Comprehensive Review on Quantum Computation

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ABSTRACT: Quantum theory is without doubt one of the 20th century's best technological accomplishments. It provides a coherent structure on which many existing physical theories may be developed. Other major scientific triumphs of the 20th century and a modern field of quantum computing are brought in after more than 50 years of the beginning date. The quantum theory is coupled with computer science. The key aim of this paper is to research some (potential) Artificial Intelligence (AI), quantum computation applications and to investigate the interplay between quantum theory and AI. A brief perspective and a popular but easy quantum algorithm are given for the writers, who are not acquainted with quantum calculations so that they can appreciate the force of quantum computation. The aim of this paper is two-fold: to give AI researchers a brief introduction and a glimpse of the panorama of quantum computation; and to examine connections between quantum computation, quantum theory and AI.

KEYWORDS: Quantum computation Quantum theory Search Learning Discrimination and recognition Bayesian network Semantic analysis Communication.

INTRODUCTION

Quantum theory is certainly one of the most significant research discoveries of the 20th century. It presents a common basis for the construction of multiple contemporary physical theories. After over fifty years from its inception, quantum theory partnered with computer science and the modern field of quantic calculations was born into another great scientific triumph of the 20th century. In 1982, Nobel Laureate physicist Feynman first envisaged quantum computers. Without exponential slowing, he discovered that a classical machine could not replicate such quantum processes and thus understood that quantum mechanical effects would give truly new calculations [1]. Deutsch developed and formalized Feynman's theories in 1985 in a landmark paper defining a quantum turning computer. Deutsch developed in particular the quantum parallelism methodology based on the quantum mechanics superposition theory, which encodes multiple intranets on the same tape and measures all feedback simultaneously with a quantum Turing computer.

In 1994, Short made one of the most impressive inventions. In exploring the potential of quantum parallelism he discovered an algorithm of polynomial time on quantum computers, the most famous algorithm on traditional computers is exponential. In 1996, Grover gave another killer application for quantum computing and found a quantum algorithm to scan an independent object at the squared root of a classical device in an unsorted array [2]. When the very notion of computation has revolutionized it, quantic computing causes one to reexamine various branches of IT and AI is no exception. AI has two main aims, broadly speaking: (1) innovation – intelligent machinery development; and (2) empirical knowledge – intelligent human, animal and computer behavior.

Researchers at AI primarily use informatics to accomplish technical goals as well as science goals. Indeed, McCarthy has recently also emphasized that artificial intelligence is a more fitting name for the AI subject to highlight AI's essential position in the machine. The rapid development of quantum simulations inevitably causes one to question if this modern computational methodology will help one accomplish AI objectives. Quantum calculations are evident to add greatly to AI's technological target by implementing them to speed computation in different AI systems, but quantum algorithms are in general very challenging to develop to address such AI-problems that are more effective for the same reason than classical algorithms [3]. There is still no strong proof at this stage how quantum computation may be used to accomplish AI's theoretical aim, and there is no substantial research to solve this issue to the best of my understanding. Rather, the fact that a large number of publications are dedicated to AI quantum theory implementations and vice versa rather than to quantum calculations is somewhat concerning. Existing research can be found that the quantum theory can be correlated more randomly with the computational AI than with rational AI because of its intrinsic probabilistic existence.

QUANTUM COMPUTATION

In a quantum machine, the fundamental data element is a qubits, which is theoretically represented by a two-tier quantum mechanical device, e.g. the photon's horizontal or vertical polarization, or the up and down flips of a single electron. Within the two-dimensional Hilbert space complex a qubits is represented mathematically by a unit vector and can be written as:

$$|\psi\rangle = \alpha_0|0\rangle + \alpha_1|1\rangle,$$

Where |0 and |1 are two basis states, and α0 and α1 are complex numbers with |α0| 2 + |α1| 2 = 1. The states |0 and |1 are called computational basis states of qubits. Obviously, they correspond to the two states 0 and 1 of classical bits. The number α0 and α1 are called probability amplitudes of the state |ψ. A striking difference between classical bits and qubits is that the latter can be in a superposition of |0 and |1.

