The Machine's Many Worlds: A Computational Analysis of the Observer to Understand the Quantum Measurement Process

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Abstract

This writing seeks to account for the information constraints of a classically-defined observer within the setting described by Many Worlds to the ends of a more complete model of quantum measurement. As in Many Worlds the wave function is treated as real and conserved and the observer's place in it is stressed, but the nature of this is considered primarily from an informational perspective as is done with QBism. By considering an observer as emergent from classical systems and therefore incapable of reflecting superpositions, we can show that their interaction with a superposition can only conserve information in the case where they fracture into the parts of the wave function where a definite result is found. Rather than being a physical process, it is purely in treatment of consistent information, enabling us to produce the measurement results described by Many Worlds without any modifications to the existing mathematical description. Explanations for how these fractured observer states can be linked to produce the multitude of stochastic and mutually exclusive outcomes are developed utilizing self-locating uncertainty and Everett's work on observer histories.

1 Introduction

The Schrödinger equation defines a continuous and deterministic world, one at the forefront of our understanding of physics. However, its viability as a model is dependent on foregoing its deterministic description at the time of measurement, treating the system instead as probabilistic and discontinuous to reconcile with our experiments. The conflict stemming from these two ways of interpreting the same physical description becomes the origin of the quantum measurement problem [14, 19, 22]. Among the prominent attempts to resolve it is Everettian quantum mechanics or Many Worlds [3, 5, 9, 20]. This interpretation treats all information described by the wave function as representative of a physically consequential system, for which measurement corresponds to branching of the wave function into a collection of states corresponding to the definite measurable outcomes. Emphasis is placed on the relevance of the observer as an element within the wave function description, from what Everett refers to as the "Relativity of States." This idea implicates among other things that observer's who are entangled to different degrees with a system by interaction will have differing observations as a result. This would then indicate that the measured result upon the apparent collapse of a wave function is subjective to the observer completing the measurement. Many Worlds produces the measurement results desired as branches each containing some definite part of the measured superposition, while maintaining an overall deterministic picture. Still criticisms follow from the open ends of the model, namely how the basis in which the branches are defined can be explained from this setup, as well as how the random singular branch perspective is the product of an explanation which includes so much more.

In focusing on measurement as the interaction of an observer with some part of their environment we can account for the constraints set by the observer's capacity for information. Doing so while reating the wave function as reflective of a physical system and attempting to conserve it through measurement regardless of the observer's limitations in this, we can produce a result in line with Many Worlds with countenance for a preferred basis and reason for a single observed outcome more concretely than otherwise provided by the interpretation. Subsequently no changes are required to the equations of our physical description and consciousness isn't offered an active role in the process. Such a case bears much in common with Albert and Loewer's Many Minds Interpretation [1]. This model tries to explain quantum measurement by subdividing the scientific observer into the abstract concepts of minds and bodies, so that upon interaction with a superposition the body is thrown into superposition itself, while at the same time containing many minds reflecting the definite substates. It treats the wave function as real while also making a classical result the observed outcome, yet the abstract basis of description leaves many questions unanswered. However, in lieu of of minds and bodies we can instead describe an observer using the simpler albeit precisely definable computer. In Everett's own work he made brief reference to the use of "automata" to contextualize the nature of interaction between an observer and their subject, the conclusions of which will be examined in later sections [9].

By considering observers as complex computers, we can show that their observation of a superposition will strongly favor the classical outcome in spite of the provided information, and that this process stems from the observer's necessary neglect of information. This approach is reminiscent of QBism in it's stress on information in the consideration of this process [10, 18], an interpretation positing that the quantum states and probabilites that pervade the established model are the product of subjective experience, making them an observer's rationalization given some uncertainty rather than a reflection of a physical system. The emphasis on information and treatment of uncertainty as the basis of subjective probability will be seen to have much in common with the ideas presented here. However the goal in this case is to consider the wave function as real. From this we can analyze the classical representation of the information comprising a superposition while also attempting to conserve the wave function's total information in spite of it exceeding the observer's capacity. This treatment of the wave function is derivative of Many Worlds and discrepant from QBism, leading to differences in conclusions.

