High Level Structures in Quantum Computing

Ross Duncan

Oxford University Computing Lab
Quantum Computing

- New computational model of great promise
  - Powerful algorithms (factoring, sublinear search, etc)
  - New protocols (encryption, leader election)
  - Implementations exist (and more to come)

- *Entanglement* is fundamental

- Existing Formalisms
  - ... don’t represent entanglement
  - ... are too low level
  - ... or both
The Need for Abstraction

Raussendorf, Browne, Briegel (2003)
Fundamental Aim:

Make quantum computation easy.

- Identify the underlying informatic structures
- Make them available to algorithm designers
- ... without all the unnecessary details
High Level Structures

Categorical approach to quantum mechanics pioneered by Abramsky and Coecke; further developed in my own research.

- Duality between states and maps makes information flow explicit
- Proven to admit generalisation and tuning
- Has concrete representation as rewriting on diagrams (proof-nets)
- Can check equivalence of computations
Rewriting Example
Why use categorical approach?

- Categorical models are intrinsically compositional
- Implementation details suppressed; algebraic structure revealed
- Abstract theory admits multiple models
- Strong connection with logic
- Opportunity for technology transfer between other parts of computer science and physics
Objectives

1. Develop abstract models of information flow in entangled systems.
   - Axiomatics and representations

2. Produce formalisms for quantum computation based on these models.
   - λ-calculi, process algebras

3. Prototype tools to support computing in these formalisms.
   - Strongly typed programming language

Disseminate this work as widely as possible.
Beneficiaries

• Specialists in quantum computation/information
  – Mathematical insights
  – Formal tools

• Theoretical computer scientists
  – Closely related to linear and resource sensitive logics
  – Make quantum computation accessible

• Physicists working with quantum systems
  – Toy models and generalised probability theory
  – Condensed matter physics
Summary

A chance to take big step forward in an important foundational problem in an inherently interdisciplinary field with many potential applications.