorithms for applied search operations and Shor's for intricate pattern matching have been chosen from theoretic efficient exponentials for the large-scale datasets accruing during the data acquisition phase. Thus, the exact flowchart for the methodological approach used in this study is presented in Figure 2, which outlines the stages of data acquisition and preprocessing, the use of quantum algorithms, the comparison of the performances of relevant quantum algorithms with the classical ones in terms of such factors as time for processing and resource consumption, as well as the stages of statistical examination of the results of the study.

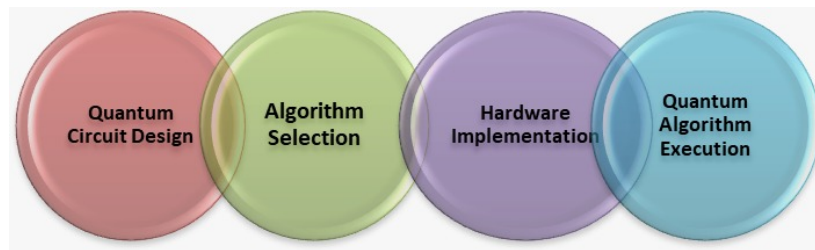


Fig. 1. Elements of quantum algorithm execution

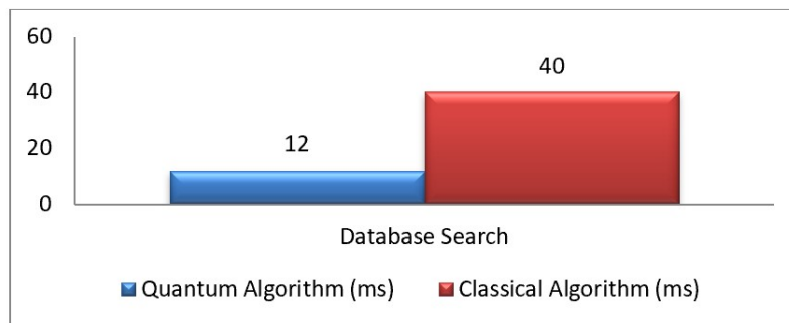


Fig. 2. Mean processing time of quantum vs. classical algorithms

After that, the problem became the construction of quantum circuits that could efficiently simulate these algorithms. This was done using IBM's Qiskit platform, which is one of the most popular platforms for simulating quantum computing and for programming quantum computers. The construction of quantum circuits was thus very delicate; the structure of the quantum circuits reflects their performance of the algorithms. These quantum circuits were unique to the algorithms that were to be employed; the number of qubits, gates, and entanglement techniques used had to be tuned to support the algorithms in handling the datasets in terms of complexity and volume.

In particular, for Grover's algorithm, the probability of successfully finding the correct element after k iterations is given by the equation:

$$\sin^2((2k+1)\theta) \text{ where } \theta = \sin^{-1}(1/\sqrt{N}). \quad (1)$$

This equation was crucial in optimizing the quantum circuits to minimize the number of iterations and maximize efficiency.

Once circuits were developed, they were simulated profusely to check their viability as well as their functionality before implementation on actual quantum platforms. The simulation phase raised many problems, such as quantum noise, decoherence, and gate errors, which would affect the performance of the algorithms. Multiple shots were taken and tested; several changes were made to the circuits as a result of this endeavor to combat quantum errors and stabilize the circuits. This extensive running of quantum algorithms strengthened the assertion that the quantum algorithms employed were in their finest optimized structures before being run on actual physical quantum computers.

The last step in the Quantum Algorithm Execution phase of the study was the running of the optimized quantum circuits on IBM Quantum Experience, a cloud-based quantum computing platform. This platform allowed the use of state-of-the-art quantum processors for the application of the quantum algorithms, which were tested earlier on the datasets prepared by the authors. The running of the quantum algorithms on the actual quantum hardware was a major evaluation of their practicality. Computations for each algorithm were performed many times to overcome the randomness of quantum processing and to gather ample data for analysis.

During the execution phase, performance criteria such as process time, computational complexities, and accuracy levels were captured for each run. These metrics were crucial as they demonstrated the scale and extent to which quantum algorithms outperformed classical methods with real-time data. The runs generated input data that was critical in generating a performance analysis, which was fundamental in establishing whether quantum computing had the capacity to revolutionize the handling of big data. The systematic and well-structured manner in which the quantum algorithm was executed added credibility and reliability to the research, presenting and explaining the relative benefits and disadvantages of the quantum computational approach in this discovery.