2 Observers as Computers

2.1 Computers and Superpositions

In the spirit of analysis of observers as machines, we will begin with a thought experiment using computers. This offers us the ideal subjects of analysis when considering the threshold between the classical and quantum worlds, in the classical and quantum computers. We will abstract these computers down to bits and qubits to focus on information. This being a thought experiment allows us to assume all relevant systems will behave ideally, meaning no bit or qubit errors. We will also allow for some means of inputting data into the classical and quantum computers, which may be passed as a definite or superposed sequence for either computer, and analyze the results generally as well as from each computer's perspective.

As our first test of this setup the input to our computers will be a classical sequence, any would suffice. This is because we will find that any sequence that doesn't exceed the number of bits of our computers will be entirely represented in both cases, with no discrepancies between the two or anything else of note. However, for our next trial we can instead pass as input a superposition of a few definite sequences. Specifically we will use the two-qubit superposition described below.

$$|\psi\rangle_{binary} = \frac{1}{2}(|00\rangle + |01\rangle + |10\rangle + |11\rangle) \tag{1}$$

Similarly to the definite sequence, our quantum computer (QC) will have the capacity to reflect the entire superposition with no loss or modification, producing the wave function below.

$$|\psi\rangle_{QCbinary} = \frac{1}{2}(|00\rangle|QC\rangle + |01\rangle|QC\rangle + |10\rangle|QC\rangle + |11\rangle|QC\rangle) \tag{2}$$

By contrast, our classical computer (CC) has no means for quantizing the whole superposition, as the computer's classical bits are only capable of reflecting one definite state. To try to get around this, we will make a collection of classical computers, each of which will contain one of our possible definite sequences. In doing this we also need to capture the weights of each definite sequence to preserve the superposition's information, so we will assign each copy of the computer a weight equal to that of its stored sequence from the original superposition. The resultant system would appear as the following.

$$|\psi\rangle_{CCbinary} = \frac{1}{2}(|00\rangle|CC_{00}\rangle + |01\rangle|CC_{01}\rangle + |10\rangle|CC_{10}\rangle + |11\rangle|CC_{11}\rangle) \tag{3}$$

Now our classical computer can be used to reflect its received superposition, by effectively being put into superposition itself. Seeing this from the perspective of the classical computer would require choosing one from the set, which would be found to contain only that choice's sequence. Unlike the quantum computer, whose perspective allows for a complete analysis of the entire superposition at once, the classical computer will only provide one definite component. While this produces the desired outcome in terms of the distribution and values our classical computers "measure," the means by which this outcome is possible is not depicted by this example and will instead require consideration of a physically consequential wave function.

2.2 From Computers to Observers

To begin we can map these results of the quantum and classical computer onto the new concepts of a quantum and classical observer. This is done by extending the capacity of classical bits versus qubits onto our observer types. To achieve this without investigating the full demands of defining an observer, we will focus on the conjecture that a classical observer is emergent from a definite system representable completely by bits, and that a quantum observer is emergent from a system that persists in and accounts for superposition like qubits. As with our classical computer, it's not that the classical observer is incapable of interacting with superpositions, but that it can only perceive definite outcomes as a consequence of the interaction.

We can substitute the superposed binary sequence used with our computers for electron spin states of two measured electrons, using the binary options for x-spin of y-spin up particles to reflect the original states.

$$|\psi\rangle = \frac{1}{2}(|\downarrow\downarrow\rangle + |\downarrow\uparrow\rangle + |\uparrow\downarrow\rangle + |\uparrow\uparrow\rangle) \tag{4}$$

Were our quantum observer to investigate the outcome of this test, they would observe the complete superposition as a result. But the classical observer is defined to require classical information, so the definite substates with known spins of the electrons are the only places where they could exist. Treating the wave function as real results in every definite measureable outcome having a corresponding definite observer upon interaction.

To better describe this from the perspective of the wave function itself, we would say that after the classical observer entangles with the spin superposition, classical observer states could only be found in components of the resulting wave function where the measurement result is definite. So rather than the classical observer parting the superposition or self-replicating, they are forced into these subsections of the entangled superposition as they are the only places where they are capable of existing. This would operate similarly to the anthropic principle [6], as continuations of the classical observer can only be found in the particular circumstances suitable to their needs. As such we've established a line of reasoning in which after measurement of a superposition our classical observer "branches" into a multitude of consistent states.

