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A Review on Quantum Vision Intelligent Learning (QuVIL) System

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***Abstract*—The dimension of Artificial Intelligence is vast and this keeps on increasing when new methodologies are incorporated in it. The main purpose of this paper is to exploit the potential Application of Quantum computing in AI. Quantum Artificial Intelligence helps in solving some of the most challenging computer science problems, particularly in machine learning. Machine learning is all about building better models of the world to make more accurate predictions. Using Quantum AI with Bioinformatics, we can get such an automata that will analyze the symptoms of patients and draw better models of how diseases develop and how to cure them. Application of QuAI in Space Research is endless. Quantum AI with Cryptanalysis can help to create more secure algorithms for Information security. So there are endless positive possibilities if application of Quantum Artificial Intelligence is applied correctly.**

Keywords-Quantum Theory; Quantum Computing; Machine Learning; Computer Vision; Artificial Intelligence.

I. INTRODUCTION

Artificial Intelligence is actually theory for the development of intelligence in a machine. Computers are fundamentally well suited to performing mechanical computations, using fixed programmed rules. This allows artificial machines to perform simple monotonous tasks efficiently and reliably, which humans are ill-suited to. For more complex problems, things get more difficult. Unlike humans, computers have trouble understanding specific situations, and adapting to new situations. Artificial Intelligence aims to improve machine behavior in tackling such complex tasks. AI research is allowing us to understand our intelligent behavior. Humans have an interesting approach to problem-solving, based on abstract thought, high-level deliberative reasoning and pattern recognition. Artificial Intelligence can help us understand this process by recreating it, then potentially enabling us to enhance it beyond our current capabilities.

There are several fields on which AI have been introduced namely:
Deduction, reasoning, problem solving, Knowledge representation, Machine Learning, Perception, Motion and manipulation, General Intelligenc, Cybernetics and Brain Simulation etc.

Machine Learning is the part of Artificial Intelligence which can learn from the data provided to it. We can classify Machine Learning into three categories. First is a supervised learning where an input and output is provided, the algorithm is asked to find a link amongst them. Second is an unsupervised learning where an input is given and the algorithm is asked to explore its link by its own to achieve its final output. The third and the last one is reinforcement learning, where the algorithm is kept in direct contact with a dynamic environment and is asked to reach some certain output. Pattern recognition is also a part of Machine Learning, which tries to identify specific arrangements in the data and falls under the section of supervised learning. In Pattern recognition, the inputs are taken in an order and a matching is done on the basis of statistics variation to provide a solution. The introduction of Pattern Recognition and Machine Learning plays a vital role in QuVIL System, as both aims to formalize and visualize a pattern. An algorithm in the Pattern Recognition is actually Probabilistic in nature and so this can be used to perform some higher machine learning tasks, by completely avoiding the problems of error propagation. There are different stages of pattern recognition which involves measurement of the objects to identify the distinguishing properties, extracting the features to define these properties and compare these unknown property patterns with the known to determine if it is a match or a mismatch.Mixing this Machine Learning approach with Quantum Computing yields a more hyper active system for processing these data. But understanding Quantum Computing needs some knowledge on Quantum Mechanics.

Quantum mechanics describes the relationships between energy and matter on atomic and subatomic scale. Classical Physics explained the entire phenomenon regarding the involvement of matter and energy, but at the beginning of 20^{th} century, scientists found some phenomenon that actually crushed all the theories of Classical Physics. Scientist was able to draw the limitation of Classical Physics, which led to the development of two more paradigms. One was Theory of Relativity and the other was Quantum Mechanics. One of those limiting experiments was 'Black body radiation'. The first quantum theory was established by Max Planck using this black body radiation experiment.

Planck's law [12] states that

$$I(\nu,T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{\frac{h\nu}{kT}}-1}$$

where, $I(\nu,T)$ is the energy per unit time (or the power) radiated per unit area of emitting surface in the normal direction per unit solid angle per unit frequency by a black body at temperature T, also known as spectral radiance; h is the Planck constant; is the speed of light in a vacuum; k is the Boltzmann constant; ν is the frequency of the electromagnetic radiation; and T is the absolute temperature of the body.

Planck proposed that subatomic particles and electromagnetic waves are neither simply a particle nor a wave but has certain properties of each and atoms absorb or emit electro-magnetic radiation in defined and discrete units called "quanta". This originated the concept of wave–particle duality [10]. Later, Albert Einstein interpreted Planck's quantum hypothesis realistically and used it to explain the photoelectric effect.

