Appendix A.[1] Wave Packet Network Theory[2]

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Abstract

Since the early days of quantum theory, the concept of wave function collapse has been looked upon as mathematically unquantifiable, observer-dependent, non-local, or simply inelegant. Consequently, modern interpretations of quantum theory often try to avoid or make irrelevant the need for wave collapse. This is ironic, since experimental quantum physics requires some variant of wave collapse wherever quantum phenomena interact with the classical universe of the observer. The paper "Quantum-Inspired Simulative Data Interpretation: A Proposed Research Strategy" (MITRE Pubic release 10-3164) proposes a pragmatic view in which wave function collapses are treated as real phenomena that occur in pairs. Paired collapses occur when two wave packets exchange real (vs. virtual) momentum-carrying force particles such as photons. To minimize reversibility, such pairs must be separated by a relativistically time-like interval. The resulting Wave Packet Network (WPN) model resembles a network of future-predictive simulations (wave packets) linked together by occasional exchanges of data (force particles). Each data exchange "updates" the wave packets by eliminating the need for them to "consider" some range of possible futures. While constructed around theories such as Feynman's path integral formulation of Quantum Electrodynamics, WPN is original and differs in a number of non-trivial ways from most interpretations of quantum theory. This appendix overviews the main assumptions of WPN, describes how they differ from other interpretations, and suggests several interesting and testable physical implications.

1. Fundamental Precepts of WPN Theory

The precepts of Wave Packet Network (WPN) theory are:

Wave packets are real. It is impossible to set up an experiment that looks at quantum behaviors without in some way forcing quantum wave functions to interact with classical machinery and observers. For example, creating an electron source for a double-slit diffraction experiment first requires that the electrons be confined to and emitted from a classical source. Such manipulations place time-dependent constraints on the physical sizes of real wave functions, since the wave function can in general expand only within the limits of the future light cone emanating from the classical source. This allows such wave functions to become very large very quickly, but it also prevents them from ever reaching the levels of mathematical state perfection used in quantum theory. For a universe with a finite duration, classically originated quantum waves thus cannot behave as pure wave states, but must instead behave as spatially limited packets that can only approach pure wave states over time. Similar arguments can be made for other quantum properties. In short, the classical origins of quantum systems force them to be expressed as wave packets, not as pure states.

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[1] Of paper "Quantum-Inspired Simulative Data Interpretation: A Proposed Research Strategy," MITRE Public Release # 10-3164, unlimited distribution. This appendix is a separate release.

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Wave collapse is real. Quantum systems cannot interact with classical systems without undergoing some form of reduction of the complexity of their wave functions, a fact that is most vividly represented by the wave-like diffraction and particle-like detection of photons, electrons, and other low-mass particles. Most quantum interpretations that disdain wave collapse neglect to notice that without it, quantum experimentation becomes literally impossible. It is not in general a good idea to ignore concepts that are intrinsic to all known experimental results, no matter how distasteful those concepts may seem from a mathematical or philosophical perspective.

The real issue with wave collapse is that it needs to be taken far more seriously from a theoretical perspective. A serious theory of wave collapse must deal meaningfully with its highly non-local (or "superluminal") component.

In WPN, the superluminal aspect of wave collapse is handled in part by asserting that an entire self-consistent classical history is selected whenever a collapse occurs. It is almost as if an entire cone-shaped wave packet "bead" in spacetime is collapsed into one classical history thread. While time-path collapse is in some ways more radical than "superluminal" interactions, it also avoids the various causal ambiguities of spatial entanglement by generating an entire self-consistent history "all at once."

When combined with the observation that all quantum phenomena are based on (possibly very large) wave packets, the reality of wave collapse means that quantum phenomena are in general cyclic or "ratchet like" in how they are expressed over time. That is, each time a new particle-like wave packet forms, it begins to spread again until another collapse event occurs, at which point its indeterminate history is replaced by a more definite classical one. For ordinary thermally-dominated classical systems, these beads of wave packet expansion and collapse will be so closely spaced that the particles involved can be said to remain "classical" for the duration.

Quantum systems collapse each other. One of the most common ways of explaining how a quantum system loses its special or wave-like features is to say that it is "disturbed" by the arrival of another particle that disrupts its quantum state. While crude, this explanation captures an essential feature of all forms of quantum collapse: Collapses are induced by "unplanned" interactions with other particles or systems of particles.

A more specific version of this idea is to say that the interaction changes the state of the particle, which in turn means the interaction "adds information" that guarantees the distinctiveness of the particle in the future.

