Leveraging the Double-Slit Experiment to Explore New Horizons in Quantum Computation

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***Abstract* - In looking at possible alternative trajectories of quantum computation it is important to revisit the famous double-slit experiment that launched inquiry into the quantum realm and arguably bootstrapped the birth of the quantum age. In the double-slit experiment the behavior of light epitomized by dual wave-particle dynamics can be seen from both a bottom-up and top-down perspective. If viewed from the bottom-up it gives rise to the classical interpretation of superposition and entanglement, primary pillars of modern day quantum computation. If viewed from the top-down, however, photons in the double-slit experiment may also be viewed as correlated with "functional" properties of light giving rise to a different interpretation of superposition and entanglement and proposing different trajectories of quantum computing development. By taking several observer views in the double-slit experiment there are several distinct quantum computational trajectories that can arise. This brief overview paper will relate today's rendition of quantum computation with one such observer perspective and highlight several other observer perspectives leading to possible different ways to grapple with the quantum realm and different potential quantum computational architectures to realize this.**

Keywords - Quantum Computation, Quantum Dynamics, Observer Effects

I. INTRODUCTION

This paper provides a brief overview of an approach to penetrating the quantum unknown by using the double-slit experiment and surfacing insight that will then contribute to alternative trajectories of quantum computational development. The structure of this paper is as follows: Section -II focuses on a functional interpretation of the double-slit experiment. Section-III introduces a cast of characters that arise in looking at the double-slit experiment from a functional perspective. Section-IV begins to construct a quantum-world based on the functional interpretation. Section-V dives deeper into different observer perspectives. Section-VI concludes with some implications for quantum computing architectures.

II. FUNCTIONAL INTEPRETATION OF THE DOUBLE-SLIT EXPERIMENT

Let's look at the double-slit experiment. As a reminder, the double-slit experiment is where we send light through a double slit, and there's an interference pattern that results on the screen behind it. The key point about this experiment is that even when we send individual photons one at a time through the double slit, it still counterintuitively results in an interference pattern [1].

So let's reflect on this experiment. First, it's almost as though each photon has knowledge of the interference pattern and knows where to fall on the screen to adhere to that. In a sense an individual photon appears to be crossing limits of time to share knowledge with past and future photons. In doing so, its displaying superposition, in that it adheres to wave knowledge of many possibilities until it hits the screen, and also, there's an implicit phenomenon of entanglement because all the photons are connected to one another in this experiment.

Let's step back and look at a couple of interpretations. There's the common interpretation that I call "bottom-up" or reductionist. If we take this point of, then the perception is that the photons connect to past and future photons and assume infinite values before they hit the screen. This way of looking at the mechanics appears also to be the result of the Copenhagen Interpretation of Quantum Mechanics [2].

Now, if we consider a different interpretation, a "top-down" interpretation, the same experiment is viewed as a totality, so that no part can be separated from the whole. Then what arises is a suggestion of a minimum viable whole that is wrapped in the space-time configuration encompassing the experiment. This is illustrated by the following figure:

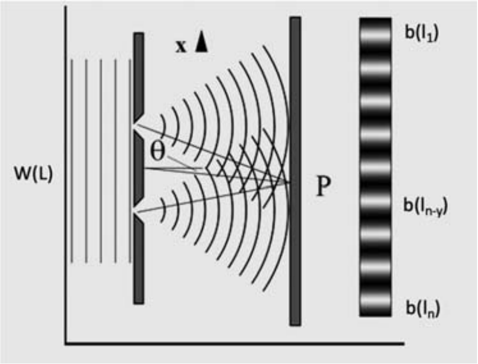

Figure 1. W(L) Double-Slit View

The whole can be referred to as W(L), where L can be considered to be light, and W is a wholeness-function of that light. In this interpretation, each photon can be thought of as being linked to a property implicit in W(L). These properties can range from ‘l1’ through ‘ln’. So, as a photon travels and hits the screen it is correlated to a function of the property, b(l), correspondingly showing up in a particular strand. Such an interpretation doesn't require that photons have knowledge of each other because they're each endowed with this specific function right at the outset, and it doesn't require that there's a connection between past and future photons either.

