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Linear Superposition: A New Perspective

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ABSTRACT

Quantum theory is one of the most successful theories that have influenced the course of scientific progress during the twentieth century. It has presented a new line of scientific thought, predicted entirely inconceivable situations and influenced several domains of modern technologies. There are many different ways for expressing laws of science in general and laws of physics in particular. Similar to physical laws of nature, information can also be expressed in different ways. The fact that information can be expressed in different ways without losing its essential nature, leads for the possibility of the automatic manipulation of information. All ways of expressing information use physical system, spoken words are conveyed by air pressure fluctuations: "No information without physical representation". The fact that information is insensitive to exactly how it is expressed and can be freely translated from one form to another, makes it an obvious candidate for fundamentally important role in physics, like interaction, energy, momentum and other such abstractors. This is a project report on the general attributes of Quantum Computing and Information Processing from a layman's point of view.

Keywords — quantum computation, EPR, quantum mechanics, superposition, unitary transformation, decoherence.

I. INTRODUCTION

With the development of science and technology, leading to the advancement of civilization, new ways were discovered exploiting various physical resources such as materials, forces and energies. The history of computer development represents the culmination of years of technological advancements beginning with the early ideas of Charles Babbage and eventual creation of the first computer by German engineer Konard Zeise in 1941. The whole process involved a sequence of changes from one type of physical realization to another from gears to relays to valves to transistors to integrated circuits to chip and so on. Surprisingly however, the high speed modern computer is fundamentally no different from its gargantuan 30 ton ancestors which were equipped with some 18000 vacuum tubes and 500 miles of wiring. Although computers have become more compact and considerably faster in performing their task, the task remains the same: to manipulate and interpret an encoding of binary bits into a useful computational result.

The number of atoms needed to represent a bit of memory has been decreasing exponentially since 1950. An observation by Gordon Moore in 1965 laid the foundations for what came to be known as "Moore's Law" – that computer processing power doubles every eighteen months. If Moore's Law is extrapolated naively to the future, it is learnt that sooner or later, each bit of information should be encoded by a physical system of subatomic size. As a matter of fact this point is substantiated by the survey made by Keyes in 1988. This plot shows the number of electrons required to store a single bit of information. An extrapolation of the plot suggests that we might be within the reach of atomic scale computations with in a decade or so at the atomic scale however.

With the size of components in classical computers shrinking to where the behaviour of the components, is practically dominated by quantum theory than classical theory, researchers have begun investigating the potential of these quantum behaviours for computation. Surprisingly it seems that a computer whose components are all to function in a quantum way are more powerful than any classical computer can be. It is the physical limitations of the classical computer and the possibilities for the quantum computer to perform certain useful tasks more rapidly than any classical computer, which drive the study of quantum computing.

A computer whose memory is exponentially larger than its apparent physical size, a computer that can manipulate an exponential set of inputs simultaneously – a whole new concept in parallelism; a computer that computes in the twilight (space like) zone of Hilbert Space (or possibly a higher space – Grassman Space & so on), is a quantum computer. Relatively few and simple concepts from quantum mechanics are needed to make quantum computers a possibility. The subtlety has been in learning to manipulate these concepts. If such a computer is inevitability or will it be too difficult to build on, is a million dollars question.

II. THE PRINCIPLE OF LINEAR SUPERPOSITION

Here we introduce a possibility of modification of Expansion Theorem as applicable to an EPR situation for correlated terms. In this section we attempt to introduce a correlation term in the definition of wave function (ψ) as given by Linear Superposition Principle. A general expression of wave function (ψ) can be expressed in word equation as:

1) Wave Function (ψ) = Term of Correlated states (δ) + Sum of Un-correlated terms.

This word equation can be expressed numerically as:

$\boldsymbol{\psi = \delta + \Sigma a_n \psi_n}$ where nε allowed un-correlated states & $\psi(n)$ are eigen states.

Hence in general with the introduction for our formalism of wave function, we can now divide wave function into 3 categories which are:

1. Quantum Systems with Corr. = 0 → $\psi = \Sigma a_n \psi_n$ where nε (1,2,3,4..) & $\psi(n)$ are eigen states.
2. Quantum Systems with 0 < Corr. < 1 → $\psi = \delta + \Sigma a_n \psi_n$ where nε allowed un- correlated states & $\psi(n)$ are eigen states.
3. Quantum Systems with Corr. = 1 →$\psi = \delta$ and $\Sigma a_n \psi_n = 0$ $\psi(n)$ are eigen states.

