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At The Intersection of Medical Robotic Surgery and Drug Discovery with Quantum Computing

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Abstract

Classical natural language processing (NLP) has been successfully modeled and implemented to enable robots or chatbots to have some understanding of human languages and communication, but this has not been very effective to help the robots communicate effectively. Quantum computers introduce a multitude of new ways in which more highly complex and integrated robotics modeling and computations can be achieved, delivering finer control in robotics use cases with humans.

As mentioned in articles "Genome assembly using quantum and quantum-inspired annealing" "The pandemic highlighted the importance of and breadth of robotics applications, shining a light on a potential robotic future in healthcare, which we discuss here", there is a lot more to explore in quantum computing. However, in this study, we will present how quantum robotics can help in developing superior surgical techniques where robots perform advanced medical surgeries, with a more sophisticated, faster, less intrusive process that achieves more successful patient outcomes in complex surgery processes that might otherwise take repeat surgeries with multiple human medical teams. This approach will include the use of quantum natural language processing (QNLP) [1,2].

1. Introduction

Quantum computers are being designed to hold the future of advanced computing technologies for human advancement. These next-generation systems have yet to be realized, physically. So, there is much room for interpretation in terms of how quantum computing will advance alongside robotics and medicine [3]. Areas "end-to-end AIdriven drug discovery system" [4]. "The notion of reinforcement quantum annealing (RQA) scheme in which an intelligent agent searches in the space of Hamiltonians and interacts with a quantum annealer that plays the stochastic environment role of learning automata [5]." "Electronic Skin Lets Humans Feel What Robots Do--And Vice Versa as we explore an integration of soft materials, sensors and flexible electronics is bringing robotic "skin" closer than ever to reality." are just sever of many leading-edge and potentially related areas of exploration for healthcare and medicine where applied and advanced quantum computing can shine. However, there are several key areas of quantum computing where the advancements in computing directly impact the accelerated advancement of both robotics and medicine. In this paper, we jointly provide a point of view regarding advancements where robotics can converge with quantum computing to realize a significant advantage in patient care and outcomes. We are already seeing this today in some of the newer surgical robotic-like tools one of which is the Davinci [6].

To explore this as the yet uncharted area of human potential advancement in a focused area of medicine we leverage a new evaluation framework that organizes the results of our research and analysis in this area from an emergent, quantum computing perspective and emphasized the importance and relevance by cross-referencing against some of the latest efforts documented in the field to date. To achieve the above we will be focusing closely on the very latest in surgical robotics that is underway today. Reflecting on the industry's "current state" of surgical robotics and lensing that over the future of what quantum computing can help make possible or realize. This generates several different types of applications for quantum computing and surgical robotics and at least one possible development in the joint fields that we will also explain.

Our goal is to be as informative as possible, from a forward-thinking perspective, and share one research viewpoint on the significant potential of this intersection between quantum computing, robotics, and medicine. The current state of quantum computing is still very emergent and nascent. So, it is very much a new frontier of science where anything may be possible. Many researchers are still working to understand design and engineering options as the initial quantum bit processing achievements could support.

Robotics, on the other hand, has been a much longer and more established area of research. We have been making progress gradually within the field of robotics to provide increased robotic assistance to mankind. Some examples of leading-edge robotics that could hold the future for both quantum computing and medicine, include earlystage system prototypes like ATLAS that can complete work in some ways as a “human-robotic assistant” [7]. Making all this happen within the context of new and emerging quantum computing will take more time and significant effort. Additional research and design iterations will be needed to hone in and optimize a solution that works well for mankind.

Medicine is continuing to advance in both surgery and pharmaceuticals. Both areas of medicine would benefit significantly from advances in Quantum Computing by enabling medical professionals to more rapidly identify and address patient care, new drug development, and faster surgical healing processes.

The detailed work of surgical robotics will require highly complex command language that instructs minute and very fine movements of surgical activity within the human body. The more complex the procedure, the more sophisticated the device must be, including checks and controls against human error, a programming error, and system malfunction. Quantum computers will have the ability to work with much more sophisticated and dynamic programming requirements. New models developed on a quantum computer could help “map out” more advanced surgical processes for practice, development, training, and testing with one or more surgical robotic prototypes. So, the technology of quantum computing can provide a significant accelerator to surgical robotics.

How this is done, at the core, will require some form of analogy to “system memory” as we have today in classical computing systems. While the methods, architecture, design, and implementation of a quantum computing memory can and should be vastly different from classical computing systems today, it is this step in the direction of a new form of memory that can advance the more complex surgical processes in near real time delivering incredible value to the field of surgical robotics and human healing.