It's worth noting that you can follow this line of events for any classical system, a classical observer or a classical computer or even a neutron particle [21]. The complexity of the definite system reflects on the outcome it perceives or if it perceives anything at all, but the need for filtration of the superposition to maintain its classical perspective would persist regardless. In this circumstance the details of the superposition and the nature of interaction with our classical system would configure what meets the requirements of a definite state, and subsequently the basis of measurement. Only the portion of the environment entangled with the observer system is required to have a definite value, as treating anyting else as definite or superposed has no bearing on our observer. This constrains the possibilites to a preferred basis for measurements, something to confine the Hilbert space into a particular set of measurables and results [2]. The consequence of this description is our chosen basis is purely subjective to the system we desire to treat as definite, but falls in line with the notion that the complete wave function is more fundamental than any of it's individual branches.

These two observers, one quantum and one classical, could adjacently witness two entirely different universes both of which derive from the same provided information. Since the quantum observer measures the complete wave function that the classical observer has lost, we can draw that this loss is not a change in the wave function itself but rather a change in the section in which our classical observer resides. Such a quantum observer could see the systems constituting our many distinct classical observer states at once.

We can draw from the above that we as observers are better described as classical than quantum. As for why we seem to find ourselves in the company of only other classical observers, the work of Gell-Mann and Hartle [11, 22] seems to provide some answers. As part of their work on Information Gathering and Utilizing Systems (IGUS) they found that were one of these information processors to accept superpositions as input, decoherence would prevent almost any comprehensibility to their measurements and leave them only noise. As systems interact with each other through processes like the exchanging of photons, their quantum information becomes entangled as their state becomes dependent on the results of interactions with others. This process compounds to apply to a larger system through repeated interactions, until even an attempt to probe a smaller part will lead to an incursion by the much larger environment it is entangled with. Any quantum observer trying to obtain coherent information in this setting would be inundated by noise leaving nothing available to process. Only by sheltering from enough of the wave function to avoid decoherence would there be usable information, as is the case with the real-world quantum computer.

However this explanation of branching alone is insufficient to explain the observed course we would expect with the perceived collapse of the wave function. Without any process to link observer states together, we've simply shown how the classical reference frame will fracture after entanglement rather than fully explaining branching. The filtration of this into our desired singular and nondeterministic progression through time is something that will require a confinement of observer continuity.

3 Observer Continuity

To begin establishing the idea of continuity we can refer back to some of Everett's ideas on this subject. In his work the term "Memory Requirement" is used to discuss how the history of the observer needs to be reflected in its current state, as a means of linking these states together through time [3, 9]. He compares the observer to a machine with sensor and data storage capacities, where a consequential measurement is indicated by it's result being stored by the machine, in the same way an observer would store the result in memory. If the memory of the observer is able to establish the nature of a past event this serves as an informational link to a prior observer state. The information relevant to the observer exceeds that contained within what we typically consider as memory since any change to the observer state introduces new information, however the same logic can be applied. The sequence produced by these acts of information updates over time would form the links between the observer states that made them and those that retain them. This way the classical observer's need for definite information would confine the system they reside in, setting a limited state for the present as well as the past from which it must have originated from. This model successfully links observer states together through branching into our desired singular and nodeterministic progression through time, since the observer can only store a single definite result from each prior superposition measurement. Although this model offers a way of linking observer states to their predecessors informationally, it doesn't offer a means of cutoff for when the states resulting from measurement are physically possible but not a valid continuation of the observer, something we would expect to be possible. In his description Everett makes use of machines to help contextualize this concept, and we will do the same to elaborate on it.

