QUANTUM COMPUTING IN HEALTH CARE

University of Maryland, Baltimore County
Foundations of Information Systems
IS 601(01.1279)
Dr. Carlton Crabtree
December 5, 2016

Submitted By:

TEAM 7

Jasleen Kaur Gorowada

Kanika Danke

Suraj Vartak

Varun Singh

Table of Contents

Quantum Computing

“Quantum computing in the future is likely to be a computer simulation of quantum systems, because that’s an application where we know for sure that quantum systems in general cannot be efficiently simulated on a classical computer.” – David Deutsch

Introduction to Quantum Computing:

The mix of two of the twentieth century's most compelling and progressive theories, information theory and quantum mechanics, offered ascend to a fundamentally new perspective of processing and information. Quantum computing investigates the consequences of utilizing quantum mechanics rather than classical mechanics to model data and its handling. Quantum computing is not about changing the physical substrate but about changing the notion of computation itself, at the most basic level.

Figure 1: D-Wave’s 2XQuantum Computer

History

The notion of a computational gadget in light of quantum mechanics was initially investigated by physicists, such as Charles H. Bennett, Paul A. Benioff , David Deutsch , and the late Richard P. Feynman. They comprehended that if technology kept on complying with Moore's Law, then the consistently contracting size of hardware stuffed onto silicon chips would in the long run achieve a point where singular components would be no bigger than a couple of atoms. Here an issue emerged in light of the fact that at the nuclear scale the physical laws that administer the conduct and properties of the circuit are intrinsically quantum mechanical in nature, not classical. This then brought up the issue of whether another sort of computer could be made based on the points of quantum physics.

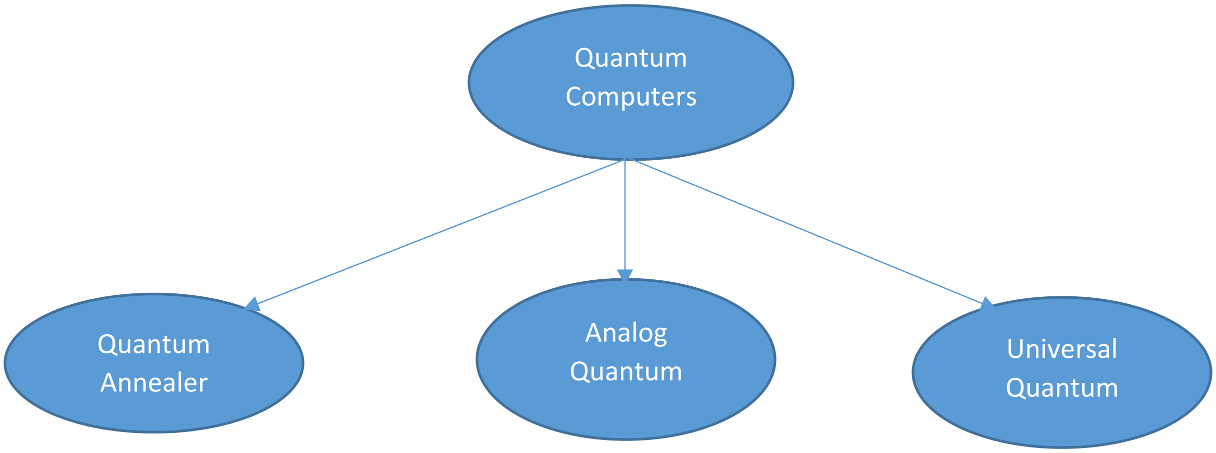
Feynman was among the first to give a response to this question by creating a theoretical model that showed how a quantum system could be utilized to do computations. Shor then set out a strategy for utilizing quantum computers to solve an imperative issue in number theory, specifically factorization. He demonstrated how numerical operations, outlined particularly for quantum computers, could be sorted out to empower such a machine to consider colossal numbers quickly, much quicker than was conceivable on traditional computers. With this leap forward, quantum computing changed from something insignificant to a national and world interest. (“The Quantum Computer”, 2016)

Basics of Quantum Computing

The massive measure of preparing force created by computer makers has not yet possessed the capacity to extinguish our hunger for speed and limit. Quantum Computers are in a general sense different from established computers because the material science of quantum data is additionally the material science of plausibility. Established PC recollections are obliged to exist at any given time as a straightforward rundown of ones. Conversely, in a solitary quantum memory numerous such mixes—even all conceivable arrangements of zeros and ones—can all exist at the same time. Amid a quantum calculation, this orchestra of potential outcomes split and union, overall combining around a solitary arrangement. The multifaceted nature of these huge quantum states made of various potential outcomes make a total portrayal of quantum hunt or calculating an overwhelming assignment.

A classical computer has a memory made up of bits, where every piece is spoken to by either a one or a zero. A quantum computer keeps up an arrangement of qubits. A single qubit can address a state of 0 or 1 or any quantum superposition of those 2 qubit states, two qubits can be in any quantum superposition of 4 states, and three qubits in any superposition of 8 states. Overall, a quantum computer with n qubits can be in a self-assertive superposition of up to 2^n unique states simultaneously. A quantum computer works by setting the qubits in an immaculate float that speaks to the current issue and by controlling those qubits with a settled grouping of quantum rationale doors. The grouping of entryways to be connected is known as a quantum calculation. The figuring closes with an estimation, caving in the arrangement of qubits into one of the 2^n immaculate states, where each qubit is zero or one, breaking down into an established state. The result can consequently be at most n established bits of data. Quantum calculations are regularly probabilistic, in that they give the right arrangement just with a specific known probability. Take note of that the term non-deterministic figuring must not be utilized as a part of that case to mean probabilistic (processing), because the term non-deterministic has an alternate significance in software engineering. (Chuang, Michael A. Nielsen & Isaac L., 2001)

Types of Quantum Computing



Each of these have their own set of applications, generality and computational power.

The quantum annealer is the least powerful and most restrictive form of quantum computer. It can only perform one specific operation and is the easiest to build. As per the scientific community, the quantum annealer has no advantages over conventional computing. It is used for Problem Optimization and has restrictive generality. Its computational power is same as that of the traditional computers.

The analog quantum computer would be able to simulate complex quantum interactions that are intractable for any known conventional machine or combination of these machines. It is believed that analog quantum computer would contain between 50 to 100 qubits. It is said that this would be the first type of quantum computer capable of showing true quantum speedup over conventional computing within next five years. Its applications are in the field of Quantum Chemistry, Material Science, Optimization Problems, Sampling, and Quantum Dynamics. Its generality is partial and computational power is high.