WPN uses this concept of information identification to provide a surprisingly simple approach to wave packet collapse: Wave packets collapse each other, without any requirement for more complex systems or for abstract ideas such as observer consciousness. Packets collapse each other simply by exchanging "disturbing" (momentum-carrying) force particles such as photons or phonons, which may in turn be carried by larger non-force particles (e.g., atoms). The result is dual collapse, since momentum is both removed from one particle and added to another. Both actions add information to wave functions. The implication in WPN is that such exchanges collapse both wave functions and reduce both into "classical" histories.

The idea of dual wave function collapse fits surprisingly well with results from quantum experiments, and also with the readily apparent lack of quantum behavior in most large objects. As noted by Richard Feynman [10], any system for which it becomes possible to distinguish "how it happened" will cease to interfere—that is, it will stop being quantum in its behavior. In everyday life, the potential for exchange of phonons and photons within any room temperature object is so enormously high that the vast majority of large-scale (atomic and above) behaviors in such an object will necessarily be classical. Quantum effects will continue to hold sway for special cases in which the exchange of momentum-changing force particles is forbidden, such as in the state-filling Fermi seas of delocalized metallic electrons. As a general rule, the dual collapse idea also fits well with the general observation that quantum effects increase as temperature are reduced. Such reductions drastically reduce the numbers of phonons in such systems, and so reduce the odds of wave collapses.

It should be noted that the idea of dual wave collapse also provides a different way to look at and understand the concept of information erasure. Reversing an exchange of momentum, if done precisely and without any losses in magnitude or changes in orientation, and before any other exchange can alter the state of either system, becomes the mechanism by which quantum behavior is restored in both the sending and receiving wave packets. This in general can occur only on a very small scale, but for entities such as electrons in orbitals, “constant erasure” can become the default rather than the exception.

Erasure is in general strongly discouraged when one of the two wave packets is delayed in time, since a delay long enough to resemble classical time will nearly guarantee that one of the other of the two systems will be disturbed by a third system before the reverse exchange can be made.

In WPN, information is in effect a version of ordinary momentum. However, in terms of its ability to induce wave packet collapse, the information interpretation of momentum imparts to it a highly disproportionate impact. For example, while a photon-sized packet of momentum typically would have no detectable impact on a large classical object, that same packet when interpreted as information has the potential to obliterate a large-object wave function. It is this extreme asymmetry of effect that makes large-object wave packets so difficult to maintain.

A final observation on dual wave collapse is that it appears to have an interesting relationship or interpretation in terms of the electromagnetic solutions of Wheeler-Feynman theory [4]. In this theory, which formed the core of Feynman’s PhD thesis, the momentum impact of two particles separated by time is mediated by two different solutions to Maxwell’s Equations: a “retarded” solution that sends momentum in the usual direction from the past into the future, and an “advanced” solution that somewhat paradoxically sends momentum from the future particle back to the particle in the past. While Feynman eventually lost interest in these solutions, it is possible they could provide a very interesting asymmetric way of interpreting how information is exchanged during the passing of time.

Wave packets are bundles of possible histories. One of the most fascinating and insightful features of Feynman’s version of Quantum Electrodynamics is its abandonment of the requirement to use a rigidly ordered time sequence when dealing with quantum systems [4]. By instead looking end-to-end from a point in the past to a point in the future, Feynman was able to show that the most accurate way to calculate the probabilities surrounding the arrival of a particle at that future point is to derive every possible way in which the event could occur, including paths that travel backwards in time in ways that a rigidly moment-by-moment approach would never even consider.

It is important to note that Feynman was not an advocate of using wave packets. For example, he once referred to them dismissively as “magic” while explaining QED. The irony of his view of wave packets is that by the very act of setting up his path integrals between distinct points in the past and the future, he made identifiable wave collapses unavoidable at both ends of any physical realization of his calculations. The initial point cannot be created without using classical equipment that constrains wave functions. The final spacetime point implies collapse by its very probabilistic nature, since experimental implementations of it necessarily must create a broader wave packet to ensure conservation of the particle if it does not arrive in the calculated target area. That packet must then "collapse."

Viewing Feynman's QED structures as maps of how a wave packet could play out over time helps emphasize that wave function collapse selects entire histories, and not just individual outcomes. For every point that is selected by experiment at the end of a Feynman structure, there is also an implied set of "most likely" paths that can be determined by tracing back from that final result. These implied histories can range from very general (e.g., one or the other side of a sphere) down to very specific (e.g., one path down a maze of partially reflective mirrors), but in all cases they involve discarding previously possible histories.

Conversely, when viewed from the originating point in the past, a Feynman structure unavoidably describes which paths are the most likely to occur in the future. It thus summarizes what is most likely to occur later given what is known from past information.

It is this combination of knowledge of the past combined with probabilistic models of future behaviors, all linked by exchanges of data, that makes WPN a promising model for how to build more quantum-like networks that may in turn be capable of handling sensor information more efficiently.