To start we can move from memory to information, focusing on classical observers and bits. The issue of a threshold of discontinuity would describe a point where the changes in sequential observer states are too large to reconcile, meaning the information has been modified in a way that cannot be corrected for by the observer system. Treating this change in the observer state as error requiring addressal in order to maintain continuity, we can apply knowledge from the existing field of error correction to better understand this process. While quantum error correction is an established field to do with the error entailed with quantum computing, we can focus on the broader field for this purpose. Error correction is a field of computer science devoted to producing and assessing processes which identify and correct errors in data mostly found during transmission. Essentially, if bits of the data are erroneously flipped during the transmission process, some means of recognizing this has occurred and potentially even correcting it increases the data's reliability. Error correction models generally try to balance the amount of data redundancy and algorithm complexity with the resiliency of the data to error. One example of this is Hamming Codes [12], a simple technique needing a relatively small data overhead to handle minor errors in the data packet. Using an amount of bits scaling logarithmically with the amount of data addressed, this algorithm is able to identify when up to two bit errors occur in the data, and for one bit of error is even able to correct it. So for zero or one bit of error, the data is completely maintainable, for two the extent of error is identifiable, and for greater than that the algorithm behaves unreliably and the data will have an unknowable degree of error, sometimes resulting in the errors not even being detected to any degree.

Drawing conclusions on the implications of this for observers, we can generalize state transitions of the observer as an error correction challenge. Any change in the information of the observer would be treated as error, and the observer would have to recognize the extent and nature of change to maintain continuity. For a functional observer, changes to the observer state can be reconciled with existing knowledge in order to maintain continuity, the outcome of which depends significantly on the observer's capacity to account for it. For a simple example, when you take a step while walking previous experience informs you on what will occur and allows you to easily account for the changes. Were you to take a step and find you had traversed several meters instead of the couple of feet you were used to, you would at least know that it's likely that something about your perception of the process has gone wrong. Information loss becomes a source of discontinuity, making it a spectral process scaling in complexity with that of the observer in question. Establishing continuity then becomes a somewhat subjective pursuit, since defining precise thresholds is higly contextual for cases avoiding an observer in stasis or having completely changed in information. This description serves to only weakly establish the effect of information loss on these processes, but due to the overhead of adequately defining and analyzing the observer and the limited relevance to quantum measurement this is the extent of discussion.

Conclusions from observer histories offer a general idea of how observer states are linked together through time, however countenance for the high complexity and variance of observers would be necessary to make this explanation rigorous. Still, for a sufficiently reliable observer this does result in an observer state being consequentially dependent on those coming before it, providing a means of linking an observer state to its precedent states based on information. It's also worth noting that this link is only of an observer state to those coming before it, making the branching process waiting in the observer's future outside of the scope of applied information. As such we still have to consider the relevance of probability.

4 Origin of Probability

4.1 Probability from Observer Continuity

We can consider the probability property of the wave function model from a different perspective. While the constraints set by the observer limit the pool of available states following a measurement, all remaining states stand as viable continuations of the observer, so to say any selection process would be arbitrary with respect to the observer. This describes a triviality of assignment from our observer to the definite substates of the measured superposition, allowing us to introduce the origin of probability in quantum mechanics: self-locating uncertainty.

The concept of self-locating uncertainty can be understood from the setup of an observer that could be in any one of n locations, where with the available information they cannot determine to any extent which of these locations they find themselves [7]. Without any means of differentiating these n location's qualitative likelihoods from one another, the observer will make an estimation that they are equally likely to be in any one of them, applying a probabity of $1/n$ to each. This concept of uncertainty in location leading to a probabilistic interpretation can be applied in many contexts, and has already been applied to explain the origin of probability in the Many Worlds Interpretation, substituting locations in the universe for branches of the wavefunction [17, 20]. To avoid so called "branch counting" which describes the treatment of each branch as an equally likely possibility, consequentially failing to produce the Born Rule probabilistic distributions, a means of decomposition of the branches was introduced to create equally likely components whose unpredictable assignment process following measurement would be the origin of uncertainty. This method of applying self-locating uncertainty had success in modeling some cases of branching probabilistically, however was unable to represent the general case in some part resulting from the decoherence-based branching mechanism not yet being fully developed [13]. Using the alternative explanation of branching established above in this text, we can apply self-locating uncertainty to the ends of a more complete explanation of probability in quantum mechanics, while applying the same fundamental reasoning as done in the above cases.