The universal quantum computer has several difficult technical challenges and is the hardest to build but is the most powerful and general one. It is estimated that this machine would have more than 100,000 qubits. It has the potential to be exponentially faster than traditional computers for several applications related to science and business. Its applications are in the field of Secure Computing, Machine Learning, Cryptography, Quantum Chemistry, Searching and Quantum Dynamics. Its generality is complete with known speed up and computational power is very high. (Desjardins, J. , 2016)

Algorithms in Quantum Computing

Quantum Computers are intended to beat standard PCs by running quantum algorithms. A quantum PC is a machine intended to utilize quantum mechanics to do things which needs more than classical physics laws to execute the various functions. Even though large scale Quantum PC's do not exist, the quantum algorithms have been actively studied since the past twenty years (Ashley Montanaro, 2016). Following are the Algorithms in Quantum Computing:

- Simons Algorithm: In 1994, Daniel Simon devised a computational problem namely the Simon's problem in the model of decision tree complexity for computational complexity theory and quantum computing. Simons Algorithm is an Algorithm suggested by Simon that solves problem exponentially faster than any classical algorithm. (Simon, D.R. 1995)
- Quantum Phase Estimation Algorithm: With this algorithm, it is helpful to measure the eigen phase of an eigen vector of a unitary gate provided access is given to a quantum state that is proportional to eigen vector and a procedure to execute the unitary conditionally. (Alexei Kitaev, 1995)
- Shor's algorithm: This algorithm was invented by Peter Shor in 1994 mainly to carry out integer factorization. Shor's Algorithm implementation however goes on to prove that cryptography implemented by the RSA public- key cryptosystem can be insecure if it where to be attacked by a large quantum computer. (Ashley Montanaro, 2016)
- Grover's Algorithm: This particular algorithm is basically used for carrying out searches in database. It was invented by Lov Grover to search a specific entry in an unstructured database using an important technique in quantum algorithm known as amplitude amplification for achieving a polynomial speedup as compared to the classical algorithm. (Bennett, C. H., Bernstein, E., Brassard, G., & Vazirani, U. (1997)).
- Quantum Walk Algorithm: In a classical random walk, the state of a variable is determined by the probability distribution over position whereas in case of quantum computing it is the superposition of positions for the variable. Quantum walk Algorithms are used to provide polynomial speedup and help in element distinctness problems in cases and situations which consist of many variables. (Childs, A. M., Cleve, R., Deotto, E., Farhi, E., Gutmann, S., & Spielman, D. A. ,2003)

Applications in Quantum Computing

In conventional computers, the processing time usually takes a bit longer or even days if there are millions of variables with millions of equations in order to predict certain outcomes. As we know the principles of a quantum computer, where two qubits can simultaneously represent four states and three bits can represent eight and so on, the problem of multiple variables could be addressed in the fields of weather forecasting, Drug design, MRI in healthcare, Cryptography, Machine Learning, and Defense for simulating war scenarios. Following are the list of Fields our group thought where quantum computing could play a big role in the years to come.

QC in Weather Forecasting

The weather forecast process involves taking observations from weather stations around the world, satellites and weather balloons that collect information about humidity, temperature, pressure, speed of wind etc. All this information is converted into variables which are in trillions of numbers consisting millions of equations which are then fed to supercomputers to come up with forecast.

However, to forecast a model which involves trillions of variables a supercomputer usually takes a trillion steps to solve it whereas because of the qubit property a quantum computer will do it in a few hundred steps. Also with the ability to solve problems fast and considering the number of variables involved it would be possible to pose questions to quantum computer like:

- With the current rate of global warming how long will the Ice at the poles last?
- How long the human species will be able to survive on this planet considering the current rate of global warming?
- What concrete efforts should be taken country wise to solve the problem of global warning? (Office, L. H. ,2009)

QC in Health

Quantum computing, which provides far more greater and faster calculation limit than old computers, could take care of exceedingly complex issues in the healthcare area. DNA sequencing emerged in the wake of fast increments in computing power in accordance with Moore's Law. In healthcare sector, quantum computers will "make it less demanding to break down hereditary data and recognize a man's hereditary legacy which can then be utilized to decide treatment choices. As it is geared to coping with a huge number of parameters, a quantum computer should be able to find out the best possible treatment for a given patient, achieving a precise and faster result. ("Quantum computing set to revolutionise", 2016)

A quantum computer will be able to simultaneously test a huge number of possible protein fold structures and identify the most promising ones much more rapidly than any traditional computer in the case of protein folding. Quantum computers can be used for improved disease screening and treatment. Using quantum computers, we can more quickly sequence DNA and solve other Big Data problems in health care. This gives the idea of personalized medicine based on individuals' unique genetic makeup. Using quantum entanglement in one of the most practical applications of the phenomenon to date, quantum cryptography prevents data from being viewed by anyone other than the intended recipient. (Kouzmine, S., 2013)

QC in Cryptography

In other words, it's called as Quantum Cryptography i.e. the science of exploring quantum mechanical properties to perform cryptographic tasks. Quantum key distribution is the best example on quantum cryptography for secured communication.

By using quantum superposition or quantum snare and transmitting information in quantum expresses, a correspondence structure can be realized that recognizes listening stealthily. If the level of listening is underneath a particular breaking point, a key can be conveyed that is guaranteed to be secure (i.e. the busybody has no information about it), for the most part no protected key is possible and correspondence is rashly finished.

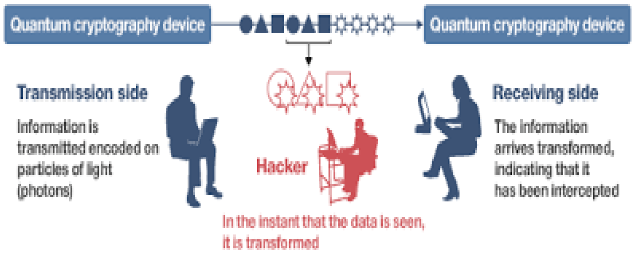

Quantum cryptography device
Quantum cryptography device
Transmission side
Information is transmitted encoded on particles of light (photons)
Hacker
Receiving side
The information arrives transformed, indicating that it has been intercepted
In the instant that the data is seen, it is transformed

Figure 2: Quantum Cryptography

Quantum Communication includes encoding data in quantum states, or qubits, rather than established correspondence's utilization of bits. Generally, photons are utilized for these quantum states. Quantum key distribution misuses certain properties of these quantum states to guarantee its security. ("Quantum key distribution", 2016)