To describe the propagation of wave associated with any particle or group of particle, Quantum physicist had developed a tool called a 'wave function' [9, 14]. It is represented by 'Ψ'or 'psi'. The wave function represents probability amplitudes, and the square of the modulus of the wave function represents the relative probability density.

$$\text{Probability density} = |\psi|^2$$

Using probability theory, and allowing for a wave-particle duality Quantum mechanics replaced electron "orbitals" of classical atomic models with allowable values for angular momentum (angular velocity multiplied by mass) and depicted electrons position in terms of probability "clouds" and regions. Now all molecules are made of atoms which, in turn, contain nuclei and electron, but the motions of these particles are governed by a new set of equations called 'Schrodinger equations':

$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$

where, i is the imaginary unit, $\hbar$ is the Planck constant divided by 2π, the symbol $\partial/\partial t$ indicates a partial derivative with respect to time t, Ψ is the wave function of the quantum system, and $\hat{H}$ is the Hamiltonian operator (which characterizes the total energy of any given wave function and takes different forms depending on the situation).

Neil Bohr further modified the Quantum Theory, by introducing the concept of Superposition, which asserts that a particle is whatever it is measured to be (for example, a wave or a particle) but that it cannot be assumed to have specific properties, or even to exist, until it is measured. This defines the principle called superposition that claims that while we do not know what the state of any object is, it is actually in all possible states simultaneously, as long as we don't look to check.

Figure 1. Support structure for installation of the D-Wave Vesuvius processor, which is cooled to 20 mill kelvin (near absolute zero).[Source: http://www.nas.nasa.gov/quantum/]

Quantum Computing uses this theory of Quantum Mechanics to processes information. Now what we know about a classical computers that this contains Bits (either 1 or 0). But in Quantum level Computing we have Quantum Bits or Qubit[11]. This Qubit has an amazing property, they seem to use this property of Superposition and Entanglement that is they can contain either 0 or 1 or both state at once. If an electron is in a magnetic field the electron spin may be either in alignment with the field, which is known as a *spin-up* state, or opposite to the field, which is known as a *spin-down* state. Changing the electron's spin from one state to another is achieved by using a pulse of energy, such as from a laser; consider one unit of Laser Energy. Now providing only half unit of energy to this electron and separating it from outside interferences, by Quantum theory the particle enters into the superposition of states that is it behaves as if it is in two states simultaneously [1]. The Schrödinger equation was made to be linear for generality, though this has other implications. If two wave functions ψ_1 and ψ_2 are solutions, then so is any linear combination of the two:

$$\psi = a\psi_1 + b\psi_2$$

where, *a* and *b* are any complex numbers (the sum can be extended for any number of wave functions). This property allows superposition of quantum states to be solutions of the Schrödinger equation.

Thus, the number of computations that a quantum computer could undertake is 2^n, where n is the number of qubits used. A quantum computer comprised of 500 qubits would have a potential to do 2^{500}calculations in a single step. 2^{500} are infinitely more atoms than there are in the known universe. Thus once the NP- Complete and NP-Hard problems which were considered to take Billion or Trillion of Years to solve by the classical computers, a Quantum Computer Will solve it in a few days. In order to interact, a particle follows the rule of Entanglement. Entanglement is an extremely strong correlation that exists between quantum particles — so strong, in fact, that two or more quantum particles can be inextricably linked in perfect unison, even if separated by great distances. The particles remain perfectly correlated even if separated by great distances.

Quantum computing was first theorized less than 30 years ago, by a physicist at the Argonne National Laboratory. *Richard Feynman and* **Paul Benioff** are credited with first applying quantum theory to computers in 1981. Benioff theorized about creating a quantum Turing machine.

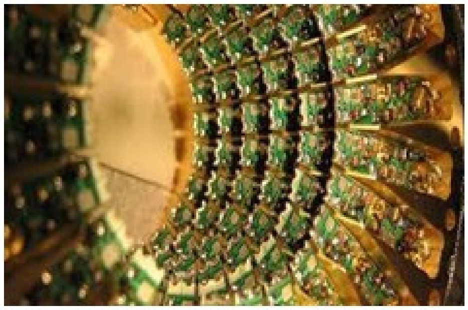

Figure: 2. [Source:http://www.tested.com/tech/concepts/455537-google-and-nasa-start-quantum-artificial-intelligence-lab/]