But this observer-centric notion of probability can be hard to describe or conceptualize effectively. As such, it's helpful to set up an analogous thought experiment first. In it, we will use the representation of pi in base ten. Since the word digit can both refer to the decimal index as well as the numbers zero through nine, from here on index will refer to the decimal index of pi and value will refer to the numerical assignment in the range of zero to nine. When an irrational number such as pi is expressed using the integer base of ten, the result is an endless sequence of unpredictable values. It's likely and we will assume the values of pi in base ten will have an uniform distribution towards infinity [8]. This means the value of each index of pi is random but still follows a predictable distribution, making it comparable to the wave function model after classical measurement. Since this representation excludes all of the concerns surrounding the model of quantum mechanics it is easily analyzed.

Each of an infinitely large group of individuals are assigned a unique index of pi without their knowledge. Each individual's only unique characteristic is this index. The values of each index have yet to be calculated, but once all are determined they will be provided simultaneously to each individual based on their assigned index. Until it's calculation all members have no means of differentiation, and will fall under the assumption that the collective contains only a single individual. Self-locating uncertainty in this case would describe that the individual's uncertainty on which index of pi they've been assigned makes it such that they can model their situation probabilistically by assigning equal likelihood to having assignment of any particular index in pi, making each of the ten assignable values equally likely due to their distribution. Sure enough, once pi has been calculated and assigned all members will split seemingly at random, but following a general rule where each value has a 10% chance of being assigned. Our individuals are now able to tell each other apart but only from those who were assigned a different value, turning one group into ten. From their perspective, a single individual has split into ten and a branching event has occured. The proportion of individuals included in each group after the calculation of pi is analogous to the weight of each observer state after measurement of a superposition. The integer base in which pi is represented corresponds to precision of measurement, and subsequently the amount of "branching."

If we consider the distribution of values across the indexes of pi as the sample space for our individuals, we can see how that leads directly to the probabilistic interpretation from their perspective. Uncertainty is the factor that leads to the individual's assignment of probability, and the branches are comprised of a set of individuals with identical established information. The individual knows it lies on a distribution based on the digits of pi, and has been arbitrarily assigned one index from the spectrum. While using indexes of pi allowed for an infinite sample space, this space was discretized and as such permitted perfect measurements that are not possible in a realistic model. An understanding of this simple concept can then be mapped onto one more in line with what's typically found in quantum mechanics, after laying some groundwork. For this we will use a superposition in one-dimensional space, with consistent but undefined units for distance as they would have no bearing on the relevant implications.

A branch of the complete wave function contains a particle with a positional superposition defined by a gaussian with a standard deviation of 1, along with an individual that has yet to interact with it. In time the individual will measure the particle's position, to determine if it's located above or below the superposition's center, where a 1 denotes a location above the center and 0 indicates below. This measurement will be done by a sensor whose spatial uncertainty has a standard deviation of 0.1.

The measurement leads to a new superposition where the result is mostly 0 for numbers significantly below the center and mostly one for those above. However, towards the center the superposition contains substantial components of both 0 and 1, with the exact center giving equal weight to both. To represent this superposition, the weights of each outcome will be combined by likelihood over the position space, as shown in figure 1. For a measurement offering a 30% likehood of returning 0 and 70% of returning 1, the result will be the probabilistic average of both, 0.7 in this case. Here, the Born Rule is assumed to hold and probabilities are derived from it, something explored in greater detail in the next section.

The individual is classical, and requires a definite result from this measurement of where the electron as a particle is located. However the observer is interacting with a superposition,