QC in Machine Learning

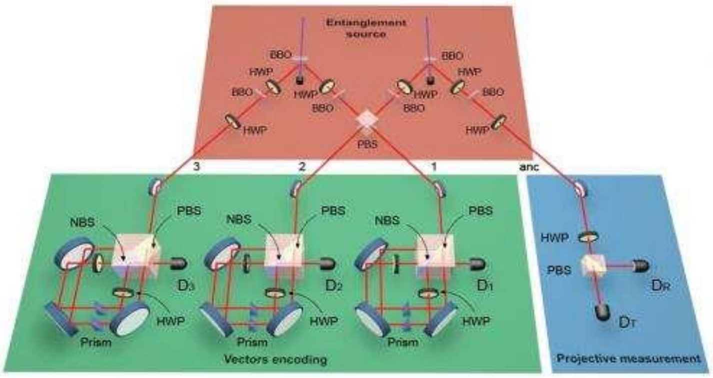


Figure3: Experimental setup for quantum machine learning with photonic qubits. ©2015 American Physical Society

Physicists have performed machine learning on a photonic quantum computer, exhibiting that quantum computers might have the capacity to exponentially accelerate the rate at which certain machine learning tasks are performed diminishing the time from a huge number of years to few seconds. The new technique uses quantum entanglement, in which at least two items are very strongly related that paradoxical impacts regularly emerge since an estimation on one object immediately influences the other. quantum entrapment gives a quick approach to order vectors into one of two classes, an activity that is at the center of machine learning.

By using quantum states to represent vectors, and after that entangling the states before looking at the distance between them. Quantum computers are normally great at modifying vectors. So to do this, they utilized a little scale quantum computer that controls optical qubits, or photons.
In the optical setup, one photon acts about as an ancillary qubit, and is utilized to entangle another photon that encodes both the reference vector and the new vector. The subsequent two-photon entangled state is utilized to group two-dimensional vectors, while three-and four-photon caught states can classify four-and eight-dimensional vectors, separately. Diverse vector dimensions are expected to explain the properties of various real world objects. (“Quantum computers could”, 2016)

QC in Defense

U.S. military wants to wipe out human fighters and supplant them with combat zone robots, the NSA wants to dispose of human investigators and supplant them with self-learning AI machines running on neural systems of quantum computing processors.

Figure 4: AI Defense BOT

The US Department of Defense reported a $45 million honor to build up the primary U.S model of an adaptable quantum Computer with memory and expressed: “Quantum-physics-based computing could increase by a billion-fold computing capability critical to accelerating the building-blocks for game-changing capabilities in command, control, communications, computers, intelligence, surveillance and reconnaissance”. – US Department of Defense

The F35 joint strike fighter by Lockheed Martin is one of the most complex system in today’s modern warfare system containing more than 24 million of code. Another use of quantum computing is that it could be utilized to check this tremendous measure of code to guarantee the aircraft will work dependably and securely. (Quantum Defense, 2015)

Near term impact of Quantum Computing in Medicare

Medicare as a term involves usage of medicine to cure patients from illnesses and ensuring their smooth and fast recovery from diseases. Today apart from just prescribing medicines modern day doctors are playing an important role by combining technology with medicine to treat deadly diseases like cancer, obesity etc. These various technologies involve populations science for treating epidemics, evidence based guidelines to treat patients, and implementing ICD-10 in the clinics to carry out diagnoses and track a companies morbidity rate. With all these advancements happening in the HealthCare sector quantum Computing is also going to play a major role in its development.

Quantum Computing in MRI

MRI which stands for Magnetic Resonance Imaging is a technique that measures the response of atomic nuclei of body tissues when a human body is placed in the presence of a strong magnetic field for producing images of internal organs. As a result the doctors today can find bone fractures and blood clots in human bodies to treat their patients. In order To carry out advanced study of diseases at the atomic structure level quantum computing holds huge promise for the healthcare sector.

A quantum Nano MRI machine consists of a single atomic qubit which is used to generate 3D images at a molecular level. All the major diseases including diabetes and viral infections have their major activity at the molecular level that enables the need to develop a technology that creates 3D images of atomic structure at molecular level. It involves placing a qubit 2 nanometers below the surface of the held molecule to be imaged. The qubit acts as the sensor and source of the magnetic fields because of its quantum magnetic properties i.e. the spin and by collecting the interaction of the qubit and molecule at various orientations it is possible to map a 3D image of the molecule. (“Proposed quantum nano-MRI “, 2016).

Quantum Computing in Drug Discovery

Chemists need to test huge amounts of molecular combinations to discover a new drug that really has properties that are viable against a disease and so building up a new drug is a confounded process. This procedure can take years and cost millions of dollars. In spite of bringing tons of these combinations to later stage trials, most of them end up failing. A quantum computer would have the capacity to outline trillions of molecular combinations and rapidly distinguish the ones that would probably not work, fundamentally chopping down the cost and time of drug development. Quantum computing could also sequence and analyze a person's genes much faster than the methods currently in use which would help make personalized drugs and healthcare more available to the masses. Usually, drugs are killed even if a small group of people react badly to it even though it might be helpful for some other group of people. With customized gene examination and better drug information we could anticipate these awful interactions. (Dickerson, K. ,2015)

Quantum Computing in Protein Folding

Proteins are the fundamental building blocks of life. They are comprised of amino acid chains which fold back on themselves to frame three-dimensional structures. The function of every protein is in this way dictated by both the arrangement of the molecule chains made by the chemical constituents and the fold structure. Malfunction of a given protein is as often as possible because of it being wrongly folded. While the chemical synthesis of proteins is very notable, their physical structure is significantly less well known, because of the high number of conceivable outcomes. Getting more in depth information of the way proteins are folded will along these lines prompt to more noteworthy comprehension of human life and to the improvement of new treatments and medicines. A quantum computer will in principle have the capacity to

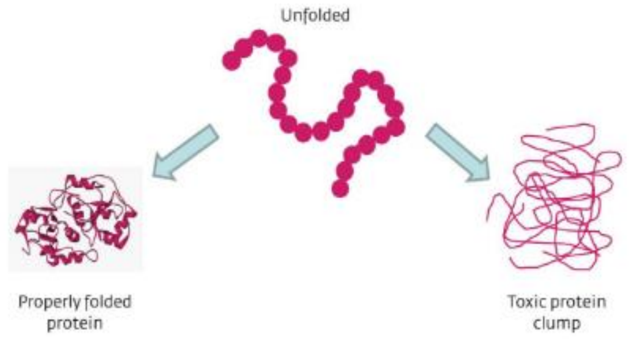


Figure 5: Protein Folding

test countless protein fold structures and recognize the most encouraging ones much faster than any traditional computer. Accordingly, D-Wave has created, in a joint effort with Harvard University, a system that empowers medical researchers to model protein folding. The most recent research demonstrates that nature streamlines the amino acid sequences to make the most stable protein. .("Quantum computing set to revolutionise", 2016)

Quantum Computing in Radio Therapy

Modern day radiation therapy for cancer involves the use of classical computers to devise a treatment plan that attacks the tumor and at the same time keeps the tissue healthy while the treatment takes place. Currently Monte Carlo codes are used to model the radiation interactions from the treatment machine through patient to cure the disease.

