Name
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Education History

I graduated from Heriot-Watt with a 1st class MMath degree. For my 4th year dissertation I completed a project on abelian categories supervised by Mark Lawson, and for my 5th year dissertation, my topic was simplical homology, also supervised by Mark Lawson. I am currently in my second year of a PhD supervised by Ross Duncan.

PhD

My PhD was originally about extending ZX calculus to infinite dimensions, but has recently been more focussed towards the Frobenius algebra/ Hopf algebra structure that underlies ZX calculus and appears in several other contexts.

Statement

During the ACT school, I will be working alongside researchers towards a project. My goal is to continue in academia after completing my PhD, so these are the people with whom I hope to work alongside professionally one day. In addition, I don't have the opportunity to work alongside many other category theorists, and I would really benefit from working alongside others who are at a similar stage as me.

It is very likely that I will end up working on ZX calculus after my PhD, so the project "Simplifying quantum circuits using the ZX-calculus" will be directly beneficial to my career: my work on Hopf algebras and Frobenius algebras is partially motivated by ZX calculus, and I am quite connected with most other ZX researchers, including Miriam. As such, having a hand in developing ZX would likely be beneficial to my career, and this school would be a useful experience. In addition, this is an important topic in ZX; simplifying circuits is something that ZX calculus is specialised to be able to do, and if the non-category theory quantum computing world want to simplify circuits, then it is likely that they will have to use ZX. As such, I believe that this is a very important topic in the development of ZX, and I would like to contribute as much as I can towards the success of ZX.

The project "Traversal optics and profunctors" focuses on the category of enriched profunctors, and I would be very interested in learning more about this category as part of my research. Ross Street did some important work on Hopf and Frobenius algebras in this category, in his paper "Frobenius Monads and Pseudomonads" which is definitely worth investigating. Also, it is a categorification of the bicategory of bimodules over rings/ algebras, which is an important

category in my work. Hence, it may end up being possible to take results from one category and apply it to the other. This means that it may become more relevant in my research, so I would like to look into it and see if I can use it.

Project Preference

- Simplifying quantum circuits using the ZX-calculus
- Traversal optics and profunctors
- Toward a mathematical foundation for autopoiesis
- Partial evaluations, the bar construction, and second-order stochastic dominance
- Complexity classes, computation, and Turing categories
- Formal and experimental methods to reason about dialogue and discourse using categorical models of vector spaces

Background in Category theory
- My PhD in category theory, so I am very comfortable with standard category theory concepts. For example, I have no problem with the material in Mac Lane.
- Specifically, I am often centred around categorical quantum mechanics, so I have gotten the most use out of monoidal categories and diagrammatic reasoning, as well as dagger categories and compact closed categories.
- Right now, I am focussed on Frobenius algebras, Hopf algebras, and PROPs.
- My research has also led me down the paths of Topos theory, Monads and bicategories.
- In addition to this, category theory is the field of maths that I am most comfortable with, and I am usually enthusiastic, and rarely intimidated, by material in category theory that I don't yet know.

Specific Project Areas
- Simplifying quantum circuits using the ZX-calculus

The original topic of my thesis was to extend ZX calculus to infinite dimensions. As such, I am very familiar with the machinery involved in ZX, and I am very comfortable using ZX to talk about quantum computing. I am active in the ZX community, as I attend weekly skype meetings with others who work on ZX, and have attended the 10 year anniversary ZX meeting last summer. In addition, my current work is partially motivated by ZX; the algebraic structure underlying ZX calculus is a pair of Frobenius algebras which interact to form a Hopf algebra, and this is the structure that I am studying.

- Traversal optics and profunctors

I am currently investigating some ideas outlined in Ross Street's paper "Frobenius Monads and Pseudomonoids", and this has led me to become interested in the category V-Mod, which is the category of enriched profunctors.

- Toward a mathematical foundation for autopoiesis

My undergraduate degree was in Heriot Watt University, which has a maths program mostly focussed around modelling techniques. Because of this, I am familiar with Mathematical biology,

mathematical ecology, thermodynamics and mechanics, which may be potentially be of some relevance to this project. In addition, I am interested in Topos theory, and I have read through the section on topoi in Borceux's "Handbook of Categorical Algebra", though I have not had the opportunity to use it.

Availability to come to Oxford
I will be able to go to Oxford. I plan on going to the ACT conference regardless, and I have funding available for travel and accommodation.

Reference for Joseph Collins

1 message

Ross Duncan <ross.duncan@strath.ac.uk>   Thu, Jan 31, 2019 at 2:47 AM
To: act2019school@gmail.com

Dear Esteemed Colleagues,

I am writing to recommend my PhD student, Joseph Collins for the
ACT school in Oxford this spring.

Mr Collins has been studying for a PhD with me at the University of
Strathclyde since September 2017 and is supported by a prestigious
Carnegie PhD Scholarship, which are awarded to the best 16 students in
Scotland across all disciplines. Previously he had completed a
Masters in Mathematics at Heriot Watt University, where he did two
projects supervised by Prof Mark Lawson on topics in categorical
algebra.

Since joining my group, Mr Collins has been working on various topics
related to the use of monoidal categories in physics, particularly on
foundations and generalisations of the ZX-calculus. Initially he
studied the theory of infinite dimensional Hilbert spaces, as used in
quantum optics, with a view to formalising optical quantum computing
in terms of internal algebras and co-algebras and their interaction
laws. More recently he has narrowed his focus and is working to
generalise the theory of interacting Hopf and Frobenius algebras in the
non-commutative setting, and the case where the internal integers of
this theory are a mere ring, rather than a field. We hope that this
will lead to a formulation of the theory in terms of distribution laws
and corresponding normal forms for quantum systems of non-prime, or
dimension.

Joe has a very strong understanding of the basics of category theory,
monoidal categories, and knows a lot about Hopf and Frobenius
algebras. I think he will gain a lot from the school in terms of
deepening his knowledge of the ZX-calculus and broadening his general
categorical culture. The ZX-calculus topic in particular represents a
move into a more applied direction which I think will be very helpful
for his future work, but all the other topics Joe mentions in his
application will be useful.

Given the above I think it is obvious that the ACT school is relevant

to Joe's research and will enhance him as a researcher. But before closing I want to mention a contingent fact, which I hope that the committee will take into consideration. Since July 2018 I have been working only part time at Strathclyde, and in consequence Joe has had less supervision and required more self-direction than is usual in an early stage PhD student. For this reason I think he will benefit more than most applicants from attending the school to broaden his network of potential collaborators.

Best wishes,
Ross Duncan

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