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# Quantum Computing and its Applications in Healthcare

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# QUANTUM COMPUTING AND ITS APPLICATIONS IN HEALTHCARE

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## I. INTRODUCTION

Quantum computing had humble beginnings as it was only a conception in the 1980s. Richard Feynman struggled to produce a quantum simulation of an experiment on a computer back then, as it would take too long and use too many resources. This led to the idea of a quantum computer because he believed that quantum experiments can be performed on quantum objects. From this point, scientists, engineers, and mathematicians have come together to turn a theory into a product, but there were and still are many roadblocks. Some of the issues lie in the error-prone computation for the computer, as quantum algorithms haven't yet been fully developed to prevent errors for this new technology. Another issue is related to the scalability of the technology. Since these chips have components working with the literal smallest particle possible, there are manufacturing difficulties. But, even with these problems, people from other fields are already looking into the application of these computers since they can compute data and train artificial intelligence models so quickly. Producing more than a third of the world's data annually, the healthcare industry is a leader pushing the advancement of quantum computing.

With the emergence of quantum computing as a new field, new ideas come to fruition as to how to apply these new types of computers. Originally, as an idea to simulate quantum mechanic phenomena, this computer would tackle the problem of Moore's law as transistors on microchips become too small to allow for better performance. Since quantum computers can process and compute data at exponential rates, it is now being considered how to implement this technology into the healthcare industry as this market as its data capacity needs increase every year.

## II. Motivation and Explanation for Quantum Computers

With more than five trillion terabytes produced in 2020 from healthcare alone, there's a demand for data processing power and the ability to make use of that information. But with so much to process, there is a price to pay and that is the time required as well as the energy cost of processing the data. Quantum computers compared to classical computers consume similar amounts of energy, if not more, per unit of time. But, because an exponentially greater amount of data is processed through quantum computers, significant energy saving is observed in the power per unit data ratio (Józefowska, 2022). Still, the only reason quantum computers consume so much energy is mainly due to the refrigeration needed to cool down the processing power of the computer (arXiv, 2019).

Because quantum computing is evolving so quickly, there have been many iterations that the design of the computer has gone through to potentially increase performance. The advantage of the processing power comes from the property of the quantum bit (qubit) in quantum computers compared to the normal bit in classical computers. A bit can only exist in 2 discrete states: 1 or 0. Many know this as a binary state, and this is where qubits take advantage of computing power. A property of qubits can exist in infinitely more states than a bit because of the property that it can be in superposition (having states between 1 and 0). With so many possible states, a qubit can hold much more information. This is only possible because of the property that these qubits can be added together to form a discrete value which can be compared to the output of a classical bit. Physicists call this property interference. Finally, the quantum entanglement phenomenon gives the qubits exponential computing capabilities. When a qubit exists by itself in superposition, depending on the state it is in, it may have different probabilities of being 1 or 0, and this probability is independent of any other particles. That is until they are entangled together so that the change in one state of a qubit will affect the probability distribution for what values it can be. Thus, this entanglement produces that for every n qubit, it produces an output equivalent to 2nbits (Horowitz & Grumbling, 2019). The discussion of the mechanism in which quantum computers operate can go deeper, but that is outside of the scope of this paper. For further interest, the types of quantum computers already produced are superconducting, optical, quantum dot, trapped ions, color center, neutral atoms in an optical tweezer array, topological, and electron-on-helium, with others still in the production stage (Jaschke, 2023).

## III. Applications of Quantum Computing in Healthcare

With quantum computing being the newest and most powerful machine today, scientists are still finding ways to apply these fast calculators. The nature of the technology age today is that most, if not every industry, produces a significantly large volume of data and this has led to the creation of a completely new industry called big data analysis. By utilizing this data, companies have found ways to improve their infrastructure and operation. Some examples could be the NBA using big data to win more games (Petra, 2020) or Walmart outcompeting Kmart to a point where Kmart is no longer in business by using data to optimize its supply chain (Leinwand & Mainardi, 2014). It's clear that there's a demand for data to be processed, and with the healthcare industry producing more than a third of the world's data, the integration of quantum computing into this industry would make a significant impact.

*Diagnosis Assistance and Precision Medicine*

According to Rodziewicz et al. (2022), 40,000 to 80,000 patients are misdiagnosed annually across all medical specialties. Medical malpractice is one of the common causes of injury or death in the United States (Rodziewicz et al., 2022), and so it's important to have a mechanism preventing this. The ability of quantum computers today to rapidly process data will not only enable physicians to rapidly make treatment plans through assisted diagnosis from the computers, but will also increase the accuracy of the diagnosis by eliminating chances for human error. Apart from this, quantum computers can continuously analyze and monitor patients which enables early detection of potential diseases (Rasool et. al., 2021). This idea of early disease detection is also related to precision medicine where genetic information is processed using modern computational techniques to provide specific treatment for the individual. Quantum computing can drive this endeavor to reality because of the sheer computing power and speed at which data can be processed (Maheshwari, 2022). After implementing quantum computers into the operation of a healthcare system, it is predicted that treatment costs can be lowered while also improving the survival rate for patients, according to Rasool et al., in 2021. That is because time spent on diagnosis patients is relieved from physicians, and early detection will also aid in later-stage treatment which is typically more expensive.


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*Research and Simulated Atomical Models*

Machine learning is one of the greatest tools for medical researchers and scientists. Computation techniques and algorithms have accelerated the discovery process of new drugs and our understanding of biochemical interactions to further medical and biological research. With the advent of quantum computing, scientists are developing ways to perform machine learning on these computers. Not only will even more discoveries be found, but the rate at which researchers can find them will increase significantly (Rasool et. al., 2021). One clear example is the use of quantum computers during the COVID-19 pandemic which aided in developing the vaccine and also in managing medical inventory when there was a sudden rise in medical equipment usage (Pathak et al., 2021). Ultimately, a better understanding of protein interactions can stem from the computing capability of quantum computers leading to a better understanding of diseases, how they form and evolve, and a better synthesis of medicine.