However, there is a limit to the speed with which the Monte Carlo Codes can be executed because of the transistor sizes getting reduced. As a result, because of quantum tunneling, there are chances of logic gate errors which gives us the need to harness the quantum systems for Radiation therapy. With the help of small quantum computers and the classical computer, it would be possible to overcome the limitations of CMOS technology that would be needed for Radiation therapy. Quantum bits would be employed with Monte Carlo Physics simulations to sample arbitrary probability density functions which would be useful in determining the accurate dosage of radiation for treatment of a patient. (Gabriel G. Colburn (May 31, 2013))

Quantum Computing in Cancer Treatment

As discussed above for MRI, quantum computing can help map 3D image of the molecular structure of any disease or virus which will be helpful for doctors to identify the compound of molecules best suited to fight the tumor or the disease. There can also be another way of treatment of cancer using quantum computing in conjunction with machine learning known as quantum machine learning algorithm. This along with the quantum simulator will help find the right combination of molecules for the treatment of Cancer. By compiling a list of compounds that can be used for cancer treatment and selecting the best molecular features and Using Grover's search algorithm will help us identify the most therapeutic molecules that can be used to treat cancer. ("ASCR Report on Quantum Computing for Science", 2016).

How will Quantum Computing impact the future

Quantum Computing as an industry today

Considering the current scenario, D-Wave Systems is the only company that claims to have developed a 1000 Qubit quantum computer. Apart from D-Wave many big giants like Microsoft, IBM, Google, Dell etc. are racing for developing high end quantum computers. Initially Quantum Computers were thought of an impossible technology. After tackling with the complex phenomenon of quantum mechanics this technology is no longer a dream today.

Quantum Computers today are used in various domains like cryptography, weather forecasting, health, and Medicare sectors for enhancing the speed of computations also to bring out accurate results. Quantum computing in collaboration with various technologies like machine learning and artificial intelligence have helped companies to find out the best possible answers for complex set of alternatives for e.g. portfolio analysis and financial services, solving logistic problems and drug discoveries. (“The growing potential of quantum”, 2016)

Developments down the line

The major limitation of Quantum Computing initially was of superposition where in a single qubit simultaneously represented 2 states. Thus, it was difficult to retrieve classical states i.e. either 1 or 0 from qubits at a given particular time. However, companies like D-Wave systems invented a unique way to decipher the quantum states by using interferences like cosmic rays that could be used to freeze the qubit into a classical state. Today quantum computing systems are built to operate in atmospheres which are as low as -273 degrees (the coldest environment in universe) in combination with magnetic vacuum so that the qubit processor operates in the purest environment. (“The growing potential of quantum”, 2016)

Development in the coming five years

With the invention of quantum computers, the number of qubits would be increased gradually over a period of years. In the coming two or three years D-Wave which officially claims to own a 1000 qubit computer will launch a 2000 qubit computer which will enhance its processing speed. Companies like IBM which use different models to build their quantum computers are also offering cloud based services to people for accessing their 5-qubit processors. As a Result, in near term we can expect companies to come out with higher qubit processors which can be utilized on a commercial as well as individual level. Quantum Computers would be used in combination with other technologies to enhace the performance of existing systems.(“ The growing potential of quantum”, 2016)

Development in the coming ten years

To stretch traditional computing as far as possible, Google opted for Edison, a standout amongst the most developed supercomputers on the planet, housed at the US National Energy Research Scientific Computing Center. Google had it reproduce the conduct of quantum circuits on progressively bigger networks of qubits, up to a 6 × 7 framework of 42 qubits. This calculation is troublesome because as the network measure expands, the measure of memory expected to store everything inflatables quickly. A 6 × 4 framework required only 268 megabytes, not as much as found in your normal cell phone. The 6 × 7 matrix requested 70 terabytes, approximately 10,000 times that of a high-end computer.

Google stopped there because heading off to the following size up is at present unthinkable: a 48-qubit framework would require 2.252 petabytes of memory, twofold that of the top supercomputer on the planet. By setting out this reasonable test, Google would like to keep away from the issues that have haunted past cases of quantum computers outflanking conventional ones including some made by Google. As a result we can see the above problem of memory increase being a hindrance to the development of high end quantum computers and the companies would be working ahead in this direction to solve the above problem in the near term of 10 years till a solution is achieved. (“The growing potential of quantum”, 2016)

How Quantum Computing will affect Healthcare

Quantum computing will have far reaching benefits for the healthcare industry as a whole than the costs it brings to the industry. With Healthcare IT gaining momentum and all the data of the of the patients, doctors, clinics, drugs and databases going on cloud the possibility of number of variables becomes innumerable.

As we know the processing power of every quantum computer goes on increasing with every qubit added it will be possible to run simulations consisting of trillions of variables and the equations could be fed to a large quantum computer to find out answers to unique questions such how to deal with an epidemic in a particular area, if a person having same attributes like another person is having the same category of cancer how should the person be treated etc. Also considering the vast databases the solutions to new diseases with new molecular properties could be simulated using machine learning and Grover's search algorithm to find out unique solutions. The benefits that quantum computing would provide will be limitless.

Quantum Computing benefits for healthcare organizations

The amount of biomedical and medical data in the given past years has increased in volume and scope. In order to make use of this vast information parallel computing can be used to make complex decisions. With the number of qubits being increased as technology advances new DNA sequencing data, the analysis of specific activities of folded confirmations of proteins and search of new drugs by docking algorithm will be implemented.

With the help of machine learning, it will be possible to train a system on a set of radiographs to identify weather a patient has tumor or not. With the help of studying a person's genome characteristics doctors would be able to identify weather the patient will respond to a particular drug or not. ("Quantum computing holds huge", 2013)

Quantum Computing benefits for patients

While optimizing the dosage of radiations to be given to patients during cancer treatment the side effects would be reduced which will help the patient to fight cancer diseases in a better way. By having a personalized health profile consisting of user diet, physical activity, lifestyle and loading the medical history of patient the quantum computer along with machine learning will help to predict whether a person would be infected by dangerous diseases or not in the near term.

By taking help of quantum computing, discovering new drugs would involve less capital costs and research expenses, these savings would in turn be transferred from the companies to the patients. Newly discovered medicines would cost less as compared to ones that are invented today if quantum computing techniques are implemented thereby benefitting patients. Various diseases which do not have cures till date would become cureable by making new drug discoveries related to those disease, once higher qubit computers become reality thereby saving lives of billions of people on the planet and benefitting humanity.