2. Quantum Computing Tech

Based on the above areas we have already covered for quantum computing advancements, it is reasonable to lightly touch on the main aspect of technology within a quantum computer where it can be applied directly to the relevant areas of drug discovery, medical surgery, Nano medicine, and robotics as covered in the prior sections.

On technical feature of quantum computing that will likely have the most widespread impact to our areas of focus in this article and many more are the faster processing times for complex computing.

At the core of the quantum computer lies a mechanism for faster-than-classical, real-time, simultaneous, and concurrent, complex processing that does not currently exist in today's classical computers. This advancement is based on an underlying physics principle called a superposition of state. This qubit superposition of states operates within a quantum computer engine. It drives the resulting calculations such that one qubit can process many aspects of information all at once. Consequently, this makes long-running and more complex calculations happen exponentially faster. In this way, complex modeling cannot do today on a classical computer because it would take many more years to complete the computations. Some even span multiple lifetimes and could happen in a few years comparatively, on a quantum computer. Daley also alludes to this desired capability in his paper titled "Practical quantum advantage in quantum simulation“Daley. So, we can know the answer and results in a timeframe that is coherent for human consumption.

3. Robotics Intro

Robotics have been in the articles for a century, the word “robot” was credited to a writer Karel Capek, who used the word literally to refer to the feudal forced laborers in Slavic languages, over a century ago [8]. The origin of the word "robot" also shared more insight into the purpose of a robot; it should be used to complement human effort or assist humans in various tasks or capacities, without any appropriate rights associated with the robot. A robotic system is a system that operates on basic robotic laws, one of which is to execute the instructions provided to it by humans [9]. Asimov introduced three basic laws of robotics in 1964.

- A robot may not injure a human being or, through inaction, allow a human being to come to harm
- A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
- A robot must protect its existence as long as such protect on does not conflict with the First or Second Laws.

These laws formed the foundation of ethical robotics systems. Over the years, all robotics designers have obeyed some or all of these laws, some government institutions also introduced robotics ethical policy to guide against any advancement in robotics design that could later harm human beings or contradicts the laws or norms of a society [10]. The field of robotics is not isolated from other machine intelligence systems, there has been researched into how to make non-living devices to simulate human beings or their routine or procedural tasks, this led to the introduction of Artificial Intelligence (AI). Artificial Intelligence as a field that encompasses all automated devices or humanlike machines including robots was first described as machine intelligence by McCulloch and Pitts in 1943, which was later broadened by Turing in 1950 [11].

Artificial Intelligence has developed beyond academics; it has become a household item and penetrated all our daily activities. The advancement in AI has also helped to develop more intelligent robots, creating industries that supply robots to replace or support laborers in industries. In the early adoption of AI, there were different classifications of AI based on the tasks or specific problems that they can solve. In the 1960s, Eliza Weizenbaum introduced a rulebased system that led to the first chatbot in 1964, created by Joseph Weizenbaum at the MIT AI Lab [11]. The classifications of early AI are based on Symbolic AI, which was the beginning of intelligence representation: Automatic Theorem Proving (ATP), Expert System (ES), and Knowledge Representation (KR). The symbolic AI declined over time, and there was a new AI representation based on human cognition or brain, Artificial Neural Networks, as new variations of AI, called connectionist AI, which is divided into "Perceptron" and Back Propagation (BP) in the early 1990s [12]. In 2006, the Artificial Intelligence field saw a dramatic shift from earlier limitations of AI to more fulfilling algorithms and techniques for training machines with big data, deviating from original Machine Learning algorithms to Deep Learning algorithms that provided efficient ways of training machines in layers with billions of parameters to create models for future training or deployment through Hilton's work with his students over the years. This research broadened the Artificial Neural Networks with new algorithms [13-15].

- Convolutional Neural Networks (CNNs)
- Recurrent Neural Networks (RNNs)
- Graph Neural Networks (GNNs)
- Quantum Neural Networks (QNNs)

4. Quantum and Classical Natural Language Processing

Classical natural language processing has been successfully modeled and implemented to learn, translate, and recognize human speech or communication. Recent researchers have shown that Natural Language Processing (NLP) in quantum computers can provide the exponential processing power needed for a robot to process natural languages quickly and efficiently [16]. Adopting quantum natural language processing with some machine learning algorithms will help machines to understand texts, image classification, and voice recognition and construct grammatically correct sentences faster and more efficiently [17].

