Applied Category Theory 2019 School Application

To whom it may concern,

My name is Diego Roque, and I'm a junior at MIT interested in category theory. My first exposure to category theory was through Haskell, and since it was combined foundations of mathematics, applications to programming languages, and generalization at the right level, I knew I wanted to continue pursuing it in an academic setting. To this end, Ive sought out many opportunities:

1. I was a part of directed reading programs on category theory with Peter Haine where we discussed topics such as kan extensions and topos theory;

2. I attended seminars such as Seven Sketches in Compositionality, a seminar taught by David Spivak and Brendan Fong;

3. I participated in classes such as Categorical Logic by Jacob Lurie where we covered syntactic categories and Deligne/Gdels Completeness Theorem; Formal Reasoning About Programs by Adam Chlipala, where I learned formal analysis of programs using machine-checked proofs and concepts such as big and small step operational semantics; and measure theory, which provided me with a more formal understanding of probability.

4. Ive contributed to research projects in program verification and AI for mathematics under the mentorship of Adam Chlipala and Andrzej Banburski respectively.

5. On the applied side, I have done quantitative and fundamental finance internships, programming internships, and machine learning projects.

Ive also done a fair bit of self studying and independent research: I have extensive knowledge of classical algorithms and data structures at a intermediate graduate level; a basic knowledge of quantum computing, quantum complexity theory, quantum circuits, and a good grasp on the details of the main algorithms (like Grover); and knowledge of theory of computation and classical complexity theory at an undergraduate level. I'm also comfortable with definitions of typed lambda calculus, have a solid background in type theory, formal logic, and interactive theorem provers (Coq and Lean in particular).

Ive been following recent development in applied category theory and related fields such as turing categories and categorical logic, and was extremely excited when I came across ACT 2019 and the papers that would be a part of the program.

As mentioned, I'm currently an undergraduate, but in the fall Ill begin applying to PhD programs in mathematics. In particular, I hope to work on topics related to logic and/or category theory.

The order of preference for the projects is as follows:

1. Complexity classes, computation, and Turing categories

   I have wondered about what would a categorical approach to complexity theory be, and in particular about intrinsic characterization of complexity classes. The standard approach is to define, say, P through an external concept of polynomial time, so a fully internal approach seems interesting. I know there are some approaches to do this internally, and Im wondering how would a categorical investigation of this would be like.

2. Simplifying quantum circuits using the ZX-calculus

   The existence of sound and complete graphical calculus, and the abundance of them, is one of the things I find most surprising, ever since I found out about `http://graphicallinearalgebra.net`. I am independently interested in quantum computation, and in particular in how to express quantum algorithms better, since currently the abstraction is too low-level. It would be akin to trying to code everything at a bit level. Improving this would be a very exciting project for me.

3. Toward a mathematical foundation for autopoiesis

   Im interested in the use of categorical logic here. I also find the application to philosophy quite engaging, and the question of what it means to be a thing seems fundamental. Im interested in how categorical logic plays into what makes things what they are.

4. Partial evaluations, the bar construction, and second-order stochastic dominance

   Im interested in the application of category theory to financial risk, especially since its through partial evaluations. Since financial risk is especially hard to asses, seeing the insight category theory could bring seems very valuable.

5. Traversal optics and profunctors

   I have extensively used Haskell, and it was actually my gateway to category theory. I find Kmetts lens library to be one of the most impressive and useful ones in Haskell, and I often wish I had an equivalent one when using a language distinct from Haskell. How and why optics work and compose seamlessly is a topic I have read much about, and seeing a categorical approach to this is interesting.

6. Formal and experimental methods to reason about dialogue and discourse using categorical models of vector spaces

   I have played a bit with NLP models in deep learning, but for the most part steered clear of it. Im not well versed in linguistics or in classical (non deep) NLP approaches. Im not very interested in this project.

Commitment: I will be able to commit coming to Oxford University, even conditioned on no funding.

Personal Statement

My interest in category theory, both foundational and applied, was first sparked through my exposure to functional programming. A friend introduced me to Haskell because of my background in mathematics. I found the type system more interesting than the functional aspect, and loved how it often generalized things at the correct level and made things clearer in code. Afterward, I saw this applied to algebra, where it turned a repetitive course of doing some of the same things in groups, rings, and modules into an overarching structure that made things clearer and more elegant. Other subjects that I was interested in, such as logic, foundations of mathematics, and computation turned out to have deep connections with category theory, which only furthered my dedication to learn more about the topic.

This particular introduction to category theory, which had applications in mind to begin with, defined my mindset and approach to it down the road, giving me a tool to find patterns among structures, like the ones remarked by Baez in his Rosetta Stone. When applied to code, for example, it becomes a formal language for design patterns, replacing ad-hoc creations with principled ones. In more than one instance I have used natural transformations in the code for a web application, which is a far cry from their starting use by Eilenberg and MacLane, speaking to the far-reaching applicability of category theory, and inspiring me to seek other impactful ways to utilize it, as well.