2. Other Implications of WPN

The main focus of WPN is to provide a pragmatic model of quantum behavior that can inspire new approaches to information processing. However, the details of WPN are different enough and specific enough that they also have a number of interesting physics implications. A few of the more interesting examples of this are described below.

State-Machine Universe (SMU). WPN interprets the universe as a state machine, one whose storage capacity is literally astronomically large, but finite. More specifically, SMU disallows the idea of a past or future that exists independently of the present. The deep symmetries of time that seem to imply the reality of the past and future are reinterpreted in SMU as consequences of conservation laws that preserve certain state configurations strongly over the evolution of the state machine. The multiplicity of worlds that seem to be implied by some quantum behaviors is similarly reduced to a resource-limited virtual effect in which the intrusion of classical time—the collapse of wave functions—will in the long run always force "atemporal" quantum regions to re-integrate back into the SMU in the form of specific historical results.

SMU disallows both relativistic world-line and quantum many-world views, since both imply limitless information storage capacities. Classical relativity interprets the world as a fixed collection of world-lines extending indefinitely far into the past and future, which in turn implies infinite state capacity. Many-worlds interpretations of quantum mechanics imply limitless expansion of information storage as new universes branch off from current states.

In contrast, any level of complexity that exceeds the total capacity of the SMU will simply be lost, in the sense of being unrecoverable by any manipulation of the current state of the universe. This is a fairly heretical idea, since conservation of information is assumed in most theories of the universe. It is possible to create a version of SMU that retains all information by expanding capacity over time, but this approach is comparable to increasing mass without limit over time. A large but finite set of states is simpler.

SMU provides a simple answer to many questions about time travel. Time travel into the past, with all of its many quandaries of how to prevent temporal paradoxes, becomes a *non sequitur*. There is no past into which to travel, only variants of the current state of the SMU. Time travel into the future, which of course is possible via relativistic time dilation, becomes little more than freezing a local pattern and reactivating it within a future SMU configuration.

In SMU, “now” is defined by the network of wave packets that represent conserved quantities and their possible histories. Time itself becomes granular, with the various sizes of uncollapsed wave packets representing regions in which the specifics of the past and future have not yet been fully decided. Classical systems represent one extreme of very finely-grained definition of the flow of time, with the constant phonon interactions of Boltzmann thermodynamics ensuring very limited growth of quantum wave packets and their uncertain time relationships. At the other extreme are small, isolated systems such as photons traveling through intergalactic space. These represent the other extreme of events whose final histories remain indeterminate over very large volumes of space and time.

Absolute reality of “classical now.” As described above, WPN assumes that if an object or particle is observed continuously and in sufficient detail to keep it from becoming significantly quantum in behavior, the concept of “now” for that object or particle becomes an invariant that remains valid and unchanged regardless of the relativistic frame of reference from which the object or particle is observed.

That is, the proper time of a classically observed particle or object cannot be reversed or altered by any manipulation of relativistic physics, although its history may remain nominally reversible via certain very low probability quantum events.

While the idea that a continuously observed event cannot “change its history” is in many ways nothing more than an affirmation of the principle of temporal causality, and thus hardly radical, the idea that a *local* procedure can create a *universal* invariant has broader implications than it might seem. One such implication is that solutions to the equations of general relativity that allow constructs such as wormholes must be incorrect, for reasons unknown but presumably related to some misinterpretation of how mathematically valid solutions to those equations apply to the physically observable universe.

Implications for relativistic time dilation. A more subtle implication of time being determined locally is that it removes an important degree of latitude that has been used in special relativity since its earliest days [15]. Specifically, the concept of absolute local time seems to imply a need for reinterpretation of the well-known time dilation effect.

The problem is straightforward: If the concept of “now” is determined solely by observations taking place locally within classical systems, then the first derivative of “now”—that is, the rate at which time flows—must also be determined by local observation. This can cause problems.

Assume you are within such a locally-determined time flow and wish to observe time flow in another frame. To avoid ambiguities caused by the delay of light, you arrange for a stream of small, point-like clocks in the other frame to flow continuously and without acceleration *through* your measuring apparatus, which relies on similarly point-like clocks. The arbitrarily close mixing of the point-like clocks from the two frames avoids the ambiguity of light delays between distant frames (e.g., spaceships).

In the standard SR interpretation of time dilation, no frame is privileged. This leads to an interesting question: In the direct-frame-contact experiment, will the two sets of point-like clocks (those flowing past and those in the observer frame) exhibit the same or a different time flows?