III. A CAST OF ACTORS IN THE FUNCTIONAL INTERPRETATION

The following figure introduces a cast of actors related to the double-slit experiment:

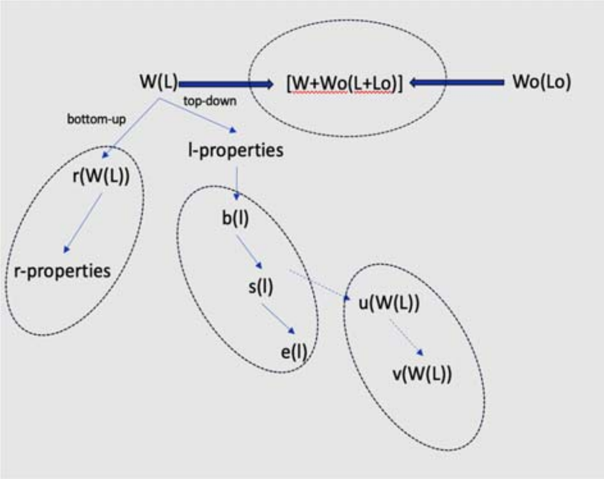

Figure 2. Cast of Actors

I’ve already introduced W(L), which represents some kind of whole. Here, the whole is the behavior of light across a double-slit experiment. When we consider or look at this behavior from the bottom up, however, we decompose W(L) and measure quantum objects that occur during the experiment. This results in an actor called r(W(L)). This is some function of this larger W(L) and will yield another set of actors that we can refer to as r-properties.

Now, when we look at the same experiment from the top down, then there are l-properties—'l1’ through ‘ln’—that are highlighted. A function of these properties is referred to as the actor b(l), and results in another set of actors—s(l) and e(l)—that can be thought of as more developed forms of b(l). The actors b(l), s(l), and e(l), suggest a "minimum viable whole" – a purer form of W(L) as opposed to r(W(L)), referred to as u(W(L)). A more sophisticated form of u(W(L)), can then be referred to as v(W(L)). Finally, there are another couple of actors that are wholes in themselves: Wo(Lo), and a synthesis of two wholes - [(W+Wo)(L+Lo)] - the latter being a new possibility that's represented by this combined whole function. These actors will be further elaborated in subsequent sections.

IV. CONSTRUCTING A WOLRD BASED ON W(L)

Having been introduced to this cast of actors, let us now construct a world based on W(L):

- In this world, each photon that originates in the quantum computational whole, W(L), is, in reality, bringing forth or carrying something of W(L).
- W(L) can be thought of as having unique and distinct quantum properties, represented by the set: $\{l_1, l_2, l_3, l_4, \dots l_n\}$.
- Each photon, then, can be thought of as being related to or derived from one of the elements in the set so that when it hits the screen behind the double-slit, it takes on the form b(l), where ‘l’ is related to one of the elements that derive from W(L).
- In this thought experiment, then, each of the strands highlights a unique aspect of W(L).
- The strand/set will practically consist of up to infinite photons that each highlight some subtle variation or nuance related to the strand/property/set it belongs to.
- Imagine now that the layer consisting of b(l) is the base layer in this double-slit world. It manifests something of W(L), but W(L), as an unseizable whole, has a lot more to it.
- W(L) wants to push forward more of what it is, and so through a process of combination, creates seeds leveraging the material forms of b(l) that become the basis for something else of itself to manifest as a second layer based on the new partial-whole, s(l):
- $s(l) = p\{b(l_1)\ x\ b(l_2)\ x\ b(l_3), \dots\ x\ \dots, x\ b(l_n)\}$.
- This process continues with many layers surfacing, each capturing more of W(L) but never the entirety of what W(L) is. In this way, all varieties of form and property can combine to create a world built from the quantum whole.
- e(l) – an evolving form - can be thought of as continuing to capture more of W(L).

The important point is that this kind of whole will require a different quantum computational architecture honed-in on perceiving quantum properties and their dynamics through logic, mathematics, and gate structure based on e(l).

To begin to get insight into other possible architectures we need to look at the experiment from different observer perspectives.

V. EXPLORING DIFFERENT OBSERVER PERSPECTIVES

Central to the prevailing current computational focus, is the notion of the act of employing probability and statistics to decompose and recompose W(L). Such decomposition and recomposition will be related to ‘Observer-1’. The following can be surmised:

- As an act of 'observation,' such decomposition and recomposition results in r(W(L)) that is different than the wholeness of W(L).
- W(L) still exists as a whole, except that we are not dealing with that anymore. We may think we are dealing with W(L), but in reality, we are now dealing with r(W(L)).
- If W(L) contained *l-properties*, {l1, l2, …, ln}, then we can think of r(W(L)) as containing a different set of observed properties, {r1, r2, …, rm}.
- Any *r-element* of this set will be superposed with all other elements of the *r-set.*
- Entangled *r-elements* will result in a new state, en{r1, r2, …, rm}.
- The quantum computing possibilities of r(W(L)) will be based on the *r-set* and will remain distinct from the wholeness, W(L).
- In other words, the possibilities of an e(l) will simply never occur.
- It is perhaps this version of quantum computation that many players in the industry are currently focused on.

