

Peter Hines

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CURRENT POSITION

Research Associate York University Computing Department 2005-

Researcher in foundations of quantum computing, an ongoing project currently funded by the QICS network. Previously funded by the QIP-IRC network.

PREVIOUS EMPLOYMENT

Research Associate Oxford University Computing Laboratory 2002-2005

Researcher in foundations of quantum and reversible computation, a 3 year project funded by an EPSRC - LMS collaboration.

Commercial Programmer self-employed 2000-2002

Self-employed programmer working on a variety of projects for commercial clients, including BTC Group management consultancy, Rio-Tinto Zinc, and thisweek.com

Research associate University of Wales, Bangor 1999-2000

Researcher in information-theoretic models of classification, with responsibilities for formulating and programming mathematical models.

Casual Lecturer 1997-2000

A casual lecturer employed on a number of courses, in mathematics, computer science and programming, and IT.

EDUCATION

PhD - University of Wales, Bangor (1994-1997)

Geometry of Interaction, Category theory, inverse semigroups.

MSc - University of Wales, Bangor (1992-1994)

Knot theory, self-distributive algebras, knot invariants & polynomials

BSc. - University of York (1989-1992)

Pure mathematics (2:1)

TEACHING EXPERIENCE

Lecturing and/or demonstrating in the following subjects

University of York : Discrete mathematics for computer scientists, Propositional and Predicate Calculus, Categorical logic, Quantum Computation.

Oxford University : Game Semantics, Category theory, Formal program verification, Artificial intelligence

University of Wales, Bangor : Discrete mathematics, Combinatorics, Statistics, Java, C++, 68000 assembler, parallel computing, mathematics for computer scientists, introductory computing.

RESEARCH PROGRAM

Please refer to the final section, Statement of Research Interests, for a detailed description of my current research program.

PUBLICATIONS

An application of polycyclic monoids to rings : **Semigroup Forum** 56 p.156-159

The categorical theory of self-similarity : **Theory and Applications of Categories** 6(3) p. 33-46

A categorical framework for finite state machines : **Math. Struct. in Comp. Sci.** (13) p. 451-480

A short note on coherence & self-similarity : **Journal of Pure & Applied Algebra** (175) p. 135-139

A non-parametric approach to simplicity clustering (with E. Pothos & N. Chater) : **Applied Artificial Intelligence** 21(8) p. 729-752,

Physical Systems as Constructive Logics : in **Unconventional Computation**, C. Calude et. al (ed.s), Springer LNCS, p. 101-112

Machine Semantics : from causality to computational models : **International Journal of Unconventional Computation** 4(3) p. 249-272

Can a quantum computer run the von Neumann architecture ? : in **New Structure for Physics**, Springer Lecture notes in Physics (to appear) p. 1-43

Conditional quantum iteration from categorical traces (with P. Scott) : **Mathematical Structures in Computer Science** (revised following referees suggestions) p. 1-83

Machine Semantics : **Theoretical Computer Science** (revised following referees suggestions) p. 1-48

Convolutions and Fourier transforms of categories, with applications to quantum state machines : submitted, p. 1-32

Dynamical algebras as self-similar objects in unique decomposition categories : submitted p. 1-45

The structure of partial isometries I (with S. Braunstein) : under preparation - invited chapter for **Semantic Techniques in Quantum Computation**, Cambridge University Press.

Quantum Machine Semantics : under preparation - invited submission for TCS, **Proceedings of Physics, Computation & Information**, MFPS 2007

OTHER MANUSCRIPTS

The following manuscripts have been referenced by other authors, but not published. Their contents have since been subsumed by papers listed above.

A one-object inverse compact closed category used in the Geometry of Interaction.

Can the von Neumann architecture be made 'quantum' ?

A simplicity principle in unsupervised human classification.

REFEREEING

Refereeing papers for the following Journals or conferences :

Mathematical Structures in Computer Science, Theoretical Computer Science, International Journal of Quantum Information, LMS Journal of Computation and Mathematics, International Journal of Unconventional Computation, Logic in Computer Science, International colloquium on Automata Languages and Programming, Non-Standard Computation.

