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A general type-theoretic approach to higher-order quantum resources

Quantum resources exist in a hierarchy of multiple levels. At order zero, quantum states are transformed by linear maps (channels, or gates) in order to perform computations or simulate other states. At order one, gates and channels are transformed by linear maps (superchannels) in order to simulate other gates. To develop a full hierarchy of quantum resources, beyond those first two orders, and to account for the fact that quantum protocols can interconvert resources of different orders, we need a theoretical framework that addresses all orders in a uniform manner. We introduce a framework based on a system of types, which label the different kinds of objects that are present at different orders. Subsequently, we equip the framework with a parallel product operation that modifies and generalizes the tensor product so as to be operationally meaningful for maps of distinct and arbitrary orders.