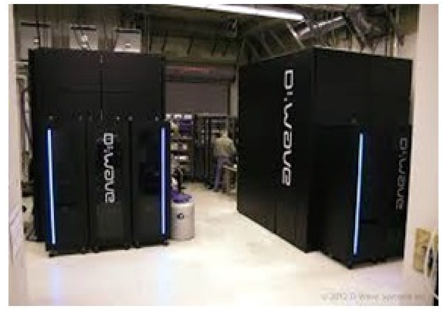

Figure. 3. Google and NASA team to establish a quantum AI research Lab. [Source: http://www.dwavesys.com/]

The basic theory is simple: we need the qubits to behave the way we want them to. This qubits can be a Photon, electron or an atom. To maintain this dual effect in a single particle is critical and a slight noise can topple the particle from either states. Developing an Integrated Quantum Circuits is still under research in Quantum Electronics. So till we develop a fully functional IQC, we need to perform all experiments theoretically under Quantum Turing Machine. There are some simulators used for quantum computing called LangQ and QCL.

In 2013, a D-Wave two system was installed at the new Quantum Artificial Intelligence Lab, a collaboration among Google, NASA and the Universities Space Research Association (USRA). The lab is housed at the NASA Ames Research Center in California.

Computer Vision is the procedure of understanding and analyzing the Image to produce data which have certain symbolic meaning. It is just copying the ability of seeing and perceiving things of a human eye. The data are of many forms such as multiple cameras or video camera, the algorithm extracts the original data from other noises.

Quantum Artificial Intelligence is the combination of Quantum Computing and Artificial Intelligence. Quantum Computing is the most important discovery in 20^{th} century. A normal automaton may never develop greater artificial intelligence capability if we continue to rely on conventional computing technology. One of the most striking advances was made by Peter Shor in 1994, by exploring the power of quantum parallelism; he discovered a polynomial-time algorithm on quantum computers for prime factorization of which the best known algorithm on classical computers is exponential. Recent research work has focused on using quantum computing to accelerate ahead with one of the most difficult points to resolve in information technology: machine learning, which is used to create highly accurate models and predictions. In 1996, Grover offered another killer application of quantum computation, and he found a quantum algorithm for searching a single item in an unsorted database in square root of the time it would take on a classical computer.

II. RESEARCH WORK ESTABLISHED ON QUANTUM AI

A. *Quantum Computation for Action Selection using Reinforcement Learning [2]*

This paper proposes a novel action selection method based on quantum computation and reinforcement learning (RL). Inspired by the advantages of quantum computation, the state/action in a RL system is represented with quantum superposition state. The probability of action eigenvalue is denoted by probability amplitude, which is updated according to rewards. And the action selection is carried out by observing quantum state according to collapse postulate of quantum measurement. The results of simulated experiments show that quantum computation can be effectively used to action selection and decision making through speeding up learning. This method also makes a good tradeoff between exploration and exploitation for RL using probability characteristics of quantum theory.

B. Pattern Recognition: An overview[6]

In this paper Pattern recognition was introduced including concept, method, application and integration. At the same time, ten definitions and more than ten methods of pattern recognition were summarized. On the end, the structure and classification of Pattern Recognition and its related fields and application areas were introduced in detail. Statistical decision and estimation theories have been commonly used in PR for a long time. It is a classical method of PR which was found out during a long developing process, it based on the feature vector distributing which getting from probability and statistical model. The statistical model is defined by a family of class-conditional probability density functions Pr(x|ci)(Probability of feature vector x given class ci) In detail, in SPR, we put the features in some optional order, and then we can regard the set of features as a feature vector. Also statistical pattern recognition deals with features only without consider the relations between features.

C. The Quantum Artificial Intelligence Lab (QuAIL)[8]

NASA aims to demonstrate that quantum computing and quantum algorithms may someday dramatically improve algorithms for optimization tasks in air traffic control, autonomy, robotics, navigation and communication, system diagnostics, pattern recognition, and mission planning and scheduling.

D. Neonatal Disease Diagnosis: AI Based Neuro-Genetic Hybrid[3]

There are a number of uncertainties involved including human errors. The problem is augmented when the domain is itself critical; for example, neonatal diseases. The problem is further augmented whenever and wherever proper experts are not available. Mitigating the kind of such problems, developing medical decision support systems using AI techniques are being explored during last few years. Combining neural networks with genetic algorithms is one of the approaches people use. It reduces various medical errors and provides better prediction of diseases. This article presents a study of neuro-genetic approach with multi-layer perceptron (MLP) neural network diagnosing neonatal diseases.