Developing intelligent robots that will have close to human cognition may not be possible with classical computations, simulating such cognition will require a more complex computation that is only realistic in the future quantum computers when robots can have human-level intelligence and intuition [18]. Language is one of the most essential components of deriving intelligence by learning, having categorical compositional distributional semantics for natural language modeling helps to understand the relationship in corpora of texts [19]. There have been various applications of the categorical compositional distributional (DisCoCat) model for connecting semantics and pre-group grammars with a deep root in computational linguistics [20]. Due to the enormous computational resources required to infer sentence meanings, or represent corpus semantics graphs, the quantum circuit model is used to model natural languages on quantum computing hardware [21].

In recent years, the advancements in quantum machine learning have expanded the hybrid of classical and quantum machine learning algorithms to solve complex tasks like language understanding, and the construction of variational quantum circuits (VQC) with an optimizer proves to be valuable on Noisy Intermediate-Scale Quantum Computer (NISQ) [22]. Quantuminspired robotics design should have more ability to represent and process information than classical counterparts, multidimensional vectors in Hilbert spaces using the quantum superposition principle is essential to developing such quantum cognitive models [23]. As the study illustrates, describing the general overview of quantum cognition as an important part of building an intelligent robot with near-human intelligence, having algorithms to improve natural language processing in quantum computers will help to realize the next generation quantum inspired robotic devices or machines.

Quantum Natural Language Processing (QNLP) is a relatively new field of study in Quantum Artificial Intelligence (QAI), there's no sufficient research or resources to establish how this is going to be more efficient than Classical Natural Language Processing Language (CNLP), but in theory, based on the computing power of quantum computing, the research community believes that QNLP on near-term NISQ systems will improve language processing, translation, and understanding. Quantum Machine Learning (QML) which is the superset of the QNLP is also very new, researchers have tried to experiment with QNLP by exploiting quantum principles like superposition, entanglement, and inference to perform linguistic processing on quantum hardware, despite the limitations of quantum qubits, a python library (lambeq) developed by the quantum community has been instrumental in preparing the future of QNLP [24].

Another interesting research area is Learning Transfer; this is a common methodology in classical machine learning, where a trained model can be transferred to another model to facilitate inherited learning features of existing models. Jun & Javier described how such classical techniques could be used to create classical-quantum transfer models, by using this technique; we might be closer to bridging the gap between near-term quantum computers in QNLP [25]. They further explained how such can become an emerging technology in QNLP if quantum neural networks (QNN) and convolutional neural networks can be used to create feature extractions for spoken words, thereby enabling language recognition for future robots. As part of their illustration, pre-trained classical models were modified to model a fine-tuned algorithm using quantum vibrational circuits [26]. This is an essential finding, with this technique; the future of QNLP is more promising than being seen as a mirage. We want to conclude that, both CNLP and QNLP will have to be integrated with some form of hybrid-C/QNLP on any NISQ system, in the future, QNLP may be able to stand independently of the CNLP when the quantum hardware has developed beyond NISQ-era.

5. Quantum Robotics

Quantum robots may sound like alien grammar, but this is a new brand or generation of robots that are very fast compared to their classical robots' counterparts. A Quantum robot is a complex quantum system composed of multi-quantum computing units (MQCU), a quantum controller/actuator, and information acquisition units. The idea of theoretical quantum robots was first introduced by Benioff. Raghuvanshi et al. demonstrated the application of classical sensors and motors to design quantum-controlled robots. In this article, we will refer the today's robots as classical robots, while the future robots will be referred to as quantum robots. The classical robots operated based on pre-programmed algorithms, the performance of these algorithms is analyzed with classical computing asymptotic analysis that illustrates how efficient is one algorithm over another. Any medical robot is designed with this understanding; the ability of the robots to respond or perform a task depends on the efficiency of the algorithm. Algorithm complexities are mostly classified as space and time, where space is the storage and time is how long to operate within the space. The classical robotics algorithms have limitations that the quantum robotics algorithms will address, the quantum searching algorithms as an example can complete a complicated search task in O(N2) while the same task will take O(N√N) in the classical searching algorithm.

