UNIVERSITY OF CALIFORNIA, RIVERSIDE

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DEPARTMENT OF MATHEMATICS | RIVERSIDE, CALIFORNIA 92521-0135

baez@math.ucr.edu

January 24, 2019

Dear Sir or Madam:

This is a letter of recommendation for Christian Williams, one my six graduate students at U.C. Riverside, and one of three who did not attend the ACT2018 school.

He is only in his second year of graduate school, but he's already passed his qualifier exams and he is bringing a lot of energy to our research group. He has a deep desire to revolutionize the world of communication and computation with better data structures founded on better mathematics. Last year he began work with my former student Mike Stay, who runs a startup called Pyrofex, to complete some research begun by Mike Stay and Greg Meredith on enriched Lawvere theories as a framework for operational semantics. I joined him in this research, and our paper on this subject is almost done.

This paper fleshes out a dream I have had for over 10 years: using higher categorical structures to represent the *process of computation*. While ordinary Lawvere theories are capable of describing a wide variety of algebraic structures; they are only able to handle equations between operations. Graph-enriched theories, on the other hand, can describe *rewrites* going between operations, and thus describe computational processes: in other words, not just denotational but operational semantics.

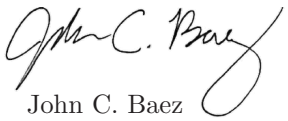
To complete our work we needed to go far beyond Stay and Meredith's original paper. Christian had all the main original ideas, though I gave him a lot of guidance. He mastered Lucyshyn-Wright's paper Enriched algebraic theories and monads for a system of arities, figured out how to extract the most useful part of Lucyshyn-Wright's very general results, and proved his own theorems to turn these result into a convenient framework for operational semantics. He figured out how to construct a V-enriched category of models of any V-enriched Lawvere theory in any suitable context, and how to integrate all these V-categories of models into a single structure using the Grothendieck construction.

This is just the first of several projects Christian has lined up. He is now working for Greg Meredith's company RChain to write a series of papers investigating applications of category theory to the pi calculus and rho calculus: two process calculi for distributed computation. In the process he is also teaching me and my other students the pi calculus.

On top of this, Christian has become excited by the environmental goals of my Azimuth Project and has put an explicitly practical spin on my network theory seminar, organizing an Applied Category Theory Seminar where we all read and explain papers on topics such as climate change, genetics, the spread of infection on networks and so on. These lectures are now available on YouTube, in large part thanks to his energy.

All these things illustrate why it's so important to have Christian Williams at the ACT2019 school. He will take it seriously, do a lot of work to organize activities and bring people together, make connections between ideas, and make the school more exciting and successful.

Sincerely,



John C. Baez

Hello, my name is Christian Williams. I am a second-year PhD student in mathematics. Here is my application for ACT 2019:

Relevant background:
I have worked with John Baez and the Applied Category Theory team at UC Riverside since Fall 2017. This is a great research group, and I am very grateful to be here. My primary focus is computer science. I entered the PhD hoping to apply categories to blockchain, and by luck I attended the opening summit for Statebox, a new categorical blockchain language. I wrote an article, and a previous student, Mike Stay, invited John and me to conduct research for his software company, Pyrofex. Mike had recently partnered with Greg Meredith and the cooperative RChain, which is founding a distributed computing infrastructure on the reflective higher order pi calculus.

Since beginning this work, Baez and I have written our first paper, called "Enriched Lawvere Theories for Operational Semantics". We show that algebraic theories can be equipped with "operational" structure, which represents the process of computation: in a Set-enriched theory, objects are types and morphisms are terms; in a Cat-theory, 2-morphisms are rewrites. Cartesian functors between enriching categories induce a change-of-semantics, and we demonstrate these ideas with SKI combinators, the variable-free lambda calculus. This is the first of a series of papers for a central algorithm of the RChain network, called "logic as a distributive law". Additionally, John and I are interested in the theoretical aspects of the RChain language. We aim to determine the categorical semantics of parallel computation as Lambek did serial computation.

PhD completion:
I expect to complete my Ph.D. in the spring of 2022. It will most likely pertain to the categorical semantics of process calculi.

Project preference:
Spivak, Hofstra, Milewski, Fritz, Backens, Sadrzadeh

Extent of commitment:
I can commit 100%.

Statement of interest:
I firmly believe in the power of categorical thinking. The ACT community are pioneers, toward a unified science and a principled society. What other academic group explores such diverse subjects - chemistry, linguistics, physics, computation, engineering - with such innovative methods? It is a group of bold thinkers who are stepping up at a crucial time. I share John's mission to help the global ecological crisis, and his conviction that ACT will be essential to a sustainable world. We hope to apply network theory to Earth Systems Models, using Odum's Energy Language - the attendees may have good insights for this and other projects. Above all, I simply want to absorb the work of this community, initiate communication, and build relationships. The computer science topics for this year sound fascinating. I am eager to meet everyone, to learn and discuss and collaborate.

Thank you very much for the opportunity.

Sincerely,
Christian Williams

Christian Williams

Curriculum Vitae

CONTACT

williams@math.ucr.edu
(281)-678-4807

UC Riverside
Department of Mathematics

EDUCATION

Mathematics PhD University of California, Riverside. 2017-

Mathematics BS, MS Texas A&M University. 2012-2017

– Minors in Computer Science, Electrical Engineering, and Physics.

RESEARCH

Enriched Lawvere Theories for Operational Semantics : *with John Baez*

Demonstrate enrichment as a way of equipping algebraic theories with the structure of computation. Maps between enriching categories translate between forms of operational and denotational semantics. Illustrated with the SKI combinator calculus, a variable-free version of the lambda calculus, presented as a graph-enriched theory: objects are types, hom-vertices are terms, hom-edges are rewrites. [1]

PROJECT

Categorical Semantics of Process Calculi

With John Baez, aim to determine the canonical category-theoretic structure of the reflective higher-order pi calculus.

Network Theory: Earth Systems Models

With ACT@UCR team, will explore application of structured cospan categories to Odum's Energy Systems Language.

Type Theory, Proof Systems, Higher Categories

Long-term interest. Will formalize future work with RChain.

OCCUPATION

RChain Coop. (2019-) Researcher

UC Riverside (2017-) Teaching Assistant

Pyrofex, Inc. (2017-2018) Researcher: [1]

Texas A&M (2017) STEM Counselor, (2016) Athlete Tutor

IBM Corp. (2015) Software Developer

TALKS

ACT@UCR Seminar

Winter 2019 "The Pi Calculus: Toward Global Computing"

Graduate Student Seminar

Spring 2018 "Categorical Computation – Form and Content"

Winter 2018 "The Philosophical Science of Logic"

WRITING

RChain The Azimuth Blog, May 2018. -

Statebox The Azimuth Blog, January 2018. -

EXPERIENCE

Mathematics Honor Society Vice President (2015-2016)

A&M Computer Science Research Assistant (2014-2015)

Electrical Honor Society Activities Chair (2013-2014)

Engineers Without Borders Team Member (2012-2014)