Risks

Quantum Computing is proving to be the biggest innovation in the modern world which will help in predicting future and solving complex problems but it will bring some risks with it.

Quantum Computing with AI and Machine Learning

- Encryption: Quantum Computer are key to secured communication. The NSA and CIA if started using the quantum computers then there will be no secrets hidden from them.
- Google and NSA teamed up to buy 512 qubit computer, this computer will be worked with machine learning working on vision recognition and with a .50-caliber pistol. In other words, teaching machines to think aim and shoot translates in turning a machine into killer.
- If by chance NSA surveillance grid is turned over to AI, humanity is finished. The quantum AI spy computer will turn into a specialist in parsing human speech, breaking down voice stress and building maps of human correspondences systems. After a short time, the quantum AI framework would far outperform anything a human mind can grasp, so they would remove the people from the circle and put the quantum computers responsible for the whole program.
- The issue with the NSA spy network, from the perspective of the NSA, is that we need to contract troves of human examiners to deal with all the data being cleared up by the observation grid. Edward Snowden being the biggest example in this area.
- Presently envisioning the god-like forces of a 512-qubit quantum computers in the hands of Google, which is working with the NSA to keep an eye on everybody seems quite possible. After a short time, an AI processing framework would choose who are the bad guys versus the good guys. It would add up to control over each webcam, each microphone, each movement light, plane, vehicle,

site and electronic board. It would choose for itself who to be wiped out and who to be kept safe. It would basically take on life and death decisions which would be devoid of feelings consisting of no heart, no soul, and no inner voice.

- In whole and sole, just in a span of next 20-30 years "*humans will be able to upload their entire minds to computers and become digitally immortal - an event called singularity' – (Ray Kurzweil, director of engineering at Google)*. ("Skynet rising", 2016)

Cryptography in the post Quantum Era

One of the apparent dangers of quantum computing's processing power is that, in the end it will crush all "classical" encryption algorithms and make current endeavors at data security miserably lacking. Quantum computing is still in its outset, and it might be decades before such computers even have the computational fortitude to handle advanced cryptographic issues. Still, the NSA (National Security Agency) feels it's best to be arranged and prepare for any possibility that may emerge.

The long lifetime of hardware in the military and numerous sorts of basic frameworks implies that many clients and providers are required to arrange assurances that will be adequate to overcome any advances that may emerge within a couple of decades. Numerous specialists anticipate a quantum computer would be able to successfully break through public key cryptography within that time span, and therefore NSA believes it is important to address this concern. (H., 2016)

Suggested Course of Action

Dealing with Quantum Decoherence

Decoherence, in quantum physics is the technique by which the quantum wave function no longer has coherence between the phase angles of a system in quantum superposition. The consequence of this loss of coherence is that the likelihood of the system can then be seen as far as classical probability. The unusual probabilistic behavior of a quantum system is a consequence of the system staying sufficiently different to keep up the coherence between the phase angles of the Schrodinger equation. At the point when that isolation separates, the procedure of decoherence results in the fall of the wave function and the quantum system then falls into a physical state. The issue with decoherence, is that it is not clear precisely where the collapse happens. There is no single point in the process that the physicist can state with confidence that a Heisenberg cut amongst quantum and classical probability has occurred. The correct nature of how, why this wave function collapse really happens is known as the measurement problem.

The decoherence does plays an important role in circumstances where researchers might want to keep up the quantum superposition behaviors for a longer time. (H., 2014).

Dealing with the risks of Quantum Cryptography

Quantum computers are proving to be a revolution in the field of high end technology. The main risk they behold is the power of code breaking. Quantum key distribution is used for secured communication but many experts predict that quantum computers will be able to successfully break open key cryptography codes within that time period, and thus NSA addresses that worry.

Use of qubits or quantum bits makes it easier to break the classical encryption algorithms as really equipped for executing different abnormal state calculations in the meantime.

Figure 6: Cryptography

However, to crack the current encryption it will require power of hundreds of millions of qubits which is a very high range and long ways past even the most energetic projections for quantum figuring sooner rather than later. (H., 2016)

Benefits of research in Astronomy and Meteorology:

Figure 7: Hubble mosaic of crab nebula

With the help of quantum computers, information from various streams can be measured at the same time, which implies that extreme climate conditions can be issued in advance and lives can be saved. That, as well as the impacts people are having on the climate can help us figure out what measures should be taken to prevent additional harm. (Vanian, J.,2015)

Quantum computing has a talent for taking care of huge heaps of information, which is the reason it is nothing unexpected that it will likewise profit space exploration. With the guide of a quantum computer, more information can be processed inside any given telescope and recognize which of these planets could harbor life. NASA wants to utilize quantum computing to help with computerized scheduling and planning, to arrange robotic missions to different planets. The objective is to arrange out the mission of the robots far ahead of time in light of the fact that real-time correspondence with the robots simply isn't attainable given how far away different planets are from the Earth. Utilizing quantum optimization, NASA researchers will have new devices to essentially gauge what may happen amid the mission and what might be the most ideal arrangement for the robots so that they might be able do their work. This all includes a considerable measure of variables that normal computers aren’t capable to process and only quantum computers can process such large amount of variables. (“Quantum Computers”, 2016)(“ 5 Cool Things Google's”, 2013)

Conclusion

The field of quantum computing is advancing with big giants like Google, IBM, Microsoft developing their own models of Quantum Computer and adding no of qubits for the quantum computer as time passes. The competition as well as the race to make the fastest and largest quantum computer is expected to increase as the day passes.

However apart from building quantum computers having a control over the quantum physics while they are built and controlling the information they generate during their computational cycles becomes an important aspect as well as challenge for the companies in the coming times.

Summary of Quantum Computing in Healthcare and other fields

With all the information of doctors, clinics, patients and monitoring sensors going on the cloud and the processing of information becoming faster with the use of quantum computing there could be faster actions taken that would save patients’ lives. Quantum Computing in collaboration with AI and Machine Learning would enable robots to carry out operations with higher accuracy and judgement reducing human errors. Although the whole purpose of utilizing Quantum Computers is to benefit humanity it would become important to control and regulate the people and organizations that use such sophisticated machines to prevent them from misuses and to avoid man-made disasters.