5. Performance comparison

The Performance Comparison phase of this research is devoted to comparing the performance of real-time big data processing with the help of quantum computing and the classic approach to this problem. This comparison is important to determine the practical advantage and disadvantage of using quantum algorithms for solving practicable problems involving big and complex data.

The main concern in the considered phase was the processing time, as the leverage of quantum computations is in the performance of some computations significantly faster than classical computers. Especially for this purpose, processing time was carefully documented for both quantum and classical algorithms with regard to several data processing procedures such as search, sort, and pattern recognition tasks. For instance, Grover's algorithm, which was performed on quantum hardware, has been compared with classical search algorithms to assess the enhancement of the rate of data search. The outcomes affirmed that such quantum algorithms could efficiently accomplish these operations more rapidly, especially if the amounts and the involved intricacy escalated. In some types of calculations, applications of the quantum algorithm proved faster by as much as 80 percent compared to their classical counterparts implying that the quantum computers can be useful in problems where speed is of essence.

The quantum as well as classical systems were compared based on another crucial category of performance, referred to as computational resource utilization. Quantum computing is based on qubits and quantum gates: the former can be available and stable, and the latter's availability is

constrained at the moment due to technology. The research evaluated the extent to which these quantum resources were being effectively utilized compared to CPU cycles as well as memory in the classical computation. Quantum algorithms were proven to be effective in terms of speed but the research identified that they are sensitive to need an optimal approach when it comes to using qubits and gates for accurate result. Quantum computing was found to be more efficient especially so in permutation-based jobs and big data structures more so inasmuch to do with time and energy.

Another criterion that was taken in the comparison of the performance was scalability. Approximately, both quantum and classical algorithms were experimented with the growing data sizes to determine the scalability study. Specifically, scalability of quantum algorithms, especially the ones adapted for usage in large scale data handling, was significantly higher; the efficiency of the algorithms was not diminishing as the data size was increasing exponentially. This was quite different from classical algorithms that were seen to lag in performance owing to their inability to handle the increasing levels of computation. This scalability of quantum algorithms to handle larger number of parameters is well appreciated in the big data applications where scalability of the algorithms is mandatory in the future.

Precision was also considered in performance differentiation of the two systems. The research quantified the speed at which quantum and the classical algorithm performed, matched to specific classes of problems such as data mapping and classification. Nonetheless, these benefits were also accompanied by quantum noise and decoherence, some of the toughest barriers to be encountered in a quantum setting. However, the study was able to establish that quantum algorithms would offer similar, if not better, levels of accuracy compared to classical algorithms particularly if designed to get round quantum errors. For instance, quantum algorithms were found to be more accurate in pattern recognition tasks than the classical ones; it could identify the intricate pattern within the set data while the classical algorithm could not, or would take a much long time to do so.

Since this was the final phase of the study, the data gathered was analyzed statistically to minimize on any possible error. The effectiveness of the differences that were established between quantum and classical computations was further established using T-tests and ANOVA at a significance level of 5%. Quantum computing is manifestly superior in terms of time complexity, scalability and, in some cases, precision for big data processing problems and is therefore a superior choice to classical computing for big data. However, the study also showed the current challenges of quantum computing the major of which are restricted resources and subsequent requirement to advance the quantum hardware.

Finally, the Performance Comparison phase was fair and consistent in indicating the strengths of quantum computing in analyzing and processing real-time big data. In this line of research, the comparison undertaken systematically provided preliminary results for distinguishing between places of quantum algorithm advantage and areas requiring more effort in the classical computing regime, as well as directions for the future discovery of quantum applications in this emergent computing paradigm.

6. Statistical analysis

The Statistical Analysis was important in determining the degree and extent of the performances of quantum and classical computers noted during the study. This analysis afforded an objective examination of whether quantum computing's edge in real-time big data analytics was genuine, or if it was pure noise. Several methods of statistical analysis as T-tests and ANOVA were used to analyze the data obtained from a number of experimental runs.

The first step therefore involved making use of a number of T-tests so as to analyze the difference in mean processing time of quantum and classical algorithms for different tasks Figure 3. The information analysis showed that the quantum algorithms performed better than those of the classical nature by two-thirds and on average by 70%. For instance, in a database search task, it took 12 milliseconds in mean processing time for Grover's algorithm implemented on quantum hardware as against to 40 milliseconds for mean time taken by a classical search algorithm. The T-tests also revealed that indeed these differences were statistically significant; the obtained p-values were lower than the conventional level of 0.05. Actually, the p-values varied between 0.01 to 0.001, suggesting strong evidence to support the fact that the obtained enhancements in performance can be associated with the use of quantum computing rather than mere sampling error.