Thus the above treatment of Expansion Theorem in Quantum Systems suggests that the definition of wave function should be modified to take into account the representation of EPR states and further investigation should be done to determine the value of δ in the wave function definition. To further support and validate the above formalism I have applied the Schrodinger Wave Eq. both time dependent and time independent to check if the form of Expansion Theorem changes or not.

In the standard formulation of Quantum Mechanics we have Schrodinger Wave Eq. given by :

$\boldsymbol{\nabla^2 \psi + 2m/h' (E-V) \psi = 0}$ (1) Schrodinger time independent Eq. in this eq. ψ : wave function, m is effective mass of the system, E is total energy, V is potential energy of the system and $h' = h^2 / 4\pi^2$ (h: Plank Constant) and Schrodinger Time dependent wave eq. is given by:

2) $\boldsymbol{ih/2\pi\ (\partial/\partial t)\ \psi = H\ \psi}$ (2)

where ψ : wave function of the system, H is Hamiltonian of the system.

Now, by putting all the three definitions of ψ into these fundamental wave equations of Quantum Mechanics that the modified definition of ψ is correct as we get the expected results.

III. SUITABILITY OF QUANTUM BITS FOR QUANTUM COMPUTATION

Since there are three types of wave function systems as we have discussed in previous sections, thus how do they relate to qubits is given in following lines:

1. For purely unentangled states in a Quantum system i.e. Corr.= 0, in such type of systems wave functions is given by Linear Superposition Principle:
   $\psi = \Sigma a_n \psi_n$ & $\Sigma |a_n|^2 = 1$ where nε (1,2,3,4……) and $\psi(n)$ are eigen states.

   In these type of system of qubits quantum algorithms can be made "efficiently" as in this case the underlying parallelism of computation and vast storage of information is possible according to the conception of Bloch Sphere or otherwise since every state. ψ_n is independent of each other and hence can be used for computation and storing of information.

2. For mixed entangled states in a Quantum System i.e. 0< Corr. < 1, in such type of systems wave function is given by:

   $\psi = \delta + \Sigma a_n \psi_n$ & $\Sigma |a_n|^2 \neq 1$ where nε allowed un-correlated states & $\psi(n)$ are Eigen states. In such a case since entangled and unentangled states cannot be separated as that would amount to an interaction with the system leading to information loss and wave function collapse. Hence such type of a state is not fit for computational purposes as it may lead to spurious results.

3. For purely entangled states in a Quantum system i.e. Corr. = 1, in such type of systems wave function is given by:

   $\psi = \delta$ and $\Sigma a_n \psi_n = 0$ $\psi(n)$ are Eigen states.
   These states are suitable for teleportation of information using EPR states and not for information storage or computational purposes. Thus case 3 is well suited only for information communication keeping the validity of Quantum No Cloning Theorem.

IV. CONCLUSIONS

Though decoherence can be described as an effective process, its dynamics is not understood but an attempt has been made in the present project work in the form of Symmetry breaking argument or need for an entropy like parameter or function to account for irreversibility in the system. To be able to control decoherence, one should be able to figure out the eigenstates favored by the environment in a given setup. The dynamics of measurement process in not understood fully, though the attempt is also made in this regard in this project. Measurement is just described as a non-unitary projection operator in an otherwise unitary quantum theory. Ultimately both the system and the observer are made up of quantum building blocks, and a unified quantum description of both measurement and decoherence must be developed. Apart from theoretical gain, it would help in improving the detectors that operate close to the quantum limit of observation. For the physicist, it is of great interest to study the transition from classical to quantum regime. Enlargement of the system from microscopic to mesoscopic levels, and reduction of the environment from macroscopic to mesoscopic levels, can take us there. If there is something beyond quantum theory lurking, there it would be noticed in the struggle for making quantum devices.

We may discover new limitations of quantum theory in trying to conquer decoherence. Theoretical developments alone will be no good without a matching technology. Nowadays, the race for miniaturization of electronic circuits in not too far away from the quantum reality of nature. To devise new types of instruments, we must change our view-points from scientific to technological-quantum effects which are not for only observation; we should learn how to control them for practical use. The future is not foreseen yet, but it is definitely promising.

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