Elaborating the r-set in today's rendering of quantum computation, qubits (the quantum equivalent of digital bits) could be based on a variety of quantum objects [3] - such as ions, electrons, or photons - that display quantum mechanical properties such as superposition and entanglement. This can be summarized by a couple of possible approaches:

- Approach 1:

- Group together a threshold number of qubits.
- Learn to map a real-world problem to them.
- Learn to leverage superposition and entanglement to process the possibilities.
- A variety of traditionally intractable computational problems may possibly be solved.

- Approach 2:

- Qubits can be made to represent atoms and molecules.
- Or perhaps even atoms and molecules can be harnessed to operate as qubits within a controllable gate-based quantum computational environment.
- Quantum mechanically see new possibility from the bottom-up.

In themselves these are great possibilities and need to be further developed. In focusing on the mechanics of manufactured quantum-objects though, the "quantum whole" that keeps silver operating as silver, or the integrity of a particular protein intact, escapes us. A different approach to quantum computation is required to begin to leverage these wholes natural to the quantum level.

Let us consider another observer, Observer-2 that could result in either an r-set or an l-set:

- Another type of observation occurs when we place a measuring device close to the double-slit.
- Depending on how it is "measured", it may result in an *r-property* or an *l-property.*
- If focused on r-properties, then subsequent entanglement, superposition, and quantum computation possibilities would be similar to that discussed in the Observer-1 scenario.
- If the latter, then depending on how the *l-property* is made to interrelate with other potential *l-properties*, quantum computational possibilities could tend toward r(W(L)) or toward some other fraction of W(L), u(W(L)).

Consider now Observer-3 that results in an increasing l-property focus:

- A third type of observer is represented by the screen, and it causes W(L) to display itself as numerous strands, each built on a different *l-property* of W(L).
- The resulting quantum computational possibilities would be a variation on that defined in the Observer-2 scenario in that if it were to tend to u(W(L)), since it is based on the set {b(l1), b(l2), …, b(ln)}, it could become a larger fraction v(W(L)) such that v > u.

Consider finally Observer-4 based on intersection of wholes:

- A fourth type of observer is defined by another type of whole, Wo(Lo). Wo(Lo) could represent an observer with unique intent.
- A way to think of intent is that it could be thought-based or emotion-based, and the intersection of W(L) with some Wo(Lo) will result in another unique whole [W+Wo](L+Lo), where '+' indicates a merger of sorts.

In the point of view elaborated here, the quantum level is interpreted as complex, sensitive, and adjustable via feedback [4], and as such, there are different ways to conduct quantum computation that will require different architectures and result in completely different outcomes. The default industry approach seems to have been captured by Observer-1. In contrast, Observer-2, Observer-3, and Observer-4 represent unique and different types of quantum computing opportunities, progressively reaching into more and more creative realms based on the evolving form, e(l), as its journeys to *quantum wholeness* as represented by W(L).

VI. CONCLUSION

The four previous observer perspectives provide some insight into alternative quantum computational architectural considerations.

Considering the Observer-1 perspective:

- The Observer-1 scenario is the commonly accepted quantum computing species in which measured quantum objects are subject to statistics and probability.
- These quantum objects potentially allow entanglement and superposition and computational speed-up.

The Observer-2 perspective may be related to function-based quantum computation:

- In the Observer-2 scenario, the observer is a measuring device placed close to the double-slit.

- However, the measurement itself may allow something of the computational whole to be measured rather than the reduced quantum object.
- Measuring the whole, though, requires a different measurement paradigm than the one in practice now.
- Gates would need to propagate property or function derived from the quantum computational whole.
- The mathematics of combining what is perceived is not based primarily on probability and statistics, as is the case in scenario 1, but on function.
- Unique function-based mathematics that allows manipulation of function would need to be leveraged.

Observer-3 relates to quantum-computational wholeness:

- The Observer-3 scenario is based on perceiving more of the wholeness (using the strands of the interference pattern on the screen as the basis/metaphor) and also uses a function-based computer.
- This computer looks at the quantum level differently, and different combinations of gates can be combined to create higher levels of computing sophistication.
- The arbitration of the higher level of wholeness that has implicit in it a larger range of functions becomes the basis of a more sophisticated quantum computing possibility.
- This may require reinterpretation of the notion of quanta and fundamental quantum computational anchors established by Feynman, Euler, Schrodinger, and Heisenberg, that begin to shed light on this approach and the possibilities of quantum computational wholeness [5].

Obswerver-4 relates to wholenesses intersecting:

- The Oberver-4 scenario, where two wholenesses are made to interact, also requires a function-based quantum computer.
- In this scenario, human beings can be a part of the quantum computational architecture.
- Some insight into the function-based computer architecture is provided by an IEEE nano-cyborg paper, and more insight into human-in-the-loop quantum computing is provided by an IEEE paper that views the universe as a complex adaptive system (CAS) [5].

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