By bringing together many qubits, a quantum register is created. The following explains the position of a quantum register of n qubits:

$$|\psi\rangle = \sum_{t\in\{0,1\}^n} \alpha_t|t\rangle = \sum_{t_1,t_2,\ldots,t_n\in\{0,1\}} \alpha_{t_1t_2\ldots t_n}|t_1t_2\ldots t_n\rangle,$$

where the complex numbers $\alpha_{t_1t_2\ldots t_n}$ are required to satisfy the normalization condition:

$$\sum_{t\in\{0,1\}^n} |\alpha_t|^2 = \sum_{t_1,t_2,\ldots,t_n\in\{0,1\}} |\alpha_{t_1t_2\ldots t_n}|^2 = 1.$$

In general, quantum calculations are conducted via quantum gate circuits. A quantum door defines a distinct evolutionary phase in a closed quantum framework. The amount gates of U are a complex matrix U such that U alternates with a matrix of identity. Thereby U alternates are represented by Hermit Ian conjugate (or conjugate transpose) of U, which is the I (j)-entry of U as the complex conjugate of (j)-entry of U as the (i). The)-entry of U as the complex conjugate of (j, i)-entry of U.

$$U = (u_{ij})_{i,j=0}^{2^n-1}$$

is a quantum gate, then the outcome of performing U on $|\psi\rangle$ is the state

$$|\varphi\rangle = \begin{pmatrix} \beta_0 \\ \cdot \\ \cdot \\ \cdot \\ \beta_{2^n-1} \end{pmatrix} = U|\psi\rangle,$$

where $U|\psi\rangle$ is given according to the usual matrix multiplication; that is,

$$\beta_i = \sum_{j=0}^{2^n-1} u_{ij}\alpha_j$$

for $i = 0, 1, \ldots, 2^n - 1$. One of the most useful single qubit gates is the Hadamard gate:

$$H = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}.$$

Only those quantum registers will calculate the effects of the quantum measurement. Quantum calculation is only known in the theoretical context. Quantum calculations may be performed on certain bases by the application of theoretical unitary transformation and calculation.

1. Models of Quantum Computation

The quantum computation structures had their origins in the study of physics-calculation interconnections. In 1973, "Bennet pointed out that a theoretically reversible process doesn't need to expel any energy to grasp the thermodynamics in classical measurement [4]. A quantum mechanical model of a Turing machine was built in 1980 from Benioff". Recently-Quantum Automata implementations have been found, such as the direct application of quantum automates to digital proof schemes, rendered by some researchers. It does not seem, however, that quantum automatics may be used to compile quantum programming languages. Table 1 provides a review of models of quantum computation to date.

2. Logical foundations of quantum computation

At present, quantum algorithms and protocols for communication are primarily represented at the very small quantity level. In the classic machine, this paper found that high-level explanations are particularly helpful for the creation and study of algorithms and protocols as it allows one to focus on a problem this paper wants to address in a logical way rather than on implementation specifics. However, there is no quantum approximation of high-level representation techniques. Some researchers proposed a category-theoretical axiomatization of quantum mechanics by using formal instruments primarily built-in computers, in particular to previous research on the semantics of competition and geometry of interaction, in response to the high-level definition of the quantum information theory [5]. More precisely, in the abstract language of extremely compact closed categories with bi-products, the spatial formalism principles of quantum mechanics by Hilbert from Neumann may be expressed.

3. Quantum lambda calculus

The lambda calculus is a systematic framework and conceptual foundation for many essential classical languages such as LISP, Schema, ML and Haskell, and can be contained in a classic application. Tonder initially proposed a quantum generalization of the μ-calculus. The quantity data's non-cloning influence makes the quantum lambda calculus loosely aligned with the linear lambda calculus of the linear logic culture [6]. They used the quantum lambda calculus in particular to include the dimensional fragment dimensional model of a quantum functional programming language, which is obtained by applying superior functions to Salinger's quantum flowchart system QFC.