In 2007, Raghuvanshi et al. proposed quantum controlled Braintenberg vehicles in a mobile quantum system that performed tasks as a robot and expresses some human-like behavioral traits or emotions. This is an example of quantum enabled robots that exhibits higher performance than classical robots. Like classical robots, quantum robots require extensive learning algorithms to manipulate some inputs and derive actionable tasks that the robots can perform, Dong et al. proposed a quantum reinforcement learning algorithm based on Grover algorithms for searching contextual data used in training robots. The recent advancement in classical artificial intelligence has provided quantum robotics researchers with extensive journals to study how similar AI algorithms can be ported to quantum computers, quantum-inspired generative adversarial networks (QGAN) was used to train robots on COVID-19 epidemic strains by manipulating GAN-style discriminator to adapt SARS-CoV-2 RNA predicting the possibility of mutations of any COVID-19 variants.

The quantum community has a strong belief that any quantum-enabled implementation stage will be far better than any corresponding classical stage, the enormous computing power to be achieved in quantum computers will always provide an upper edge over a classical computer running the same implementation. It is with this belief that we are investigating what the future of robotics will be if we were to adopt quantum algorithms to existing classical algorithms used to control and manipulate robots today. Current robots are already designed with Quantum mechanics principles, and the development of micro-electronics and microchips helped the researchers to create robots in use today, we want to establish our thought as well, that the Quantum robotics hardware may not be different from the current hardware used to construct or design today's robots. Quantum robotics is also a new specialization in Quantum computing, it will take some years for it to fully develop, the more we have researchers interested in developing faster and smarter robots, we can expect a leap in this field.

The development of cloud-based quantum computing software or algorithms can help to provide robotics intelligence as a service (RInaS) to serve the robots in the future.

6. Medical Surgical Robotics

The last few decades have witnessed the advancement in assisted robotic devices across all major fields of medicine, especially in surgery and clinical care to support human experts in carrying out some delicate procedures with no or minimal errors. There are many procedures by category that robots can carry out from open to minimally invasive surgeries. In 1805, the first robotic-like innovation was invented cystoscope with the use of Bozzini's cystoscope, which allowed endoscopic exploration. After many decades, the invention of digital cameras helped to remove the eye-based endoscopes, the invention of the Hopkins Rod endoscope used the camera to peer through endoscopes, this was the beginning of the robotic monitoring devices that aid surgeons during procedures. The most common medical robotic devices are developed by the da Vinci registered Surgical robots, revolutionizing medical robotics with high precision and minimal human support [27].

In Minimally Invasive Surgery (MIS), surgery can be performed with a very small incision without any noticeable opening in the body, with high precision, less pain, and faster recovery compared to open surgery. This kind of procedure requires guided assisted devices to avoid any surgical errors that can lead to complications or death, assisted robots are used to perform most of the MIS surgical operations [28]. In modern cyber warfare, it is prevalent that many bad actors will want to hack anything that can offer them leverage to extort victims of resources or money, surgical robots are not exempted from this threat as well, with about 20% or more yearly increase in medical robots developed, the invention of tele operated robots promises highly secure transmissions of data between surgeons and the remote robots to counter any cyber threat due to the wireless networks used by most robots in the hospitals [29]. Another way to minimize any surgical robots being hijacked by the attackers is the introduction of human-robot shared responsibility, without leaving the robots to be fully autonomous, but depending on some human inputs before taking any actions. The procedures to be performed by the robots will be validated by human experts, in most cases, the resident surgeon may not necessarily be a senior surgeon but have the knowledge to demonstrate the procedures to the robots before carrying out the surgery, and this approach is called learning from demonstration (LfD) [30]. The discovery of augmented reality (AR) is another promising technology that empowers robots and human experts to collaborate during and after surgery. Head-mounted display (HMD) system uses AR to guide robots in surgery, this offers the medical knowledge domain to the robots and helped the experts to still be relevant when robots are somehow replacing some of their repetitive procedures, the robots benefit from the years of study that the human expert has spent to be expert in a specialized medical field [31].

We know how important medical robots are in Minimal Invasive Surgery, and how they are increasing yearly with many clinics adopting assisted or guided robots in any of the minimally invasive procedures. The adoption of assisted robots has faced some challenges over open surgery, a robot is a system, and with every system are technical hurdles or faults. Some robots require continuous maintenance by the designers to keep the robots up to date and perform surgeries with the latest discoveries in research and development, leading to more costs of maintenance. Another challenge is the speed of reasoning that humans operated on, sometimes, the robots might not be able to be fast enough to respond quickly to an instruction, which may lead to some errors or gaps in performing the task. The robots require a more sophisticated computing power that can offer faster processing to aid robots' response time to be faster or almost like human pace, the future of robots depends on quantum computing that promises enormous computing processing power than what is possible with classical computing used by the medical robots today.

