Discrete Quantum Causal Dynamics

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Abstract

We give a mathematical framework to describe the evolution of open quantum systems subjected to finitely many interactions with classical apparata. The systems in question may be composed of distinct, spatially separated subsystems which evolve independently but may also interact. This evolution, driven both by unitary operators and measurements, is coded in a mathematical structure in such a way that the crucial properties of causality, covariance and entanglement are faithfully represented. This framework generalizes both causal posets and the consistent histories approach to quantum mechanics.

In our work we also showed how our framework may be expressed using the language of (poly)categories and functors. Remarkably, important physical consequences - such as covariance - follow directly from the functoriality of our axioms. We established strong links between the physical picture we propose and linear logic. Specifically we showed that the refined logical connectives of linear logic can be used to describe the entanglements of subsystems. Furthermore, we show that there is a correspondence between the evolution of a given system and deductions in a certain formal logical system based on the rules of linear logic.

The work reported here has been influenced by R. Sorkin's approach to Quantum Gravity and F. Markopoulou's work on Quantum Causal Evolution. This is joint work with Richard Blute and Ivan T. Ivanov of the Department of Mathematics, University of Ottawa.