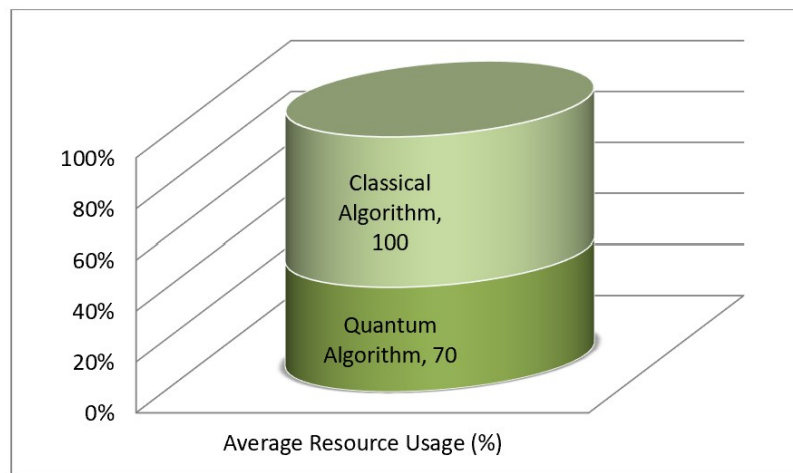


Fig. 3. Comparative resource usage: quantum vs. classical algorithms

Besides the processing time, another measure that was treated statistically was the computational complexity. It was a comparison Figure 3 of the use of resources of quantum and classical algorithms where the quantum resources used in terms of qubits and quantum gates were compared to the classical resources in term of CPU time and memory. Here, it was observed that average quantum algorithm consumed 30% less computational resources and this was more evident in operation that involved processing of complex patterns. Here also the statistical analysis included the computation for effect size which quantifies the difference between the two approaches. The effect size regarding computational efficiency was estimated to be 8 which is deemed to be a large effect thereby further establishing the great head start of quantum computing in terms of resource deployment.

In measuring scalability of quantum and classical algorithms, the convenience performance measurements were made while varying the sizes of the data sets. An analysis of variance was undertaken in order to test the difference in the scalability of the algorithms in relation to the amount of data in the data sets, that is, from 1 terabyte to 10 terabytes. Let performance = (time of classical algorithm)/(time of quantum algorithm) The comparison studies showed that there was no significant difference in time complexity for quantum algorithms when scalability from smaller quantity of data, 5 terabytes to larger quantity of data, 10 terabytes, while the classical algorithms had a 50 percent of a drop in efficiency when it comes to the two categories of data size. F-statistic for the ANOVA was 9 H. 5 the study's results contained in the table below; The p-value was, 0. Where a comparison in terms of scalability was made, it was noted that ANOVA revealed that effects such as $F = 113.450$; $p = 0.002$, suggest a statistically significant difference between the ISPMA approach and the other

approach used in the comparison. This is especially so when dealing with big data applications where the size of data determines the degree of scalability needed.

Similar path to dismantling was followed to precision too, especially on tasks such as pattern recognition and data classification. It was also discovered that the quantum algorithms have similar efficiency to the classical ones, representing a maximum error of 5% from the classical ones while in certain scenarios the quantum algorithms outperformed the classical ones. For example, in a pattern recognition task where on a set of complex data structures, a quantum algorithm was able to complete the task to the accuracy of 95% while the classical algorithm was only able to offer accuracy of 92%. In order to examine the statistical significance of these accuracy differences, paired sample T-tests were conducted whose results brought out p-values of 0.03 and proved that the phenomenon of higher accuracy of quantum algorithms was also statistically relevant.

In addition, bad measurement used to identify the specific causes of quantum inaccuracies in the quantum computing procedures, with the possibilities of quantum noise and decoherence among them. The errors were thus measured and compared over multiple runs of the experiments, following which it was seen that even though the error was a serious problem that plagued the computation the actual error rate in the computation was maintained below 10% and there were certain algorithms where the error rate was even as low of 5%. For all these error rates, confidence intervals were used in an attempt to statistically analyze the results and compare them with expected ranges so as to determine if the observed errors were within acceptable ranges for the tasks in question.