I'm currently an undergraduate at MIT, and in the fall Ill begin applying to PhD programs in mathematics. In particular, I hope to work on topics related to logic and/or category theory, in both pure and applied areas. Part of the appeal of ACT 2019 is being able to engage with this material in a rigorous manner, which will allow me to concretize my specific interests, allowing me to more effectively contribute to the field as a graduate student and beyond. In addition, as a program which gathers the foremost experts on the topic, ACT 2019 offers an opportunity to connect with other young academics, from whom I could learn an incredible amount as well as collaborate in the future. All of this make me excited to be a part of the Adjoint School in ACT 2019.

Sincerely,

Diego Roque

DIEGO ROQUE

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EDUCATION

Massachusetts Institute of Technology   Cambridge, MA
Bachelor of Science in Mathematics
Technical courses: Formal Reasoning about Programs, Topology, Measure Theory, Algebra I/II,
Analysis, Deep Learning, Graph Theory and Additive Combinatorics, Social Choice and Networks,
Algorithmist's Toolkit, Categorical Logic, Category Theory and Topoi Reading Program

AWARDS

International Mathematical Olympiad (IMO)   2010 — 2014
- Historically best ranked Mexican competitor
- **Gold** Medal, 3 Silver Medals, Bronze Medal
- Seven times National Gold medalist

International Olympiad in Informatics (IOI)   2013 — 2014
- Historically best ranked Mexican competitor
- **Gold** Medal, Silver Medal
- Three times National Gold medalist

EXPERIENCE

EngineML   San Francisco, California
Software Engineer   Fall 2018
- Coded in a Haskell codebase.

Bridgewater Associates   Westport, Connecticut
Investment Associate Intern   Summer 2018, January 2019
- Investment Associate in Disruption Lab.

Tudor Investment Corporation   New Yorkt, New York
Quant Intern   Summer 2017
- Researched machine learning algorithms on financial databases in order to predict asset returns,
  which were integrated into the overall trading strategy.

Poggio Lab at Center for Brains Minds and Machines   Cambridge, MA
Undergraduate Researcher   February 2018 — Present
- Developing an artificial intelligence system capable of doing mathematics.

MIT Programming Languages and Verification Group   Cambridge, MA
Undergraduate Researcher   September 2017 — Present
- Implementing concurrent semantics for RISC-V in Haskell.

Kueski   Guadalajara, Mexico
Software Engineer   2015 — 2015
- Worked in the backend of Kueski, an online lending startup.

Centre for High Academic Achievement   Monterrey, Mexico
Software Engineer Volunteer   2015 — 2016
- Developed an admission system (written in Purescript and Haskell) with statistical methods to
  evaluate student performance, such as IRT. Used to screen more than 3000 students.

Mexican Computing Olympiad Committee   Mexico
Problem Setter and Training Program Organizer   2015 — 2016
- Wrote part of the tests used to select the Mexican team for the IOI 2015 and 2016, as well as
  helping with the organization of the selection process.

IQ+   Monterrey, Mexico
Board Member   2016 — Present
- IQ+ is an educational nonprofit specialized on gifted youth.

Tutor   2014 — 2016
- Tutored three students that went to international olympiads. One student got a bronze at IOI,
  and the other two got silver at IMO.

SKILLS

Programming Languages:	Haskell, Coq, Purescript, Elm, C/C++, Python, Ruby, Javascript, Julia
Languages:	Spanish (Native), English (Full Professional), Chinese (Beginner)

January 29th, 2019

To Whom It May Concern:

I give my strongest recommendation for Diego Roque to be admitted to the ACT School 2019.

I have known Diego since January 2018, when he participated in the Seven Sketches course that David Spivak and I taught at MIT.

Diego has since been a regular attendee at the MIT Applied Categories seminar, where he has shown great understanding, regularly asking insightful questions even in difficult talks. He took our course 18.S097 (Applied Category Theory) in January 2019, and all his assignments were excellent. We have also spoken about my research on graphical regular logic a number of times, where he has always been quick to understand.

Diego has completed reading courses on topos theory, and attended Jacob Lurie's extremely fast-paced course on Categorical Logic in Spring 2018. His talent is evident in conversations with him, and from a brilliant record, which includes five International Math Olympaid and two International Informatics Olympaid medals.

Diego has a strong and demonstrated interest in applied category theory, and is exceptionally talented. Although still an undergraduate, I am confident he is up to the rigours of the ACT School, and strongly encourage you to admit him; I have no doubt that if he decides applied category theory is his path, he will make strong contributions in the years to come.

If you require any further information please do not hesitate to contact me.

Sincerely,

Brendan Fong

Postdoctoral Associate
Department of Mathematics
Massachusetts Institute of Technology
email: bfo@mit.edu