References

- The Quantum Computer - Rice University. (n.d.). Retrieved December 4, 2016, from https://www.bing.com/cr?IG=F0A8375FBF4A4B7C845BDFA1C5BF221F&CID=28AFCFE2524F65D538F1C603537E643B&rd=1&h=UgiXl6cmlWx_wzv5qwkd7ilngAbNCMtSReCc5UIlpHA&v=1&r=https://www.cs.rice.edu/~taha/teaching/05F/210/news/2005_09_16.htm&p=DevEx,5084.1
- Nielsen, M. A., & Chuang, I. L. (2009). Quantum Computation and Quantum Information. doi:10.1017/cbo9780511976667
- Desjardins, J. (2016). The 3 Types of Quantum Computers and Their Applications. Retrieved November 17, 2016, from http://www.visualcapitalist.com/three-types-quantum-computers/
- (n.d.). Retrieved December 04, 2016, from http://www.nature.com/articles/npjqi201523
- Simon's problem. (n.d.). Retrieved December 04, 2016, from https://en.wikipedia.org/wiki/Simon's_problem
- Alexei Kitaev (November 1995) quantum phase estimation algorithm. Retrieved December 04, 2016
  from https://en.wikipedia.org/wiki/Quantum_phase_estimation_algorithm
- Bennett, C. H., Bernstein, E., Brassard, G., & Vazirani, U. (1997). Strengths and Weaknesses of Quantum Computing. *SIAM Journal on Computing*, *26*(5), 1510-1523. doi:10.1137/s0097539796300933
- Childs, A. M., Cleve, R., Deotto, E., Farhi, E., Gutmann, S., & Spielman, D. A. (2003). Exponential algorithmic speedup by a quantum walk. Proceedings of the Thirty-fifth ACM Symposium on Theory of Computing - STOC '03. doi:10.1145/780551.780552
- Office, L. H. (2009). Quantum computing may actually be useful. Retrieved December 04, 2016, from http://news.mit.edu/2009/quantum-algorithm
- Quantum computing set to revolutionise the health sector. Retrieved December 04, 2016, from http://www.atelier.net/en/trends/articles/quantum-computing-set-revolutionise-health-sector_437915
- Kouzmine, S. (2013). 4 Ways That Quantum Technology Could Transform Health Care. Retrieved December 04, 2016, from https://www.fastcoexist.com/3016530/4-ways-that-quantum-technology-could-transform-health-care
- Quantum key distribution. (n.d.). Retrieved December 04, 2016, from https://en.wikipedia.org/wiki/Quantum_key_distribution
- Quantum computers could greatly accelerate machine learning. (n.d.). Retrieved December 04, 2016, from http://phys.org/news/2015-03-quantum-greatly-machine.html
- H. (2015). Quantum Defense - The Race to Military Applications of Fundamental Science | Hacked. Retrieved December 04, 2016, from https://hacked.com/quantum-defense-race-military-applications-fundamental-science/
- Proposed quantum nano-MRI could generate images with angstrom-level resolution. (n.d.). Retrieved December 04, 2016, from http://phys.org/news/2016-12-quantum-nano-mri-images-angstrom-level-resolution.html
- Dickerson, K. (2015). 7 awesome ways quantum computers will change the world. Retrieved December 02, 2016, from http://www.businessinsider.com/quantum-computers-will-change-the-world-2015-4
- The growing potential of quantum computing. (n.d.). Retrieved December 04, 2016, from http://www.mckinsey.com/industries/high-tech/our-insights/the-growing-potential-of-quantum-computing

- Quantum computing holds huge promise. (2013). Retrieved December 04, 2016, from http://www.healthcareitnews.com/news/quantum-computing-holds-huge-promise
- Skynet rising: Google acquires 512-qubit quantum computer; NSA surveillance to be turned over to AI machines. (n.d.). Retrieved December 04, 2016, from http://www.naturalnews.com/040859_Skynet_quantum_computing_D-Wave_Systems.html
- H. (2016). NSA Warns of the Dangers of Quantum Computing. Retrieved December 02, 2016, from https://futurism.com/nsa-warns-dangers-quantum-computing/
- The Near-Term Future of Quantum Computing? Analog Simulations. (n.d.). Retrieved December 04, 2016, from http://motherboard.vice.com/read/the-near-term-future-of-quantum-computing-analog-simulations
- H. (2014). Decoherence - Making sense out of quantum wave function collapse. Retrieved December 04, 2016, from http://physics.about.com/od/physicsatod/g/Decoherence.htm
- Vanian, J. (2015). How NASA uses quantum computing for space travel and robotics. Retrieved December 04, 2016, from https://gigaom.com/2015/02/13/how-nasa-uses-quantum-computing-for-space-travel-and-robotics
- Quantum Computers: The Future of Everyday Life | Fiat Physica Blog. (n.d.). Retrieved December 04, 2016, from https://www.fiatphysica.com/blog/everyday-physics/quantum-computing-explained
- @. (2013). 5 Cool Things Google's Quantum Computer Could Do. Retrieved December 04, 2016, from https://www.techopedia.com/2/29425/development/web-development/5-cool-things-googles-quantum-computer-could-do
- Gabriel G. Colburn (May 31, 2013). Hybrid Classical-Quantum Dose Computation Method for Radiation Therapy Treatment Planning. Retrieved from https://ir.library.oregonstate.edu/xmlui/handle/1957/40035

Annotated Bibliography

- H. (2015). Quantum Defense - The Race to Military Applications of Fundamental Science | Hacked. Retrieved December 04, 2016, from https://hacked.com/quantum-defense-race-military-applications-fundamental-science/

The article talks about the future of quantum computing in the field of defense. How the newly developed warfare machines working on the quantum computing to emerge as deadly monters to fight on modern world

As the world is growing at impeccable rate, so the risks of wars coming with it. So in order to be retaliate to the other forces some robots need to be developed to fights the war instead of humans to save the human life and race.

- Nielsen, M. A., & Chuang, I. L. (2009). Quantum Computation and Quantum Information. doi:10.1017/cbo9780511976667/

This web journal talks about the basics of quantum computing and its working, how the quantum computer. The main idea of the article is to explain the how qubits store the data and how the quantum calculation is performed over it.

The basics of quantum computing needs to be understood to proceed ahead with the paper, so that's why we have included this in our paper.

- Quantum key distribution. (n.d.). Retrieved December 04, 2016, from https://en.wikipedia.org/wiki/Quantum_key_distribution/

This explains the phenomenon of quantum cryptography in secured communication using using quantum key distribution.

The secured communication is the basis of every confidential meet and data, and quantum computing being the application in cryptography makes it necessary to include in the paper.

- @. (n.d.). Revealed: Google's plan for quantum computer supremacy. Retrieved December 04, 2016, from https://www.newscientist.com/article/mg23130894-000-revealed-googles-plan-for-quantum-computer-supremacy/

This article is about the developments down the line, what is going to be more innovations in the quantum computers. It has some limitation today but what is going to be done in future to overcome those limitations.

The memory space and high end processors, and the scope of advancement in the future. That's why we included this in our paper.

