Closed System Approaches

Consider a system that is desired to be measured and a large set of particles (including atoms, molecules, and other fundamental constituents of matter) with Hamiltonian H that are in a configuration defined by the quantum state $|\Psi\rangle$. The configuration space consists of both spatial coordinates for the particles and their wave functions as well as the energies and couplings between all sets of particles, allowing the formation of molecules, dissociation, etc.

The closed system approach posits that under certain conditions given by $|\Psi\rangle \in \mathcal{R} \subset \mathcal{H}$, the set of particles forms a δ efficient measurement device for the system, that is, the probability of measurement when the particle completely impinges on the detector, is greater than δ. The set $\mathcal{R}$ defines those states of particles for which the device will be considered efficient. Other states $|\Psi\rangle \notin \mathcal{R}$ may form measurement devices, but are not δ efficient.

In the closed system approach, it is further stipulated that the physical reason that the device is capable of measuring the system when $|\Psi\rangle \in \mathcal{R}$ is related only to the internal physics of the set of particles. That is, if one had available $\mathcal{R}$, one would be expected to see different physics in terms of why the particles function as a δ efficient detector, while other configurations that are less efficient as well as those configurations that act unitarily.

Note that the requirement that a device function non-unitarily is related only to the physics of the particles in the closed system approach. That is, the goings-on of the rest of the universe are irrelevant. The internal physics of the closed system is significant in the closed system approach, not the environment. The physics of the closed system when the state $|\Psi\rangle \in \mathcal{R}$ is the reason that the closed system constitutes a bona fide measurement device.

Historical statements during the formation of the Copenhagen interpretation by Bohr, Heisenberg, Dirac, and Pauli indicate the framers believed that closed systems evolve mechanically and deterministically. In their view, it is the inability to be capable of knowing exactly the preconditions that allows for a seemingly nondeterministic action. Moreover, if an attempt is made to determine the state evolution of a closed system, a device is required that interacts with the closed system. Such an interaction was believed to create a sufficient disturbance due to the Heisenberg uncertainty relationship for which an uncontrollable action occurs leading to the destruction of coherence.

We have seen however that this explanation is not sufficient to be considered as a resolution of the measurement problem, as long as one can initialize the state of a detector, as the entanglement predicted under unitary evolution is inconsistent with any particular outcome occurring in the closed system hypothesis.

In 1927 this would not have been fully understood, as the quantifiable differences between entanglement and product states were not known. The paradoxes of unitary evolution were further illustrated by Schrödinger in 1935, for which the concept of entanglement was first introduced [119]. The quantifiable difference between product states and entanglement became clear with the advent of Bell's inequality in 1964 and the era of quantum information that began in the mid-1990s.

In closed system approaches, there is physical rationale for which non-unitary evolution occurs that can be traced to the internal properties of a given closed set of particles. One example of a closed system approach is whereby a set of particles exists in a configuration that has a sufficient measurement latency, bandwidth, etc., and a significantly amplified signal when the particle impinges on the closed system that is typical of a detector. The act of amplification may be claimed to be non-unitary, irreversible, and be the direct cause of measurement.

Another example of a closed system approach is the proposition that a conscious system is a measurement device because a conscious system has the property of becoming aware of external phenomenon upon measurement. In such a theory, it could be surmised that the interaction between a system of particles and an external quantum particle, for which no conscious tinge within the closed system of particles can result, would constitute a deterministic unitary interaction.

Continuous stochastic theories are based on an underlying continuous stochastic process that affects the evolution of quantum particles. Such theories suggest that the existence of such a continuous stochastic process would provide a mechanism to resolve the measurement problem, although to date the existence of such a process has not been reported. Whether such theories are closed or open depends ultimately on the physics as to why such effects are occurring. If the effect always occurs, and is a property of individual particles that can be considered irrespective of the environment, then the effect could be considered to be a closed system effect. Moreover, Adler in [100] makes the important point that only environmental particles that are within a distance $c\tau_l$, where c is the speed of light and τ_l is the measurement latency time, can causally affect the experimental outcome without violating no-signaling.

Considerations in Closed Systems

Major considerations in a closed system deductive approach are the formation of the initial assumptions that will constitute and drive the investigation. An approach has been suggested in Chapter 6, in which the Bohr/Wheeler principle of radical conservatism provides the guide of the selection of conservative time-tested assumptions as well as the radical probing of such assumptions during the investigation. The importance of the selection of time-tested assumptions cannot be overly stressed, as the violation of this rule could easily lead to the dismissal of the correct solution and lead to significant wasted effort. A logical and rigorous foundation is desired in order to properly proceed.

We propose the following Ten Commandments of measurement in closed system investigation:

The Ten Commandments

(of measurement)

1) Thou shalt conserve energy

   Total energy of the system plus measuring device plus space-time surrounding environment is conserved in the process of measurement.

2) Thou shalt conserve momentum

   Total momentum of the system plus measuring device plus space-time surrounding environment is conserved in the process of measurement.

3) Thou shalt conserve charge

   The net charge of the system plus measuring device plus space-time surrounding environment is conserved in the process of measurement.

4) Measurement shalt be gauge invariant

   The measurement results and statistics of occurring are independent of the particular electromagnetic gauge.

5) Thou shalt not signal

   Measurement theory cannot lead, in principle, to information transmitted faster than the speed of light.

6) Thou shalt have no other preferred reference frames before Me

   There is no preferred frame that can result in the theory of measurement for which the theory is different than in other frames.

7) Thou shalt obey the equivalence principle

   The equivalence principle due to Einstein is that it is impossible to locally distinguish if one is being accelerated by a gravitational force or by a local force. Any measurement theory that violates such distinguishability is invalid.

8) Thou shalt not create perpetual motion machines

   Work from a fixed source cannot be delivered perpetually to drive a separate system. Any measurement theory that violates this premise is invalid.

9) Thou shalt make measurements obeying $|\Psi|^2$

   Measurement theory must respect Born's law.

10) Ye who covet the theory of measurement shalt be exalted amongst the heathen Unitarians.

These Ten Commandments and their implications on the theory of measurement will be expanded upon by the authors in future publications regarding the theory of closed system measurement.