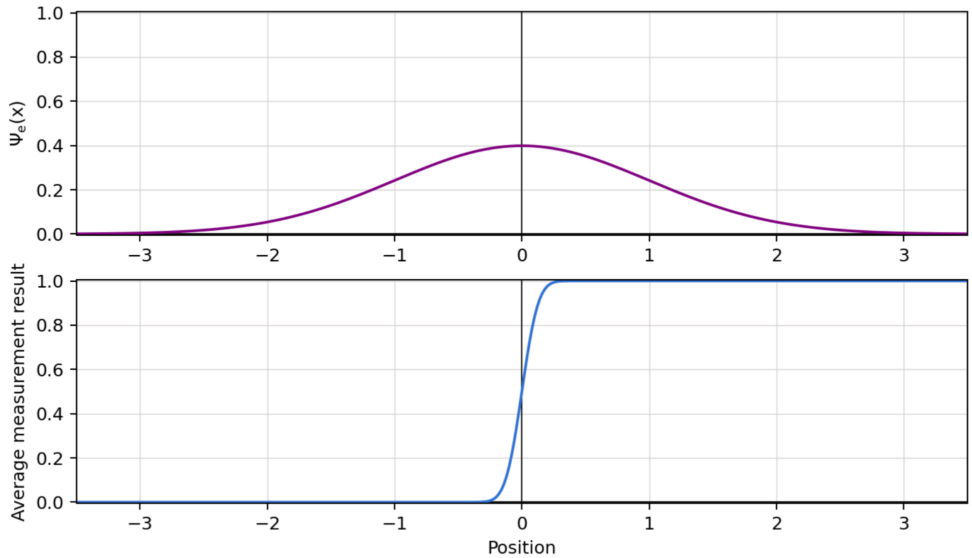

Figure 1: The top graph shows the wave function of the particle in space relative to its center. The bottom graph shows the average measurement result for the defined sensor as a function of the measured location relative to the center of the particle's positional superposition.

one dependent on the position of the particle in space. In order to make the classical individual compatible with the continuous wave function describing the unmeasured particle in this branch, we can split the individual into many based on the assignment of a unique point from the distribution described by the square of the particle's wave function. As identified by Saunders [16], treatment of wave function as real makes the individuals of future branches identifiable prior to their splitting in deterministic quantum mechanics. Projecting this into the future for all measureables leads to a functionally infinite number of individuals, identical aside from their indeterminate futures. These individuals have no means of differentiation from one another, and will operate under the implicit assumption of there only being one. This change is not to the nature of the system, only modifying the reference frame to accomodate the branch's superposition within the definite requirements of our individuals. This process could be compared to analyzing an ideal gas from it's overarching properties or that of each particle. So to say quantum mechanically our individual is the entirety of a particular spectrum of states, while classically each of these states could be seen as an individual. The information is the same, but how you look at it can contribute to different conclusions.

Here self-locating uncertainty applies to the individuals' uncertainty on their positional assignment of the particle, leading the individuals to give an equal likelihood to all possibilities, making measuring a 0 or 1 equally likely considering their distribution. After measurement this presumption is confirmed, as half of the individuals end up with either possible value. Now, our individuals' information systems are inclusive to some positional information of the particle, making them incompatible with those who measured a different result. The individuals are now distinct but only from those who measured the other value, turning one group into two. Returning to our continuous reference frame we find these two groups as branches whose size corresponds to the proportion of individuals they contained previously. Because quantum mechanics occurs in the continuous space it makes sense to analyze at this level, but for our definite individuals and their measurement processes it's beneficial to change reference frames to reflect the way they consider the same information. Again, none of this information itself has changed and the definite frame does not correspond to any physical processes, but the relevancy of both perspectives in a quantum mechanical world populated by classical observers seems qualified.

The implication of the model permitting an infinite number of our observers in a single state is to say this metric doesn't capture that of the wave function, as you would find in measuring the length of a line segment in points. Rather than describing a singular world, a "branch" defines a set of classical states that follows some constraints about their requisite definite information. These sets contain infinite instances due to the endless degrees of freedom that have yet to be classically confined, as well as the triviality of their confinement with respect to the laws of nature. The fundamental wave function has remained singular and continuous, entirely incompatible with this representation indicating its triviality.

4.2 Consideration of Implications

Both a fixed observer state prior to measurement and a superposition are deterministic, the former being a constant by definition and the latter following the rules of quantum mechanics. With our infinite observers residing within the original observer state we could assign each an outcome in line with the wave function and Born rule prior to measurement, and self-locating uncertainty would make this result unknown to the observer until after measurement has occured. In this way, the stochastic nature of classical measurements of wave functions becomes possible specifically from the observer's reference frame.