- H. (2016). NSA Warns of the Dangers of Quantum Computing. Retrieved December 04, 2016, from https://futurism.com/nsa-warns-dangers-quantum-computing/

This article is all about the dangers(risks) in quantum computing like breaking the quantum key encryption and if gone in wrong hands then it can also be boon to mankind.

- Google acquires 512-qubit quantum computer; NSA surveillance to be turned over to AI machines. (n.d.). Retrieved November 19, 2016, from http://www.naturalnews.com/040859_Skynet_quantum_computing_D-Wave_Systems.html

This Article portrays the dark side of quantum computing; the innovation of this modern computing is not only boon but also can be bane for humans. Quantum computers being the secret key to unlock encryption once go into widespread world by NSA, Google then there will not be any more secrets kept from the government. It brings the thought of danger to human race if the self-learning AI machine and robots were created who can think and act more significantly than humans, then it will be like god like powers given in hands of high tech sellouts.

- Ashley Montanaro (January 12, 2016) Quantum Algorithms: An Overview. Retrieved November 26,2016 from http://www.nature.com/articles/npjqi201523

This web based article gives brief description of some of the quantum algorithms with an emphasis of broad overview of their near term uses rather than their technical details.
This article is important to us since it introduces us to the algorithms that are used in quantum computing and gives explanation of each of them along with their relative application in diverse fields. It also Talks about how Shor’s algorithm would be important and at the same time pose a threat in daily applications.

- Simon's problem. (n.d.). Retrieved December 04, 2016, from https://en.wikipedia.org/wiki/Simon's_problem

This article gives detailed description of simon’s algorithm, its problem description and detailed steps of calculation in the model of Decision tree complexity.
This link is important to us since it tells us when it was invented as a computational problem by Daniel Simon, how quantum algorithms differ from the classical algorithms in terms of speed and applications.

- Alexei Kitaev (November 1995) quantum phase estimation algorithm. Retrieved December 04, 2016 from https://en.wikipedia.org/wiki/Quantum_phase_estimation_algorithm

This article gives detailed description of Quantum Phase Estimation algorithm, its problem description and detailed steps of calculation in the model of Eigen Value Estimation.
This link is important to us since it tells about its application as a subroutine in other algorithms.

- Bennett, C. H., Bernstein, E., Brassard, G., & Vazirani, U. (1997). Strengths and Weaknesses of Quantum Computing. *SIAM Journal on Computing*, *26*(5), 1510-1523. doi:10.1137/s0097539796300933 retrieved from https://en.wikipedia.org/wiki/Grover's_algorithm

This article gives detailed description of Grover’s algorithm, its problem description and how it is different from other quantum algorithms.
This link is important to us since it tells us when it was invented as a computational problem by Lov Grover how this algorithm is useful in finding a unique input to a black-box function.

- Childs, A. M., Cleve, R., Deotto, E., Farhi, E., Gutmann, S., & Spielman, D. A. (2003). Exponential algorithmic speedup by a quantum walk. Proceedings of the Thirty-fifth ACM Symposium on Theory of Computing - STOC '03. doi:10.1145/780551.780552 retrieved from https://en.wikipedia.org/wiki/Quantum_walk

This link explains the Quantum Walk Algorithm, its types and also the reason for invention of such type of algorithm.
This link is important to us as it gives a brief overview of its uses and its possible application in the near future.

- Larry Hardesty(October 9, 2009). Quantum Computing may actually be useful. Retrieved November 28, 2016 from http://news.mit.edu/2009/quantum-algorithm

This link talks in short about the phenomenon of the quantum principles its possible applications in various fields along with weather forecasting and how the field is still in its developing state.
This link was important to us since it gave us a brief overview of how weather forecasting takes place and as the field of quantum computing gains ground the accuracy of weather predictions would become strong due to the use of quantum super computer.

- Lisa Zyga (December 1,2016) Proposed quantum nano-MRI could generate images with angstrom level resolution. Retrieved November 29, 2016 from http://phys.org/news/2016-12-quantum-nano-mri-images-angstrom-level-resolution.html

This links talks about the involvement of quantum computers in healthcare field and gives us a brief explanation of how qubits would be used for 3D imaging of Atoms at the molecular level.
Since our group focuses mainly on how quantum computers will pay an important role in the healthcare sector this link was an important source of information since it described the conceptual framework of how 3D imaging would be possible at the molecular level with the use of qubits.

- Gabriel G. Colburn (May 31, 2013). Hybrid Classical-Quantum Dose Computation Method for Radiation Therapy Treatment Planning. Retrieved from https://ir.library.oregonstate.edu/xmlui/handle/1957/40035

This paper talks about the use of quantum computers in healthcare field and gives us a brief explanation of how limitations in classical computers would give rise to the need of quantum computers in Radiation therapy.
Since our group focuses mainly on how quantum computers will pay an important role in the healthcare sector this link was an important source of information since it described the current radio therapy process and the shortcomings that will be experienced in this field in the near term because of which it would be necessary to harness the benefits of quantum computing principles.

- ASCR Report on Quantum Computing for Science n. d. Retrieved November 19, 2016, from https://cfwebprod.sandia.gov/cfdocs/CompResearch/docs/ASCRQuantumReport-final.pdf

This report on Quantum Computing highlights the opportunities that quantum computing will provide in conjunction to techniques like linear algebra, graph theory and machine learning. The scientific community having met at a workshop in February 2015 discussed how quantum computing would help to achieve the various DOE (Department of Energy missions) and the improvements quantum computing still needs so that it can have solid impact in the coming future.
Since our group focuses mainly on how quantum computers will pay an important role in the healthcare sector this link was an important source of information since it described the method for improving the current practices used for cancer treatment which would benefit the patients in the years to come

- Mike Miliard (July 18, 2013) quantum computing holds huge promise . retrieved November 26, 2016, from http://www.healthcareitnews.com/news/quantum-computing-holds-huge-promise

This link talks about the various set of companies who have entered in to the quantum computing field and the efforts they are taking so that quantum computers be useful in fields where there have been limitations posed by the principle of classical computing.
This link was useful to us because it mentions about the various applications that quantum computer will have in the near term for improving the field of healthcare

- Rieffel, E. G., & Polak, W. H. (2014). Quantum Computing. Retrieved December 04, 2016, from https://mitpress.mit.edu/books/quantum-computing

The article gives an overview about quantum computing and explains what quantum computing is all about.
Since this article provides information about quantum computers and gives us a brief idea about them,we can use it in our paper.