*Cost and Supply Chain Analysis*

Stemming from how quantum computing aided in medical inventory management during the COVID-19 pandemic, supply chain operations are also a major problem experienced by many other industries. During the pandemic, various companies closed and to this day strict shipping policies remain due to the pandemic as well as the inflation observed in the economy. This has led to a greater need for companies to find more cost-effective ways to receive resources as well as manage inventory. This task and the added expectation of maintaining customer satisfaction have been a great challenge. Efforts have been made to implement quantum computing to solve supply chain problems such as canonical inventory problems (Jiang, 2022) and issues involving logistics and optimization (Gachnang, 2022). The results shown are promising for solving these problems at an unprecedented speed. Therefore, if applied to the healthcare industry, limitations such as medical equipment shortages or drug shipment logistics can be solved to increase the safety of physicians, increase the survival rates of patients, reduce costs, and reduce patient care time (thereby increasing patient turn-around rate, maintaining high customer satisfaction, and many more benefits with the advent of quantum computing).

Solving the supply chain problems can already do so much to reduce costs and help healthcare providers, and yet there are more ways cost can be reduced while also increasing customer satisfaction. Quantum computing, as previously mentioned, can provide a more accurate prognosis. This will reassure many parties: the physician, the patient, and the insurance company. Because everyone is more informed, insurance premiums have the potential of being lowered (Rasool et al., 2021). The problem of providing more accurate health results is ongoing, to which the entire field of “health analytics” is dedicated. As described by Nguyen and Lu in 2021, insurance expenses can be reduced with the condition that there are more accurate health results. However, this source speaks from a classical standpoint without the consideration of quantum computers. Progress that has already been made using classical methods and quantum computing will only further health analytics with faster computing and machine learning capabilities. According to the Department of Justice, over $1.4 billion of alleged losses were fraudulent in 2021. Without the use of advanced data analytics, a significantly large amount of money may be stolen from patients, the government, and various other healthcare firms, which could lead to a higher cost of care. With better fraud discoveries, more money can be saved leading to increased customer satisfaction. Di Pierro and Incudini propose that quantum machine learning can achieve greater fraud detection results. Healthcare fraud can also be detected more quickly with the faster processing power of computers. In 2022, Tapia et al. were able to perform quantum machine learning on a single qubit computer architecture and match the performance of state-of-the-art supercomputers today. This has major implications for the future of quantum computing considering that computers with more than one qubit can outperform present-day technology and further the endeavors of fraud detection.

*Security*

According to Nguyen and Lu (2021), some of the biggest challenges that big data analytics face in healthcare pertains to the privacy and security of healthcare data. With technology becoming more of an integral part of any operation, there are more exchanges of information to outside companies that manage data. But many limitations exist to maintaining data security as healthcare firms are aware of a string of high-profile breaches and hacks in recent years. Executives have to make tradeoffs, but with quantum computing and new encryption algorithms, these companies will have to worry less about the possibility of data being leaked into the public domain. Novel methods for encrypting data using quantum computers have been observed to secure data to a high degree by disabling breaches using classical computers (Kuang & Perepechaenko, 2022; Li et al., 2019; Gong et al., 2020). These algorithms are secure yet lightweight enabling data to be transferred with a small footprint and low computational complexity while maintaining high security.

It is also important to begin implementing quantum computing as a security precaution because endeavors have been made to decrypt current cryptography methods. RSA encryption is a standard cryptography scheme that is used in numerous applications including healthcare data encryption. Even if this methodology is impervious to classical computers, quantum computers have proved such schemes obsolete (Sharma et al., 2020). As quantum computers are becoming more readily available, all data will be at risk.

*Discussion and Future of Quantum Computing and where to Improve*

As quantum computing becomes more powerful and reliable this can further efforts in reducing the carbon footprint of companies. This will be the case because resources are optimized and quantum computing will be more cost-effective compared to classical computers (Cooper, 2022). One of the limitations of quantum computing lies in resource constraints leading to errors in the computation. But these problems can be addressed through better/error-free algorithms (Fellous-Asiani, 2021). However, this puts quantum computing at a risk as well because quantum computers can be over-corrected still leading to errors. That is why, until there is a breakthrough in computer and architecture design, hybrid quantum computing can be a more robust and viable option which quantum computers may inevitably become to solve the world's biggest problems (Herman, 2022). Other issues pertaining to the development of these are related to the input/output of data. There is no efficient way of translating digital data into analog quantum data for computation. That is due to the absence of a reliable temporary memory for the computer to use (Horowitz & Grumbling 2019).

The current limitations in the construction of a quantum computer lie in the nature of quantum particles being highly sensitive leading to being noise prone, and the inability to load large amounts of data as stated regarding no form of temporary memory. Reliable algorithms for data encryption and data processing are a challenging endeavor. Because quantum computers are inherently analog, there is no definite interface to interact with the computer itself.

## IV. CONCLUSION

There have been great breakthroughs in the development of quantum computers. Every day, there are new ways to implement quantum computers and new discoveries which improve computation performance. This paper served as a source to bring a multidisciplinary perspective to the world of quantum computing and how it can be applied to healthcare and improve the state of the industry. Though quantum computers may not be ready to be implemented into public operations, scientists and businesspeople need to begin considering ways to reduce the time/cost to integrate these systems as well as preventative measures for a time when quantum computers become more accessible to the public.

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