Table 1: Review on Model of Quantum Computation

1. Quantum Turing machine and quantum automata	The first truly quantum Turing machine was described by Deutsch in 1985. In his machine, the tape is able to exist in quantum states too. This is different from Benioff's machine.
2. Quantum circuits	The circuit model of quantum computation was also proposed by Deutsch. Roughly speaking, a quantum circuit consists of a sequence of quantum gates connected by quantum wires that carry qubits. Yao showed that quantum circuit model is equivalent to a quantum Turing machine in the sense that they can simulate each other in polynomial time. Since then, quantum circuits has become the most popular model of quantum computation in which most of the existing quantum algorithms are expressed.
3. Adiabatic quantum computation	Quantum Turing machine, quantum automata and quantum circuits are quantum generalizations of their classical counterparts. Recently, several novel models of quantum computation have been conceived and they have no evident classical analogues, one of such models is adiabatic quantum computation proposed by Farhi, Goldstone, Gutmann and Sipser. Different from all of the other models considered in this section, which are discrete-time models, adiabatic quantum computation is a continuous-time model of computation.
4. Measurement-based quantum computation	Another model of quantum computation without a classical counterpart is measurement-based computation. In the quantum Turing machine and quantum circuits, measurements are mainly used at the end to extract computational outcomes from quantum states. However, Raussendorf and Briegel proposed a one-way quantum computer and Nielsen and Leung introduced teleportation quantum computation, both of them suggests that quantum measurements can play a much more important role in quantum computation.
5. Topological quantum computation	A crucial challenge in constructing large quantum computers is quantum decoherence. In 1997, topological quantum computation was proposed by Kitaev as a model of quantum computation in which a revolutionary strategy is adopted to build significantly more stable quantum computers.
6. Distributed quantum computation	A major motivation comes from the studies of quantum communication. By employing quantum mechanical principles, some provably secure communication protocols have been proposed, and quantum communication systems using these protocols are already commercially available.

4. *Quantum computational logic*

Birkhoff and von Neumann proposed quantum logics some 70 years earlier, as a principle in quantum mechanics. The Quantic Logic Propositions are then simply represented as the closed substantial subspaces of a quantum system's state space (a Hilbert space), or as their algebraic representation, orthomodular lattice components and logical connections [7]. This logic can be used to describe and reason about quantum circuits. It seems that some interesting connection between quantum computational logic and the work on the algebra of quantum circuits exists and worth some further studies.

INTERPLAY BETWEEN QUANTUM THEORY AND ARITIFICAL INTELLIGENCE (AI)

Work arising from the interplay between quantum theory and AI can be divided loosely into two categories: (1) use some of quantum theory's ideas to solve other AI problems; and (2) adding other AI ideas to quantum theory, conversely. This paper will see how AI uses concepts in quantum theory, bringing two common cases into consideration.

1. Semantic analysis

Some comparisons were found with those used in quantum mechanics with the conceptual hierarchical form used by the AI group in the semantic study of the natural language. But these correlations seem very simplistic and do not persuade me to assume that there is some inherent association between semantic pated research and quantum mechanics, since it is not shocking that the same math methods are used in non-related realms [8]. However, it is also helpful to note this resemblance, because it may give analogies that show, in semantically analysis or more broadly, how to take certain ideas from the well-known subject matter of quintal mechanics. Figure 1 depicts the interplay of quantum theory and semantic analysis.

2. Entanglement of words in natural languages

The existing AI group is mainly concerned with designing computational strategies that incorporate knowledge to cope with classical problems. The work described in the following subparagraphs may be regarded as AI strategies that incorporate knowledge to cope with quantum problems [9]. Besides, physicists who work in the field of quantum knowledge have discovered and intensively researched the quantum equivalents of many important AI problems, such as learning and pattern recognition. There appears to be little knowledge regarding this sort of study by AI researchers.

3. Quantum Bayesian networks

Owing to the basic probabilistic existence of quantum mechanics, statistical inference is at the core of the quantum theory. Bayesian approaches were used widely in classical world mathematical inference. In the physical literature, several versions of the quantum Bayes rule were recently derived [10]. Bayesian networks are graphical structures for probability knowledge representation and inference and are commonly utilized by AI. It is assumed that such a visual model will be taken into consideration when talking about the actions of broad quantum systems. A researcher implemented a Bayesian network quantum generalization in which complicated amplitudes are allocated to its nodes rather than (conditional) probabilities and used them to measure probabilities for certain physical experiments.