E. Scikit-learn: Machine Learning in Python[7]

Scikit-learn is a Python module integrating a wide range of state-of-the-art machine learning algorithms for medium-scale supervised and unsupervised problems. This package focuses on bringing machine learning to non-specialists using a general-purpose high-level language. Emphasis is put on ease of use, performance, documentation, and API consistency.

*F. Survey of Mul-tilinear Subspace Learning for Tensor Data, Pattern Recognition.***[10]**

Increasingly large amount of multidimensional data are being generated on a daily basis in many applications. This leads to a strong demand for learning algorithms to extract useful information from these massive data. This paper surveys the field of multilinear subspace learning (MSL) for dimensionality reduction of multidimensional data directly from their tonsorial representations. It discusses the central issues of MSL, including establishing the foundations of the multilinear projections, formulating a unifying MSL framework for systematic treatment of the problem, examining the algorithmic aspects of typical MSL solutions, and categorizing both unsupervised and supervised MSL algorithms into taxonomies.

G. Thirty years of Graph Matching in PatternRecognition[4]

This paper tries to characterize the role that graphs play within the Pattern Recognition field and two taxonomies are presented. Firstly, it includes almost all the graph matching algorithms proposed from the late seventies, and describes the different classes of algorithms. Secondly, the taxonomy that considers the types of common applications of graph-based techniques in the Pattern Recognition and Machine Vision. In many applications a crucial operation is the comparison between two objects or between an object and a model to which the object could be related. When structured information is represented by graphs this comparison is performed using some form of graph matching. Graph matching is the process of finding a correspondence between the nodes and the edges of two graphs that satisfies some (more or less stringent) constraints ensuring that similar substructures in one graph are mapped to similar substructures in the other.

H. Anatomy on Patter Recognition [5]

Pattern Recognition is the science of recognizing patterns by machines. This is very wide research area as of today, because every new research tries to make machine as intelligent as human for recognizing patterns. Pattern recognition is an active research and an important trait of 'artificial intelligence'. This review paper introduces pattern recognition, its fundamental definitions, and provides understanding of related research work. This paper presents different types of algorithms, their limitations &applications of pattern recognition. A pattern is defined by the common denominator among the multiple instances of an entity. For example, commonality in all fingerprint images defines the fingerprint pattern; thus, a pattern could be a finger print image, a handwritten cursive word, a human face, a speech signal, a bar code, or a web page on the Internet. Often, individual patterns may be grouped into a category based on their common properties; the resultant group is also a pattern and is often called a pattern class. Pattern recognition (PR) is the most important trait of cognitive ability, be it of mans or animals. The ability to recognize patterns is central to intelligent behavior. We receive signals from environment through our sensor organs which are processed by the brain to generate suitable responses. The whole process involves extraction of information from the sensory signals, processing it using the information stored in the brain to reach a decision that induces some action. All these information we work with are represented as patterns. We recognize voices, known faces, scenes, written letters and a multitude of other objects in our everyday life.

I. The Discipline of Machine Learning[13]

This document provides a brief and personal view of the discipline that has emerged as Machine Learning, the fundamental questions it addresses, its relationship to other sciences and society, and where it might be headed. A field of Statistics that largely ignored computational considerations, to a broad discipline that has produced fundamental statistical-computational theories of learning processes, has designed learning algorithms that are routinely used in commercial systems for speech recognition, computer vision, and a variety of other tasks, and has spun off an industry in data mining to discover hidden regularities in the growing volumes of online data

III. METHODOLOGY

Combining all these aspects like Machine Learning, Computer Vision and Quantum Computing, there may be a chance to develop new concept of Quantum Visual Intelligent Learning (QuVIL) System.

On one hand we will get a Computer Vision, capable of extracting data from an image or a video. Then on the other hand we use those extracted refined data in Machine learning to define a specific pattern. We can keep those data for future references to learn and draw some conclusions from it. Because of application of these algorithms will be huge, thus for a normal computer processing this huge data in a low time complexity is not possible, especially in cases like a space rover and real-time experiments. That's where Quantum computers and Quantum computing comes handy. One can use these perfected algorithms through Quantum computing on a Quantum Turing Machine, as in India Quantum Computers is still a fiction.