7. Enhanced Robotic Surgery with Quantum Computing

Robotic surgery has the potential to benefit directly, as a sub-field of robotics advancement, from quantum computing in several key ways as covered in the previous section.

However, humanity is just now starting to realize the benefits of robotic-assisted surgery with systems like DaVinci that have advanced with repeat usage and support. As this capability continues to develop, quantum computing can help open doors to new methods of advanced programming simulation using quantum computers for the programming component. Additionally, more complex training simulations for the robotic controls could be advanced rapidly with quantum computers running the program training robotics. Since fully automated robotics in complex procedures would still require hours of robotic surgical operation, quantum computers could help enhance the control stages needed for more sophisticated procedures that alleviate the need for rotating medical teams.

In addition, some of the strategic benefits of robotic surgery include minimally invasive surgery which can translate into faster patient recovery times and better overall surgical outcomes and a reduction in what is typically referred to as surgical fatigue. With robotic surgery aided and guided by quantum computer programs, for more complex surgeries, it "could be a total game changer" totally avoiding fatigue and increasing procedure safety and success rates [32]

We already have automation in other areas of human treatment. For example, the recent article titled "Globus Medical Announces Frist Surgeries Using Excelsius3D. This solution is targeted for spine surgery [33].

Eventually, progress in robotic surgery could lead to some initial, fully automated surgical robotics in the future.

As we found in the article by PLosOne, new forms of medical teams would be alleviated surgical fatigue that might otherwise impact the treatment process [34]. As a result, the medical teams might have more time to focus on patient surgery prep and oversight, calibrations, monitoring, and ideally, spending much more time on ensuring good recovery outcomes (faster and better healing) for patients, along with post-surgery medical analytics, that can all make a significant leap in treatments and increase the number of patients treated simultaneously and consistently.

8. Drug Discovery with Quantum Computing

Drug discovery with quantum computing is a new and emerging area of opportunity for quantum computers that holds a lot of promise for improvements in new medicines for humanity. In the recent publication “A Medical Informatics View of Quantum Computation” the expert discusses various aspects of gaps where today is medical centers can benefit significantly from a quantum computer. In a recent June 2022 paper, A perspective on the current state-of-the-art of quantum computing for drug discovery applications Nick S. Blunt, Joan Camps Ophelia Crawford, Robert Izsak, Sebastian Leontica, Arjun Mirani, Alexandra E. Moylett, Sam A. Scivier, Christoph Sünderhauf, Patrick Schopf, Jacob M. Taylor, and Nicole Holzmann the team cites various aspects of applications where quantum computing can indeed assist with the acceleration of new drug discovery. The team boils it down to understanding the particle-level chemistry needed to make new drugs and mapping that process to faster-than-ever runtimes using modeling techniques that drastically reduce the time windows from upwards of 5 years or more, potentially, to a few hours.

With these types of minimum-level advancements in the pharmaceutical drug discovery industry, quantum computers are well positioned to help solve some of mankind’s toughest requirements for advanced medicines.

Furthermore, this opens the door to unknown potentials where "New tools (may) enable new ways of working." as the authors in the article, "Accelerating materials discovery using artificial intelligence, high-performance computing and robotics" discuss.

Related more specifically to the subject matter of this article is their section titled “Applying computational creativity to the molecular design problem” where they also address how quantum computation could benefit the discovery of new (drug) compounds via greater understanding, ultimately, of molecular structures leveraging the best of some of these new computing technical techniques and ways of working [35].

Given the fact that multiple teams are studying different applications, and all seem to hold unique promise for drug discovery advancement, quantum computing does indeed play an increasing role in achieving this goal of accelerated or advanced discovery.

9. Quantum Computing – Driving One Possible New Form of Medical “Pairing”

An exciting aspect of discoveries with quantum computers in the medical space that these authors think could be very important to humanity is the ability as these authors identify as the ability to “pair” the solutions with other medical techniques that are also advanced with quantum computing. The ability for, example, to “pair” a new drug discovered with quantum computing to a new surgical procedure that has also advanced with the aid of quantum computing has the potential to significantly revolutionize the end-to-end patient experience in terms of cure and outcomes for conditions treatable in this way.