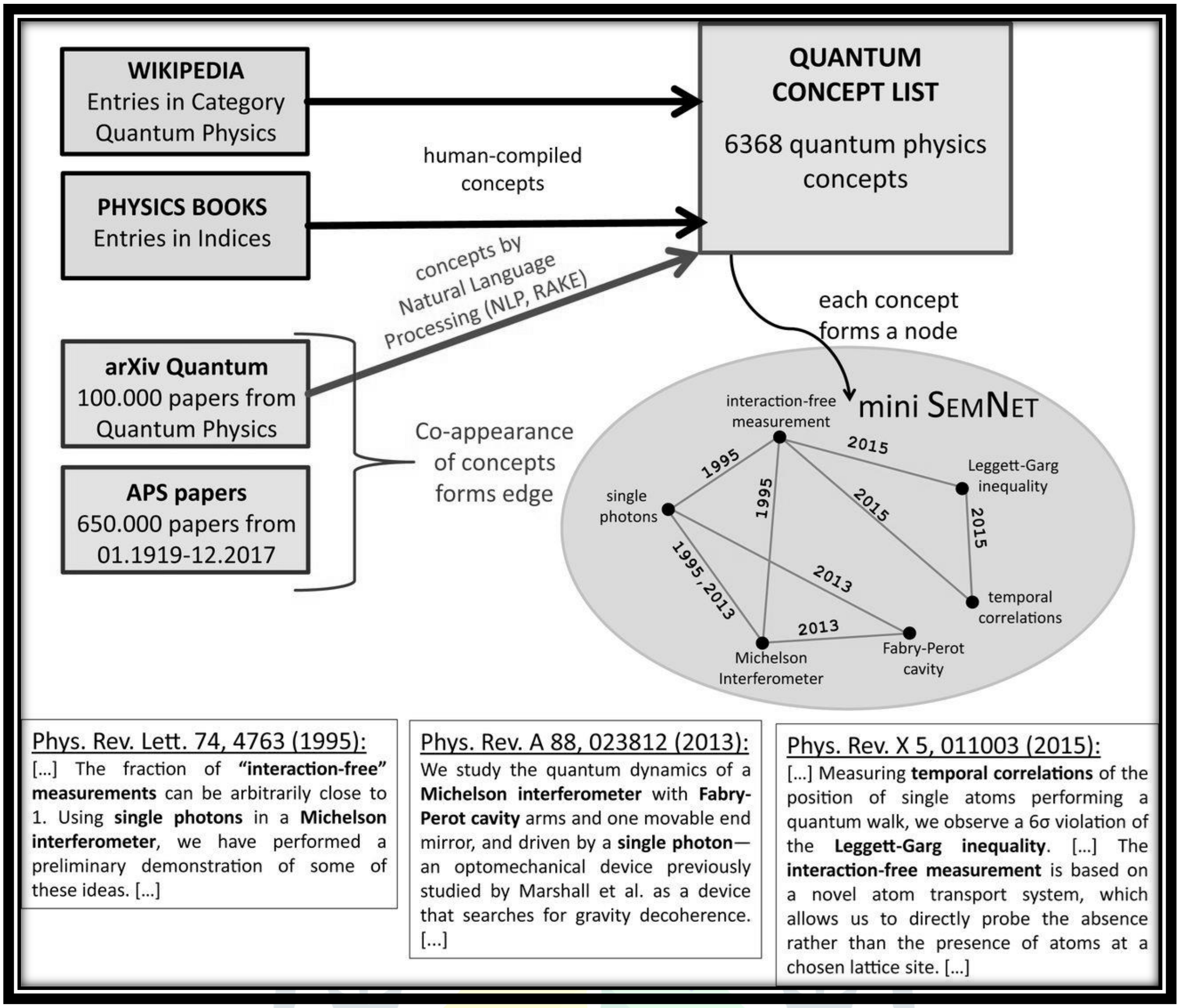

Figure 1: Interplay of Quantum Theory and Semantic Analysis

CONCLUSION

This paper discusses three groups of possibilities for Ai researchers at the intersection of physical, physical theoretical and AI. Build quantum algorithms to solve Ai problems in an effective way; create more powerful approaches to officialize AI issues by using concepts from quantum theory; Build modern AI strategies for solving problems in a quantum universe. The first study class is only at the initial growth level and there has not been any improvement. Many researchers identified several explanations for the difficulties of finding quantum algorithms. Such explanations are sadly often true for AI problems. Such scattered and isolated second-class work has a long tradition and certain revolutionary concepts may be also traced back to Niels Bohr. Work has been very involved in this field in recent years. But it seems like some of these works are quite simplistic and that a more rigorous theoretical study of these works' formal methods is needed. More longitudinal work is required in particular to assess efficacy. Work in the third level seems to be advancing slowly. My principal concern is that the AI techniques built in this class of work are useful and valued by physicists in quantum physics. The advancement of this area would definitely benefit greatly from the cooperation between AI researchers and physicists.

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