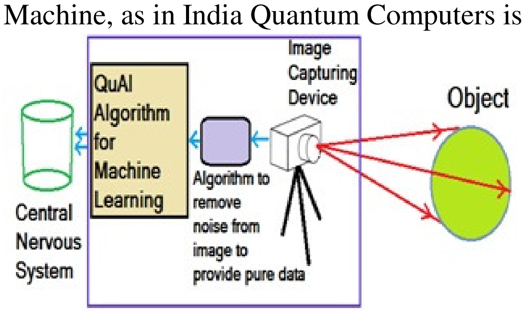

Figure.4. Quantum Vision Intelligence Learning System

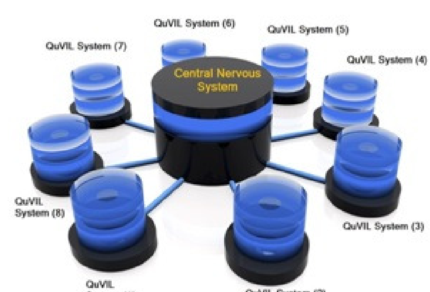

Figure 5. QuVIL Central Nervous System

The concept can be easily explained if a normal video camerahaving a computer vision recognizes the data and differentiates a "ball" from all other noises. We use those refined data called "ball" and store it memory and learn its properties that any spherical shaped object can be considered a "ball" (irrespective of its chemical property).

Then we place a simple Quantum Integrated Circuit in that video camera to process these huge data. We will get a video camera capable of recognizing data from computer vision then learning and drawing some conclusion from those data.

Now, take such several QuVIL System capturing and understanding images and continuously updating a single database or some online central nervous system. So the system will grow with experience. So, suppose in future when we will send some rover in Mars, we just need to place an online QuVIL System in it.

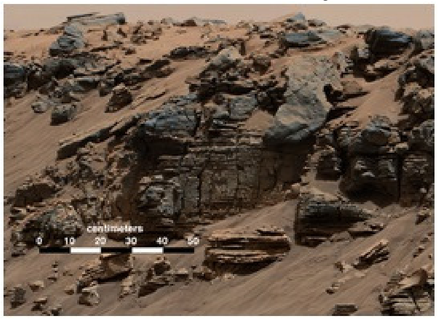

Figure 6.*The scene combines multiple frames taken with Mastcam's right-eye camera on Aug. 7, 2014, during the 712th Martian day, or sol, of Curiosity's work on Mars. [Source:http://www.nasa.gov/multimedia/imagegallery/iotd.html#lowerAccordion-set2-slide15]*

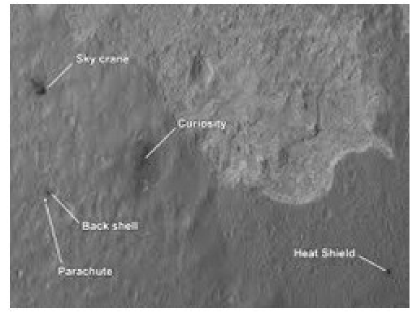

Figure 7.'Crime Scene' Photo shows Curiosity Landing Site [Source: http://spectrum.ieee.org/automaton/aerospace/robotic-exploration/crime-scene-photo-shows-curiosity-landing-site/].

The Automata will have an idea of a plane and a rough surface defined from their property and decides which area will be the best for its landing, we will not have to preprogram it.

IV. Conclusion

The ultimate goal of this review is to develop a Quantum Automaton and an algorithm that is capable of learning and taking decision from computer vision. The Application of Quantum Artificial Intelligence with Machine Learning and Computer Vision opens a broader aspect in Space Research or in bioinformatics Medical Research. We can develop an automaton capable of taking its own decision ranging from landing into a comet or a planet or detecting a disease by merely scanning the human body and even performing any surgery if needed, which is actually the advanced form of Computer Aided Diagnosis (CAD). QuVIL System is just an introductory part in the new Machine Learning concept. A more beautiful complex system can be created if this Vision part is integrated with QuSIL System which is Quantum Sound Intelligent Learning System. An automaton capable of taking decisions by seeing and hearing things.

This paper identifies three classes of opportunities for AI researchers at the intersection of quantum computation, AI and Computer Vision. Firstly, how Quantum Algorithm and Quantum Computing can be used in a more decisive way to solve Artificial Intelligence problems effectively. Scientists can work on more complex AI problems and leave the hard processing part for Quantum Computers to solve. Secondly,traditional AI algorithms are based on a single processes execution, but introducing Quantum computers means high end data execution rate, so a new AI technique is needed to define these problems.The third and the last part is integrating the vision part with this new AI technique.