One example of this “pairing success” could happen in the field of robotics. Today’s surgical robot includes brand-working robotics like that of a device called The Davinci at this time The Davinci is medical-guided robotics. However, it still requires a medical expert to guide and operate the robotic system to complete the surgical procedure. These medical robots are highly specialized and unlike a full, walking humanoid version one of which is called ATLAS, this robot is designed specifically for doctors to operate during surgery to achieve greater surgical precision.

However, in the future, with the aid of quantum computers, it may be possible to have this machine fully automated and without medical personnel operation but, rather with medical professional oversight and observation. This could drastically improve the outcomes of patients undergoing those surgical procedures, specifically, when “paired’ before and after surgery with new and enhances state-of-the-art medicines that help prepare faster, protect stronger, and heal more completely both before, during, and after the surgical procedure. In this scenario, the patient who might take weeks or months to fully recover (no signs or symptoms post-surgery) may be able to do so in days. Getting back to a full and normal life in a matter of days from what was formerly, a major surgery requiring sometimes months of painful recovery time would indeed be amazing [36].

10. Advanced Thoughts: Nano-Medicine Next Gen

Coming back to the field of drug discovery and the potential for medical advancements that benefit drug discovery with quantum computing, we continue to explore how this field could expand with the use of quantum computing.

One additional area of expansion and close consideration would be the sub-field of Nano medicine. Nano medicine offers the possibility of a more precise drug, medicine, or in-stream" delivery model that could target certain conditions more precisely than ingestible drugs.

In this case, the method utilizes different types of more sophisticated medicines or drugs that act directly on targeted internal body systems and structures more effectively. So, these techniques could also be discovered or advanced with the help of quantum computer modeling.

However, Nano medicine, like robotic surgery, is a relatively new method of medical treatment. There is less study-based information on this subfield of medicine yet, it also has the potential to benefit rapidly from the use of quantum computer based medicine or drug modeling, much in the same way that other medicines could be discovered using sophisticated or targeted quantum computer modeling. However, more exploration is needed.

This form of treatment can leverage new molecular structures that could attack harm-causing pathogens from within the body systems rendering instant relief and abatement of destructive pathogen processes without the patient having to undergo surgery or surgical recovery at all.

It can also be extremely successful in situations where surgy would not typically be possible and the treatment or medicine needed to be applied directly to an otherwise unreachable location in the body.

To do this on a more molecular level quantum computer models could help to advance this field of medicine, along with related areas where it is applicable like drug delivery to help provide more effective cancer treatments. As stated by Daley, "Many of the most promising short-term applications of quantum computers fall under the umbrella of quantum simulation: modeling the quantum properties of microscopic particles that are directly relevant to modern materials science, high-energy physics, and quantum chemistry [37]".

So, it is very clear that quantum computing can play a significant role on the computing side as an aid to researchers seeking to model new materials at the Nano level for drug delivery and cancer treatments.

Since quantum, computers can handle more advance and sophisticated or complex simulations and model generations, researchers who might otherwise have to wait a decade or more for computing results could receive the information in days. This could significantly accelerate all the related industries and allow humanity to take advantage of better treatments sooner to save lives and deliver cures.

11. Final Insights & Synthesis

As presented above, advancements in each of these areas rely on the combined industry success with quantum computing. To make this possible many teams of professionals across multiple disciplines are working tirelessly to realize the future of a real and operational quantum computer [38].

Because of the sensitive nature of qubits, the equipment must be developed in highly controlled labs where specific materials are used to create qubits and start to manipulate them in ways that resemble quantum computing. Firms and institutions like the U.S. Department of Energy, IBM, Microsoft, and MIT are all working on their version of a quantum computer [39]. How they achieve it could also differ widely as the underlying physics of qubit technology can happen from different techniques and approaches.

So, there is still much uncertainty and a lot to learn along the way as further research, development, and testing of quantum computing technologies at many institutions and organizations around the globe continues [40].

12. Conclusion

The fields of robotics, drug discovery, medical surgery, and Nano medicine continue to advance and grow in a classical computing way too [41]. As each of these disciplines advances, it continues to add to the enrichment of solutions that are available within the field of quantum computing growth, to help humanity achieve more in future generations.

Quantum computing will continue to make progress alongside the classical computing industry for some time to come. So, there is significant potential for other synergies and advancements that were not covered in this paper, and these are beyond the scope of this point-of-view paper.

As quantum computing technology and capability make further progress toward the operation of a quantum computer successfully, we will continue to monitor the field for new applications to the areas we covered in this paper. Ultimately, we foresee that the more sophisticated goals for humanity that we can attain with a quantum computer will be something to reckon with for decades to come [42,43].

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