- The Quantum Computer - Rice University. (n.d.). Retrieved December 4, 2016, from https://www.bing.com/cr?IG=F0A8375FBF4A4B7C845BDFA1C5BF221F&CID=28AFCFE2524F65D538F1C603537E643B&rd=1&h=UgiXl6cmlWx_wzv5qwkd7ilngAbNCMtSReCc5UIlpHA&v=1&r=https://www.cs.rice.edu/~taha/teaching/05F/210/news/2005_09_16.htm&p=DevEx,5084.1

The article explains about the concept of qubits. Qubits have 2 states simultaneously(0 & 1) .The author of this article further explains this concept through an experiment. Then the potential of quantum computing is discussed . Although classical computers can perform all tasks that quantum computers can perform but classical computers but quantum computers can perform many tasks simultaneously and with ease which sets them apart from classical computers. Then the author speaks about the history of quantum computing. Various obstacles in the field of quantum computing are then described with research happening in that particular area. Then the future prospects in the field of quantum computing are described.

This article gives an overview of quantum computing, provides information about qubits and provides an insight in the history of quantum computing, it can be used in the paper.

- Quantum computers could greatly accelerate machine learning. (n.d.). Retrieved December 04, 2016, from http://phys.org/news/2015-03-quantum-greatly-machine.html

The article describes how quantum computers can be used in machine learning. Quantum computing can speed up the pace at which machine learning tasks can be performed. The author then goes on to explain about supervised and unsupervised machine learning and quantum entanglement. If the vectors are represented with quantum states, and then the states are entangled then the distance is compared between them. Quantum computers are good at manipulating vectors. They use a small-scale quantum computer that manipulates optical qubits, or photons to do this.

- H. (2014). Decoherence - Making sense out of quantum wavefunction collapse. Retrieved December 04, 2016, from http://physics.about.com/od/physicsatod/g/Decoherence.htm

In this article the author explains about quantum incoherence. Physicist David Bohm, presented a paper in 1952 in which he introduced quantum incoherence as an attempt to offer a physical explanation for the collapse of a wavefunction . Due to loss of quantum incoherence, the system can be viewed in terms of classical probability. One advantage of accepting quantum incoherence is that Schroedinger's cate experiment is solved without the need of an observer. However the disadvantage of incoherence is that where the collapse took place cannot be determined. The article then discusses about decoherence and measurement problem in detail further.

Since this article explains the phenomenon of quantum incoherence which is a part of quantim computing, it could be included in the paper.

- Vanian, J. (2015). How NASA uses quantum computing for space travel and robotics. Retrieved December 04, 2016, from https://gigaom.com/2015/02/13/how-nasa-uses-quantum-computing-for-space-travel-and-robotics/

The article tells that NASA is using quantum computing to design safer methods space travel and for sending robots for missions. NASA intends to solve use quantum computers to solve optimization problems and for automated planning and scheduling. The NASA mission needs to be planned for robots that are sent to planets for various errands. For that the batteries of the robots needs to be maximized so very coordinated and careful planning is required.
The article can be used in the paper beause it explains how the quantum computing and its application in robotics and space travel.

- Quantum Computers: The Future of Everyday Life | Fiat Physica Blog. (n.d.). Retrieved December 04, 2016, from https://www.fiatphysica.com/blog/everyday-physics/quantum-computing-explained

The web based article states that scientists tend to benefit from quantum computing as it as many direct applications. In medical industry, quantum computing helps to test the varieties of molecular combinations. Quantum computing is also helpful in space exploration as these computers can analyze a lot of data. Quantum computers can modify or change themselves if something goes wrong. Quantum computers are also very useful in weather forecasting, help reduce traffic problems, securing credit card Data if something goes wrong.
The article explains the benefits of quantum computers in various sectors and it can be used in the paper.

- @. (2013). 5 Cool Things Google's Quantum Computer Could Do. Retrieved December 04, 2016, from https://www.techopedia.com/2/29425/development/web-development/5-cool-things-googles-quantum-computer-could-do

The article provides information about the various things quantum computers can do like providing accurate weather reports, searching data on web engines faster than ever. The increase in the quantum computer’s storage capabilities will allow users to both store information *and* allow faster access to it. This would be tremendously beneficial for search engine giants like google. Quantum computers can also be used for improving speech recognition technology, Provide better artificial intelligence and increase the computation power faster than ever.
Since the article provides information about the capabilities of quantum computer, it can be included in the paper.

- Quantum computing set to revolutionise the health sector. Retrieved November 17, 2016, from http://www.atelier.net/en/trends/articles/quantum-computing-set-revolutionise-health-sector_437915

In this web based article, the writer Pierre Pariente talks about the major concerns of the future of health sector and how quantum computers can be used to overcome them. He gives a brief description of what a quantum computer is. He introduces quantum computing with the intend of letting the audience know about the capabilities of computer calculations. He talks about the various applications of quantum computing in the health sector like ‘Optimised treatments through computing’, ‘More comprehensive Analysis will lead to more effective radiotherapy’ and ‘Understanding the structure of proteins’. He also talks about when can we hope to see all this in practice.

This article introduces quantum computer and lists its few applications in the field of health sector which we can use in our project.

- Dickerson, K. (2015). 7 awesome ways quantum computers will change the world. Retrieved December 02, 2016, from http://www.businessinsider.com/quantum-computers-will-change-the-world-2015-4

In this web article, the author Dickerson talks about the impact quantum computing can have on drug discovery. Chemists need to test huge amounts of molecular combinations to discover new drugs. This procedure takes years to complete and is a complicated process. A quantum computer would ease this process.

This article throws light on the use of quantum computing in drug discovery and hence can be used in our project.

- Desjardins, J. (2016). The 3 Types of Quantum Computers and Their Applications. Retrieved November 17, 2016, from http://www.visualcapitalist.com/three-types-quantum-computers/

The author of this article tells us about the three types of quantum computing and the applications, generality and computational power of each one of them. ‘Quantum Annealer’ being the least powerful and most restrictive one followed by ‘Analog Quantum’ which can simulate complex quantum interactions and finally the ‘Universal Quantum’ which is the most powerful and hardest to build. This article also gives us an explanation about Qubits. It shows us the position of quantum computing on Gartner’s emerging technology hype cycle.

Since this article tells us about the various types of quantum computers and its position on the emerging technology hype cycle, we can use this in our project to give detailed description on quantum computing.

- H. (2016). NSA Warns of the Dangers of Quantum Computing. Retrieved November 19, 2016, from http://futurism.com/nsa-warns-dangers-quantum-computing/

In this web based article, the author talks about the threats Quantum Computing can pose to data security. The super-secretive National Security Agency(NSA) has warned to beware of the code breaking power of quantum computers. The processing power of quantum computers will eventually defeat all classical encryption algorithms. But since quantum computing is still in its infancy, the agency should come up with options for quantum resistant cryptography to deal with this threat posed by quantum computing.

This article tells us about the threat quantum computing can pose with its advent. We can use it in our project to talk about the long-term risks of quantum computing and can make suggestions in order to deal with this possible risk.