CASYS 99-Abstract

Quantum Semiotic and Interaction Bond Graphs

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1. (What is the problem to resolve?)
The quantum formalism, although well- established and confirmed, still seems counter-intuitive in many ways. How do we develop our mental images of reality and an epistemological framework such that the whole thing will seem intuitively clear and sensible?

1. the Vicious Circle of Quantum Semantics

The *mechanical* part of Quantum Theory, i.e. equations of motion and the construction of operators for observables, seems quite uncontroversial; there is no need for different "schools" disputing, e.g. the proper form of the Schr�dinger- or Heisenberg-equations, because this part of the theory is so well integrated with the canonical methods of classical mechanics. However, *Quantum Semantics*, the way to define the *meaning* of Quantum-symbols in terms of ordinary language and classical concepts is still a matter of dispute between different schools of interpretation, and recent experiments, e.g. Aspect's (1982) (note 1) and those of the Innsbruck-group (1998) (note 2), that have validated the non-local, or "entanglement" properties of quantum states seem to have accentuated, rather than settled, the semantical problems. According to Niels Bohr (1935) and the "Copenhagen interpretation" (note 3):

> "There can be no question of any unambiguous interpretation of the symbols of quantum mechanics other than that embodied in the well-known rules which allow to predict the results to be obtained by a given experimental arrangement described in a totally classical way."

This statement of Quantum Semantics leads into a vicious circle for a theory of measurements: How can we know that a given piece of measurement equipment "described in a totally classical way" will behave according to the "well-known rules"? A quantum mechanical account of the action of the apparatus is out of the question because the meaning of the quantum symbols is undefined, unless the classical description alone provides a sufficient guarantee for its proper functioning. The Copenhagen interpretation is thus unable to tackle the measurement problem, except for some vague hints to the Correspondence Principle and an anti-realistic conviction that the reduction or collapse of the wave function is a purely conceptual tool with no physical background.

2.(What is well-known?)

2. Non-Locality or Contextuality?

Classical, non-contextual logic implies Bell's inequalities, which are clearly violated by the formalism and experiments. To explain this violation by non-local action-at-a-distance is unsatisfactory, because there is no such thing in the fundamental principles of relativistic physics and no practical ways of using it (e.g. for super-luminal communication). A common context for the detection of the two separate (but entangled) particles might explain the violation of Bell's inequalities even without action-at-a- distance (note 4). Such a common context could be provided by the coincidence counters in Aspect's experiments (note 1), but the recent experiments in Innsbruck (note 2) have shown that the inequalities are violated and the predictions of Quantum Mechanics are satisfied under circumstances where all coincidences are found retrospectively by comparison of the arrival times of the individual particles. It seems, thus, that contextuality alone is not a sufficient explanation�One has to accept some sort of non-locality, or "passion-at- a-distance" as it has been called by Shimony(1983).(note 5)

It is necessary to break the vicious circle of quantum- semantics such that the setting of semiotic sign- relations by physical means is considered more basic than semantics.

3.(What is the novelty of the paper?)

3. Sign relation and Quantum Semiotic.

The triadic sign-relation of C.S. Peirce is well-suited as a starting point for the epistemological discussion of quantum phenomena. The Peircean sign relation can be stated diagrammatically as I-R-O, where R stands for *the Representamen*, or Sign Vehicle, O for *the Object*, and I for *the Interpretant*. These three factors are connected with two *sign- links*, R-O, and I-R that can be rgarded as representing the physical processes of *Prepara- tion* and *Detection*, respectively. Peirce's three phenomenological categories (note 5) can be assigned to these links with the following meaning:

1. Potentiality
2. Actuality
3. Generality

The three categories of the two links have to be combined with the selection rule that the category of the *Detection* (I-R) link (1:icon, 2:index, 3:symbol) cannot exceed the category of the *Preparation*) (R-O) link (1:tone, 2:token, 3:type). The semiotic classification of the two-link sign then leads to six classes of signs that can be related to the Dirac-notation in the following way:

(33)
symbol
$\langle q|p\rangle$

(13)
icon-type
$|p\rangle$

(23)
index-type
$\langle\ |p\rangle$

(11)
tone
Hilbert Space
H

(12)
icon-token
$|\ \rangle$

(22)
index-token
$\langle\ |\ \rangle$

The Peircean classification of a three-link sign relation, J-I-R-O leads similarly to ten classes of signs that are relevant if we consider the human interpretation (J-I) of the measurement result (I) as well. For a *physical* discussion of measurements, however, it would seem sufficient to consider the third link (J-I) as a potentiality, leave the human observer in the background and consider the two links and the six classes above as sufficient for Quantum Semiotic.

4. (What results are obtained?)

4. Interaction Bonds as sign links.

Sign relations can be synthesized by means of the interaction-bond-graph-technique, developed by H.M.Paynter (note 7). This framework for the building of dynamic models has a natural affinity to the principles of thermodynamics, relativity, and quantum mechanics. Although all interactions are local, the system also contains non-locality in the form of *causal constraints* that account for the non-local entanglement of quantum states. Such constraints enter the definition of some of the icons, like the two "junctions" that represent Kirchhoff's node- and mesh- equations for networks. The iconical (pictorial) representation of dynamic relations in the formalism makes it possible to circumvent the prohibition against ontology and the use of mental images of the quantum world. An implementation of the bond-graph icons as computing elements may provide a crucial step in the development of quantum computers. In the most general formulation of the technique every bond is associated with a metric tensor that defines the scalar product of the two complex vectors (effort and flow) that constitute the interaction. The technique thus incorporates the general principle of relativity, including Einstein-locality. The *Reticulation* (network-structuring by bond- graph-icons) of the sign relation leads for the representamen R to the partial differential wave- equations described as sections repeated in space like a three dimensional crystal. The processes of *Preparation* and *Detection*, associated with the R-O, and the I-R bonds, respectively, are naturally *Quantized* as causal shifts that are distributed through the network from the connecting junctions. In this way the quantization of action and the projection postulate for measurements are given a natural and realistic explanation.

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