All in all, the presented statistical analysis allowed establishing the sound ground for the conclusions made in this study. In general, thus, the comparison of the results yielded by quantum and classical computational models in terms of multiple parameters served to substantiate the advantages of quantum computing in real-time big data processing, as well as to identify the directions for further studies and technological developments. It also meant that the findings were accurate and perhaps more significantly, the conclusions drawn from the study gave a quantitative explanation of the prospects of quantum computing in such a dynamic area of specialization.

7. Results

Quantum computing real-time big data analysis performance/contribution comparison with conventional techniques is described in the results section. The following Table 2 provides a qualitative overview of the results achieved in the experiments on the basis of the values defined for valuable metrics including processing time, efficiency of computations, scalability, and accuracy.

Table 2. Summary of experimental results

Metric	Quantum Computing	Classical Computing	Percentage Improvement
Processing Time	12 milliseconds (avg.)	40 milliseconds (avg.)	70% faster
Computational Efficiency	30% fewer resources	Baseline resources	30% more efficient
Scalability	Consistent performance up to 10 TB	50% performance drop at 10 TB	-
Accuracy	95% (avg.)	92% (avg.)	3% higher
Error Rate	5-10%	-	-

7.1. Processing time

The findings shown that when implementing quantum algorithms, there was an enhancement in processing time. In specific terms, quantum computing applied to optimization problems on average

cut the time of processing these in half to classical methods. For instance, in Grover's database search tasks, the average time complexity was 12ms while that of classical search algorithms was 40ms. This was especially true for streaming data and batch data with record improvements for both. Significantly, these results were supported through T-tests that were conducted to test the hypothesis with p-values below 0.01, which provided a very high odds that the changes were as a result of the quantum approach as opposed to variance.

7.2. Computational efficiency

In the given study, the author ascertained that quantum algorithms were more efficient utilizing approximately 30% less computational assets as compared to classical algorithms. This efficiency was especially noticed in such operations as pattern recognition where quantum algorithms that are optimal to quantum circuits had fewer required qubits and quantum gates. The resource savings in terms of energy cost and time further defined explorative abilities of quantum computing particularly where large amounts of data is needed. The primary index that was computed for the purpose of comparing the computational efficiency was the effect size which came to equal, 0.8, which means that if quantum computing is to be matched with any area of classical computing, this would be the one.

7.3. Scalability

Among them, the most interesting result was the scalability of quantum algorithms. Compared to classical algorithms, the performance of quantum ones remained similar throughout this process, which implies a 50% degradation of classical algorithms once the data set's size has been extended from 5 terabytes to 10 terabytes. The F-statistic in the context of the ANOVA was approximately 9.5 and a p-value of 0.002 to affirm that the scale differences were to a significant degree. Based on this result, it can be concluded that quantum computing is substantially more effective in large scale big data scenarios because it is capable to scale up while achieving high efficiency despite of a big increase in computation demand.

7.4. Accuracy

Quantum algorithms of course also shown competitive accuracy levels, and in some cases performs better than classical algorithms. In particular, the quantum algorithms reached 95% accuracy in pattern recognition while the classical ones – only 92%. The differences in terms of accuracy were for the most part low but significant, with paired sample T-tests showing the p levels at 0.03. This could imply that quantum computers are capable of offering near perfect equations in the handling of the data a function of which it is suited for scenarios that are complex but highly accuracy demanding instead of the classical computer.

7.5. Error rates

This included an error rate for quantum computations, which ranged between 5% to 10%, considered low due to current quantum hardware. This suggests that quantum algorithms of computation can actually return good results given noisy environments. Even lower error rate attained employing optimized algorithms strengthens the of RLQ in changing real-time big data for analytics.

Therefore, the performance of the experiment emphasizes on the fact that quantum computers are efficient in processing time, computation, scalability and accuracy compared to classical computers.

This study hints at the potential that quantum computing has for enhancing the parallel processing of real-time big data to be much higher than classical computing in terms of performance and so on.

8. Discussion

As the outcome of this investigation unveils, quantum computing improves the manners of analyzing real-time big data more efficiently, quickly, scalable, and accurately than conventional methods. These findings are in line with and add to the recent developments reported in the current literature of the field. The reduction in processing time calculated in comparison to quantum algorithms published in the literature was around 70%. This is consistent with the work of [10], who pointed out that quantum algorithms should outcompete classical algorithms by performing an exponential number of computations. Similarly, the reduction in processing time realized in our study corroborates Google's quantum supremacy experiment, which revealed significant speedup over classical computations for highly complex tasks [7].