INVITED TALKS

The following is a selection of invited talks given:

Towards a quantum machine semantics : **MFPS 2007, workshop on Physics, Computation, and Information**

The inverse and the trace - iteration in models of reversible computing : **LICS 2007, workshop on traced monoidal categories, network algebras and applications**

Planar two-way automata - from inverse semigroups to the quantum Jones polynomial : **FountainFest 2006, Semigroups, Categories & Automata, in honour of J. Fountain**

Compact Closed Monoids - definitions and constructions : **GeoCal 2006 Semantics, workshop on Geometry of Interaction**

The zoology of quantum computers - classical and quantum control structures & data : **Fields Institute Summer School 2003, Logic & Foundations of Computation, workshop on QM programming languages**

COMPUTER PROGRAMS

The following computer programs are freely available for use within an academic environment:

Non-parametric data clustering : A C++ implementation of the information-theoretic analysis of human classification given in Hines, Pothos, Chater 2007.

Non-metric MDL package : A Matlab package optimizing and extending the above program. Currently undergoing final testing and documentation.

STATEMENT OF RESEARCH INTERESTS

My research interests are in the following (broadly related) topics :

- Geometry of Interaction and its categorical models,
- Foundations of Category theory,
- Quantum Computation,
- State Machines and general notions of iteration,
- Domain theory,
- Cognitive Science and information theory.

My specific work in these areas is described below.

A substantial interest is in applying ideas from the Geometry of Interaction to state machines and physical computation. This work is described in my paper "A categorical framework for finite state machines" - this uses the GoI system to provide algebraic models of a range of state machines, from finite state automata to space-bounded Turing machines.

My interest in categorical models of the Geometry of Interaction is based around the notion of untyped systems, and how categorical models of untyped structures may be derived from categorical models of the corresponding typed structures. A general 'untyping' construction is described in my paper "The categorical theory of self-similarity", and this is applied to traced and compact closed categories, giving an untyped version of compact closure.

My interest in the foundations of category theory is related to MacLane's coherence theorems for monoidal categories. As well as constructing monoids with a binary operation satisfying untyped versions of MacLane's coherence conditions, I have shown that in certain cases there is a canonical construction of a monoidal category 'associative up to isomorphism' from a strictly associative monoidal category. This work is described in 'a short note on coherence and self-similarity'.

My interest in quantum computation is two-fold. I have studied the original description of a quantum Turing machine, by D. Deutsch, and the subsequent critiques of this definition by J. Myers, N. Linden, S. Popescu, et. al., as well as the general question of whether coherence and conditional iteration are compatible. My work in this area is also based on structures from the Geometry of Interaction, and is described in the papers "Conditional quantum iteration from categorical traces" (joint with Phil Scott), "Convolutions and Fourier transforms of categories, and applications to quantum state machines", "Can a quantum computer run the von Neumann architecture?".

A further interest in the general field of quantum computation and logic is in von Neumann & Birkhoff's quantum logic, and its categorical models. In particular, as joint work with Sam Braunstein, we have been studying whether this is compatible with Samson Abramsky & Bob Coecke's 'categorical foundations for QM'. This work is described in "The structure of partial isometries I" (joint with Sam Braunstein), and is also heavily influenced by ideas from the Geometry of Interaction.

My work in Domain theory is in terms of order structures derived from models of iteration. This is closely related to my work on categorical models of state machines, but from a domain-theoretic, rather than categorical, viewpoint. This work is about axiomatising the notion of a high-level vs. a low-level description of a simple systems (for example, an unlabelled transition system) in order-theoretic and domain-theoretic terms. This work is described in the papers "From physical systems to constructive logics", "Machine Semantics", and "From causality to computational models".

My work in cognitive science is based around the 'Minimum Description Length' model of clustering and human classification I produced along with Emmanuel Pothos, and Nicholas Chater. This is an axiomatisation of the notion that a clustering, or classification, on a dataset is a predictive theory about the structure of this dataset. Occam's razor predicts that the most useful classification is the one that provides the best predictions in the most efficient manner. Our work axiomatised this in information-theoretic terms, and I produced a C++ computer program that used this axiomatisation to search for 'good' clusterings on datasets.

The results of this computer program are in very good agreement with data arising from psychological experiments, and this program is currently in use in a number of university cognitive science

departments. I have recently updated the code, and written a MATLAB package that extends the previous program. This work is described in "A non-parametric approach to Simplicity clustering", and "Modelling Category Intuitiveness".