This leaves us with a deterministic model of quantum mechanics where variable assignments unknown to the observer dictate quantum measurement outcomes, and where uncertainty as to the value of these variables is the origin of probability. Such a model seems comparable to the genre of hidden-variable theories, meeting many of the qualities these theories often contain. However, one noticeable difference from the prominent theories like de Broglie-Bohm theory [4, 15] is the lack of physical implications for any variable's value. Instead, these parameters are physically trivial as a result of them being defined within our observer's classical reference frame which is arbitrary with respect to the quantum mechanical reality. Rather than deciding which outcome from our wave function constitutes reality, variable assignment here serves only to decide the observed outcome after measurement for a particular observer.

In David Wallace's 2007 paper [22], he divides the problem of probability in quantum mechanics into the incoherence and quantitative problems. The incoherence problem has to do with the discrepancy in the transition from a deterministic quantum world to a stochastic classical one. This can be answered by self-locating uncertainty, where the stochastic model is simply a product of arbitrary information neglect from the perspective of the classical observer states.

The quantitative problem on the other hand, has to do with why it is that the Born rule is sufficient to assign probabilities to substates of a superposition. However, a primary result of self-locating uncertainty is that probability isn't inherent to nature but a product of observer uncertainty. If that is the case, then what metric are we meant to use to intrinsically describe the distribution of a wave function or the magnitude of its whole, since the normalized and unitless representation is not provably intrinsic? Imagine a line segment of some length is split into two equal segments. This result will be sampled at random points along the total length, returning whether the point came from one half or the other. Knowing nothing about the segment beforehand you could determine from the result of enough of these samples that there are almost certainly only two subsegments, which are very similar in length. However, you would have no means of determining how long either segment or the combined segment are in any unit of length. This is the problem we find ourselves in. The square of the wave function defines a continuous spectrum of outcomes we inhabit like points. With the provided information the proportions of the wave function are the most we are capable of determining, and the true metrics underlying these values are unattainable. Rather than finding an answer to this problem, this explanation indirectly implies that we reside in the space defined by the square of wave function and probability comes from uncertainty of our location in this space. It appears that nothing more can be said from this model leaving the problem somewhat open ended.

5 Conclusion

In this piece, by utilizing a few operating assumptions it was possible to produce an apt explanation for several of the uncertainties at the threshold between the quantum and classical worlds. Using quantum and classical computers as stand-ins for observers, we are able to explicitly constrain the classical computer's information network to only contain one definite "branch" of the received superposition, an apparent collapse from it's perspective. Defining observer continuity from the information within an observer state links it to those the information originated from, permitting the transformation of these branches into a set of individual paths each containing their own unique observer. This combined with the implications of self-locating uncertainty establishes a means by which after measurement of a superposition a classical observer will from their perspective branch probabilistically into a definite measured outcome in line with the Born Rule.

The limitations of this work lie in its operating assumptions. While the assumption that observers are entirely emergent from their physical system is plausible, which would make them accurately modeled as computers, it is still not proven in the full applicable scope. Also, while a quantum computer fulfills the requirements of a quantum observer as described here the implications are still difficult to realistically verify, as we are necessarily excluded from that system in this explanation. In modeling observer continuity major simplifications were made to the observer system that are not necessarily applicable in all cases. The potential complexity of observers not addressed in the above description leaves room for a more rigorous explanation. Such a subject is deserving of a more thorough analysis than is directly relevant in this context.

Errors caused by human bias in early inquiry were what lead to the emergence and success of the scientific model, aimed at eliminating such a problem from the equation. In its larger success, we may have become complacent to the idea that all our results are nearly impartial, and that with thorough and copious trials we can be expected to play no significant role in the outcome. Assuming the merit of this model of quantum measurement, which requires only that the wave function is physically real and observers be modelable by classical computers, the collapse of the wave function and the probabilities brought with it are removed from the physical equations of quantum mechanics entirely, left to the devices of the observer's virtual reference frame. The error of their inclusion in the larger model would seem to stem from failing to account for ourselves as the final arbiters of every experiment. The "shut up and calculate" attitude appears founded in the notion that experiments are truly impartial, and that neglecting to treat their results as law is a failure to science. Instead, a neglect in analysis of the nature of experimentation and its results has put ourselves as observers on a pedestal, rather than considering us as beings beholden to the very nature we hope to understand.

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