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Monoidal Institutions: an abstract framework for modeling concurrency

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Background and Motivation

- Modern computing systems increasingly involve concurrency, interaction, and distributed processes.
- **Quantum systems** inherently exhibit structured forms of concurrency through tensor composition.
- Classical logical frameworks are often not well-suited to describe compositional and parallel behavior.
- My research aims to provide a uniform logical framework that can model such systems with potential relevance to quantum computing and complex system design.

Current Situation

- Existing approaches to concurrency and quantum systems are often fragmented using different mathematical and logical tools.
- There is a need for a unified perspective that connects logic, concurrency, and quantum theory in a way that is both abstract and applicable beyond purely mathematical contexts.

Setting & Research Overview

This work is based on institutional model theory, an abstract framework for logic grounded in category theory.

In our approach models are monoidal categories, where:

- objects represent systems or states,
- morphisms represent processes,
- the tensor product models parallel composition.

This setting allows us to describe concurrent behavior and capture structural similarities with quantum systems, where tensor products play a central role.

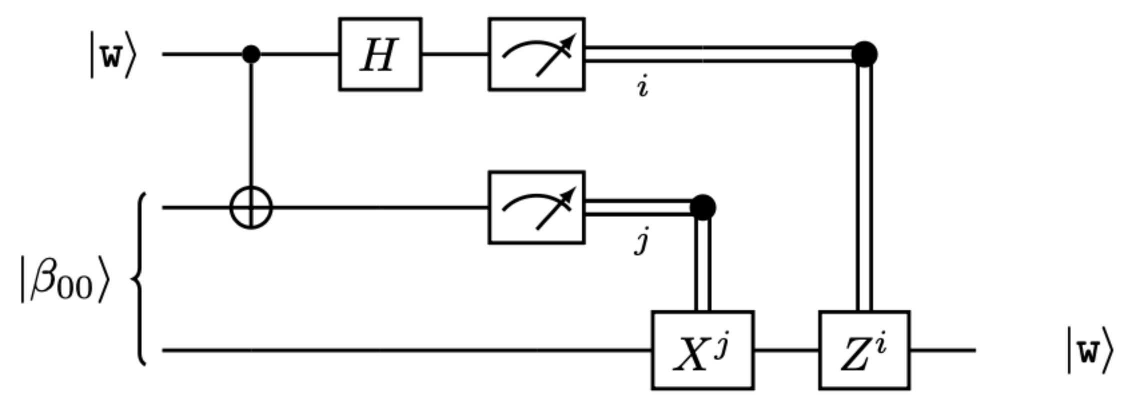

Fig. 1: Quantum teleportation

Development

The research develops an abstract logical framework for reasoning about parallel and concurrent systems. Its semantics, based on a monoidal structure, enables:

- modeling of concurrent and distributed systems in a uniform way,
- connections between classical and quantum computational models,
- improved abstraction for system design and verification.

Potential applications include quantum computation, formal verification, and modeling of complex interactive systems, where understanding composition and interaction is essential.