The first phase is a basic approach for the development of this technology is to create a pattern recognition algorithm that can manipulate the actual data to define a pattern from the basic properties of the object and store it in the system. The second phase is to interpret this algorithm through Quantum Computing. As Quantum Computing is used, a huge collection of data can be taken into consideration while building the pattern recognition algorithm, which was not possible for a normal computer to process. So basically when a huge amount of data is taken for processing,it is expected that a more perfect system can be approached. We can include the entire essential and non-essential or even some such pattern which was thought was never possible to be implemented via a normal system. The system will become more responsive through vision, which was never possible for a traditional AI algorithm to perform or could have taken a high time complexity to complete it.

REFERENCES

[1] Anya Tafliovich and Eric C. R. Hehner, "Programming with Quantum Communication", Electronic Notes in Theoretical Computer Science 253 (2009) 99–118, Computer Science. University of Toronto, Toronto, Canada.
[2] C. L. Chen, D. Y. Dong, Z. H. Chen, "Quantum Computation for Action Selection using Reinforcement Learning", Volume 04, Issue 06, December 2006, Department of Automation, University of Science and Technology of China, Hefei, Anhui, 230027, P. R. China.
[3] D. Roy Chowdhury, M. Chatterjee, and R. K. Samanta, "NeuroGenetic fusion approach towards developing a Decision Support System for Neonatal Disease Diagnosis", NaCCS, National Conference on Computing and Systems, Dept. of Computer Science., Burdwan University, W. B., India. pp. 242-248, 2012.
[4] D.Conte, P. Foggia, C.Sasoneand M.Vento,"Thirty Years of Graph Matching InPatternRecognition", International Journal of Pattern Recognition and Artificial Intelligence, Vol. 18, No.3, (2004), 265-298.
[5] Mayank Parasher, Shruti Sharma, A.K Sharma, J. P. Gupta, "Anatomyon PatternRecognition", Indian Journal of Computer Science and Engineering (IJCSE), ISSN: 0976-5166,Vol. 2 No. 3 Jun-Jul 2011.
[6] Jie Liu, Jigui Sun, Shengsheng Wang, "Pattern Recognition: An overview",IJCSNS International Journal of Computer Science and Network Security, VOL.6 No.6, June 2006.
[7] Fabian Pedregosa,Ga¨el Varoquaux,Alexandre Gramfor,Vincent Michel,Bertrand, "Scikit-learn: Machine Learning in Python", Journal of Machine Learning Research 12 (2011) 2825-2830 ,Thirion,Parietal, INRIA Saclay Neurospin, Bˆat 145, CEA Saclay,91191 Gif sur Yvette –France.
[8] Google, NASA and USRA Collaboration, "The Quantum Artificial Intelligence Lab(QuAIL)" .
[9] Yong-Ki Kim (September 2, 2000). "Practical Atomic Physics". *National Institute of Standards and Technology* (Maryland): 1 (55 pages). Retrieved 2010-08-17.
[10] Haiping Lu, K. N. Plataniotis and A. N. Venetsanopoulos, \A Survey of Mul-tilinear Subspace Learning for Tensor Data", Pattern Recognition, vol. 44, no.7, pp. 1540-1551, Jul. 2011.
[11] C. Monroe, D. M. Meekhof, B. E. King, W. M. Itano, and D. J. Wineland," Demonstration of a Fundamental Quantum Logic Gate",National Institute of Standards and Technology, Boulder, Colorado 80303(Received 14 July 1995).
[12] Rybicki, G. B.; Lightman, A. P. (1979). *Radiative Processes in Astrophysics*. John Wiley & Sons. ISBN 0-471-82759-2.]
[13] Tom M. Mitchell, "The Discipline of Machine Learning,July 2006,CMU-ML-06-108,School of Computer Science, Carnegie Mellon University, Pittsburgh, PA 15213
[14] Camilleri, K. (2006), "Heisenberg and the Wave-particle Duality", in Studies in History and Philosophy of Modern Physics, 37: 298–315.
[15] http://www.alanturing.net/turing_archive/pages/reference%20articles/what%20is%20ai.html
[16] http://en.wikipedia.org/wiki/Machine_learning
[17] http://googleresearch.blogspot.in/2013/05/launching-quantum-artificial.html
[18] http://en.wikipedia.org/wiki/Quantum_Artificial_Intelligence_Lab