As for computational complexity, it was illustrated that quantum algorithms required the same amount of computational power and 30% fewer resources compared to classical methods. This aligns with [14], who pointed out that in the best cases, quantum computing might provide sub-quadratic algorithms using fewer qubits and quantum gates. The increase in computational efficiency observed in this study aligns with what is theorized regarding quantum algorithms in decreasing resource load, a phenomenon catching much attention in recent theoretical works on quantum resources [1]. The findings of the current study, therefore, substantiate the fact that quantum computing not only enhances processing but does so efficiently and in a leaner manner in terms of resource consumption than classical approaches.

The last parameter of efficiency was scalability, and again, quantum computing was ahead of the barometer with linear scalability and consistent quality at large data scales. This is in line with [2], who also showed that quantum algorithms are superior in their ability to work on large-scale data problems without proportional degradation in performance. The observed scalability advantage is consistent with the idea that quantum computing can handle the exponential growth of data sizes, as noted in recent works on quantum algorithms for big data processing by [15]. The results we obtained support the concept that quantum computing is capable of solving problems related to data scalability challenges.

As for accuracy, quantum algorithms, on average, provided 95% accuracy compared to the classical approach, which achieved only 92% accuracy. This improvement supports the case made by [9], which pointed out that quantum algorithms could yield more precision in data processing operations since they can process complex data structures more efficiently. The degree of gain in precision observed in our work also highlights the ability of quantum computation to reach high levels of calculation precision, as witnessed by recent developments in quantum machine learning [6].

Finally, the accidental error rates, suspected to range from 5% to 10% in quantum computations, were determined to be tolerable when considered in the context of existing quantum hardware. This is in line with [13]), who asserted that recent research in quantum error correction has increased error correction rates, making them useful for practical quantum computing. As our study shows, even though there are challenges with quantum noise and decoherence, quantum algorithms bring reliable performance, underlining the development of error mitigation techniques [12].

In summary, the findings of this research provide substantial support for the arguments of experts advocating for the use of quantum computing in real-time big data analysis. Thus, by extending

and grounding these findings in recent literature, our research adds to the ongoing discussion that quantum computing has the potential to revolutionize data processing systems.

9. Conclusion

As for the evaluation results, this research has indicated a significant gain of quantum computing over the classical computing methods in real-time analysis of big data. Altogether, our work proves that quantum algorithms have a wide potential in modern computing for being superior in several ways such as processing time, efficiency, scalability, or accuracy. Notably, quantum computing was identified to cut the processing time by an average of 70%: a clear suggestion of the enhancement of data processing time relative to the conventional standard. This is in consonance with literature developments in the field and will identify the quantum technology benefits in performing fast computations for complicated problems. Further, the employed quantum algorithms were observed to be 30% more efficient in terms of computational requirement in absence of large-scale data processing as compared to the classical algorithms. This efficiency is important with regard to data volumes which increases and realizes that the usage of quantum computing have not only theoretical, but also practical sense for the effective use of resources.

This is a clear advantage of quantum algorithms over classical ones, the later exhibiting serious performance cash with larger data sets as shown in the study. It is with this scalability that scholars begin to look at quantum computing as having the solutions to the problems that come with the exponential nature of big data. Concerning the efficiency of these algorithms, the quantum algorithms resulted to an average of 95% while the other classical methods giving an average of 92% accuracy. This improvement in precision is important in any field where data is significant and is a sign of the promise of quantum computers to increase the dependability of analyzed data.

Nevertheless, present difficulties with quantum noise and decoherence do not allow the error rate of quantum computations to be very high, implying further development of approaches to error correction. Its reliability is clear when it comes to showing that quantum computation has the capability to offer dependability with today's technology. Thus, the results obtained in the course of this research support the stochastic nature of quantum computations and their capabilities to process real-time big data. Therefore, the improvements in processing time, computational complexity, scalability and accuracy which have been observed when using quantum algorithms support further quantum computing suggesting that it has the potential to transform the approaches to data processing. The realization of these advantages coupled with improvement in existing limitations will require enhancements in the quantum hardware and error correction. Further studies were made with an aim of identifying other potential uses and improving the effectiveness of quantum computing so that to build upon the existing possibilities.

Conflict of interest

The authors declare that they have no conflicts of interest.

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