Minkowski [15] supported the view that time must remain indeterminate as long as there is no acceleration of a frame. The ambiguity introduced by the delays of light travel would then cover up this ambiguity of time dilation until the two systems are reunited into a single frame.

In the direct-frame-contact thought experiment, both the measurement ambiguity of distance and the distinction of frame acceleration are absent. Observers in both frames can make unambiguous measurements of the time rates of the others by comparing two point-like clocks as they pass closely by each other. Direct-frame-contact thus captures the essence of the WPN idea that time rates are determined by local observation, not deferred until a later resolution.

Stated another way, observers within each frame should be able to calculate and agree upon a single *absolute* time dilation ratio that exists between their two frames.

If full frame equivalence (a type of symmetry) is to be maintained, only one result is possible: Both frames in the direct-frame-contact experiment must see a time dilation ratio of exactly one. Any other result violates equivalence.

Unfortunately, this prediction violates very well-known physics. Any particle with a known half-life, such as muon, can be used as a point-like clock. Furthermore, it is not difficult to find or arrange scenarios in which such particles travel unaccelerated, at high velocity, and in intimate contact with similar clocks in other frames. Muons generated by cosmic rays striking the top of earth's atmosphere are a good example. Such muons undergo major accelerations only at the starts and ends of their journeys, while for the rest of their trips through the atmosphere they maintain unaccelerated velocities very close to c. In the absence of acceleration, full frame equivalence demands that the observed time dilation ratio between the muons and earth's atmosphere be exactly one. In reality, the unaccelerated muons exhibit an externally observable Lorentz factor (time dilation ratio) of roughly 5. This enables a huge increase (about five orders of magnitude) in the number of muons that strike the earth's surface, and creates an inverse reduction in the decay ("clock speed") of the muons as they pass through the atmosphere.

Other examples of asymmetric Lorentz factors during unaccelerated phases in the travel of point-like clocks are easy to find, since modern particle physics depends upon this property to observe rare and highly unstable particles. Even an experiment as simple as an old-fashioned cloud chamber science kit is fully capable of exhibiting particle time dilations that, strictly speaking, violate the assumption that time dilation remains indeterminate until some final acceleration event reconciles the two frames into one. In contrast, the WPN view that time is locally determined and invariant regardless of frame is entirely compatible with all of these everyday examples of particle-level time dilation.

There is more. If any two unaccelerated frames have a single asymmetrically applied Lorentz factor that fully characterizes their relative rates of time flow, an unavoidable implication is that by comparing all possible pairs of relativistic frames one would eventually uncover at least one frame for which time dilation reaches an absolute and literally universal minimum. That is, it implies that there exists a fastest time frame (FTF) in which time passes at a faster rate than for any other frame of reference possible in the universe.

Using energy conservation arguments beyond the scope of this appendix, the FTF can be identified as the "center of all mass" of the universe. The concept of a universal center of mass is tricky in an expanding universe. However, there is a well-known distinguished frame that arguably defines just such a center of mass: the Cosmic Microwave Background (CMB). Thus a plausible route for attempting to access the FTF experimentally would be to cancel out all motion relative to the CMB frame. This could be done by traveling at 369.0 km/s (relative to the sun) towards the celestial coordinate $(\alpha, \delta) = (23^h 11^m 57^s, +7.22)$, which is about one-third of the way along a line from Gamma Piscium (in Pisces) to Alpha Pegasi (in Pegasus) [16]. If the concept of locally determined time is valid, a speedup in time of somewhat less than one part per million (~0.7575 x 10^{-6}) should be seen. The simplest test would be to inject and maintain muons at 0.001231 c (369 km/s) in a roughly oval loop whose long axis points at the above coordinate, ideally corrected for earth orbit and rotation vectors at the time of the experiment. Measuring relative decay rates on either side of the loop axis should exhibit a muon decay rate delta of up to about 1.5 parts per million.

Notably, such a setup resembles Michelson-Morley [17]. This makes a final crucial point: Michelson-Morley proved frame invariance for massless photons, but it did *not* prove invariance for the case of traveling particles with mass. The generalization of Michelson-Morley to particles with mass was assumed, but does not appear ever to have been tested. Muon loops would provide one way to do so.

Finally, partial alignments of earth orbital velocities with the CMB frame vector could provide smaller time dilation deltas in the range of a few parts per billion. Low-earth satellites with seasonal corrections could show alignment deltas with magnitudes less than one part per billion. High precision systems such as Gravity Probes A and B could be rich data sources in searching for such lesser effects. Aligned extreme-precision ground clocks are another option.

Any result verifying the existence of an FTF would of course have interesting implications for physics and astrophysics. Observed astrophysical relativity would be reinterpreted as a result of the ambiguity in defining a 3D center of mass in a 4D universe, rather than of special relativity.

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