Gmail

Applied Category Theory <act2019school@gmail.com>

Application for ACT2019

1 message

Jack Hidary <hidary@google.com> Wed, Jan 30, 2019 at 11:41 PM
To: act2019school@gmail.com

Hi,

I am very interested in participating in ACT2019. I am passionate about mathematics both in terms of pure mathematics as well as its potential to give us more insight into a wide range of other fields. Here is a python notebook colab I developed, for example, to share the details of the Riemann Hypothesis with my colleagues at Google and in the larger community.

I am not a traditional applicant for the program in that I lead two research groups at Google X (AI and Quantum Computing). Nevertheless, I hope to be included in the program as I would like to ramp up my knowledge of category theory as well as contribute to the group.

I have recently written a 300-page graduate-level textbook on quantum computing; the book was commissioned by Springer. They will publish it ~June of this year (detailed TOC attached; I can show the full draft if needed online over a video chat). I wrote the book not only for physicists, but for mathematicians and researchers in other fields who want to learn more about quantum computing.

I also develop mathematics courses and teach higher mathematics at our internal university at Google, engEDU. I enjoy writing these courses and teaching these subjects even though it is not part of the remit of my role, since it spreads the use of mathematics across the company.

Category theory is a very useful framework and I hope to be part of the program to contribute to this important field.

Sending this in at 11:40pm pacific time January 30th. Attached are the requested items.

Jack

Jack Hidary
AI@X & Quantum@X
Alphabet X Labs
new colab on Riemann

2 attachments

QuantumComputingBookTOC.pdf
94K

ACT2019 - Hidary1.pdf
119K

Quantum Computing: A Practical Approach

first edition
26 January 2019

Jack D. Hidary

Contents

Preface **xiii**

Acknowledgements **xvii**

Navigating this Book **xix**

I Theory

1 ***Introduction*** **3**

2 ***A Brief History of Quantum Computing*** **11**

3 ***Qubits and Unitary Operators*** **19**

3.1 Quantum Operators **21**

Unary Operators **22**

Binary Operators **25**

Ternary Operators **27**

3.2 Comparison with Classical Gates **28**

3.3 Universality of Quantum Operators **29**

3.4 The Bloch Sphere **30**

4 ***Measurement and Quantum Circuits*** **33**

5 ***Complexity Theory*** **39**

II Hardware and Applications

6 ***Building a Quantum Computer*** **47**

6.1 Assessing a Quantum Computer **48**

6.2 Neutral Atom **49**

6.3 NV Diamond **51**

6.4 Photonics **52**

6.5 Quantum Annealers **56**

6.6 Spin Qubits **56**

6.7 Superconducting Qubits **57**

6.8 Topological Quantum Computation **58**

6.9 Trapped Ion **59**

7 ***Dev Libraries for QC Programming*** **61**

8 ***The Canon: Code Walkthroughs*** **65**

8.1 The Deutsch-Jozsa Algorithm **66**

8.2 The Bernstein-Vazirani Algorithm **73**

8.3 Bell Inequality Test **76**

8.4 Shor's Algorithm **81**

Introduction to RSA cryptography **81**

The Period of a Function **82**

Period of a Function as an Input to a Factorization Algorithm **83**

8.5 Grover's Search Algorithm **95**

9 ***Quantum Teleportation and Superdense Coding*** **101**

9.1 Quantum Teleportation **101**

9.2 Holevo's bound **103**

9.3 Superdense Coding **104**

10 ***Real-World Applications*** **119**

10.1 Variational Quantum Eigensolver **119**

10.2 Quantum Chemistry **125**

10.3 Quantum Fourier Transform **126**

10.4 Quantum Approximation Optimization Algorithm (QAOA) **128**

10.5 Machine Learning on Quantum Processors **131**

10.6 Quantum Walk **131**

11 ***Quantum Computing — The Future*** **137**

III Toolkit

12 ***Mathematical Tools for Quantum Computing*** **141**

12.1 Introduction and Self-Test **141**

12.2 Basic Linear Algebra **143**

Vectors and Notation **144**

Basic Vector Operations **146**

The Norm of a Vector **150**

The Dot Product **153**

12.3 The Complex Numbers and The Inner Product **155**

Complex Numbers **155**

The Inner Product as a Refinement of the Dot Product **157**

The Polar Coordinate Representation of a Complex Number **161**

12.4 A First Look at Matrices **170**

Basic Matrix Operations **170**

The Identity Matrix **178**

Transpose, Conjugate, and Trace **179**

12.5 The Outer Product and The Tensor Product **186**

The Outer Product as a Way of Building Matrices **186**

The Tensor Product **188**

12.6 Supporting Set Theory **191**
The Basics of Set Theory **191**
The Cartesian Product **194**
Relations and Functions **195**
Important Properties of Functions **201**
12.7 The Definition of a Linear Transformation **206**
12.8 How to Build a Vector Space (from scratch) **209**
Groups **209**
Fields **216**
The Definition of a Vector Space **222**
Subspaces **225**
12.9 Span, Linear Independence, Bases, and Dimension **226**
Span **227**
Linear Independence **229**
Bases and Dimension **231**
Orthonormal Bases **234**
12.10 Linear Transformations as Matrices **235**
12.11 Matrices as Operators **241**
An Introduction to the Determinant **241**
The Geometry of the Determinant **245**
Matrix Inversion **246**
12.12 Eigenstuff: Eigenvectors and Eigenvalues **254**
Change of Basis **257**
12.13 Further Investigation of Inner Products **259**
The Kronecker Delta Function as an Inner Product **262**
12.14 Hermitian Operators **263**
Why We Can't Measure with Complex Numbers **263**
Hermitian Operators have Real Eigenvalues **264**
12.15 Unitary Operators **265**
12.16 The Direct Sum and The Tensor Product **266**
The Direct Sum **267**

The Tensor Product **269**

12.17 Hilbert Space **273**

Metrics, Cauchy Sequences, and Completeness **273**
An Axiomatic Definition of The Inner Product **277**
The Definition of Hilbert Space **278**

12.18 The Qubit as a Hilbert Space **279**

13 ***Additional Mathematical Tools*** **283**

13.1 Boolean Functions **283**

13.2 Logarithms and Exponentials **284**

13.3 Euler's Formula **286**

14 ***Table of Quantum Operators and Core Circuits*** **289**

Works Cited **291**

Jack Hidary - Application to ACT2019 hidary@google.com

Hi,

Here is the requested info for the application to ACT 2019:

1. I serve as the lead of quantum computing research and programs and co-lead of AI research and programs at Alphabet (Google) X.
2. CV: https://www.linkedin.com/in/jackhidary/
3. Recent publications: Google Scholar page
4. I can commit to attending the Oxford program for both weeks (the school and the conference). I will not require any support to attend.

Statement on why the program and projects would match well with my research interests

The projects that I would look forward to working on are:

1. ## Pieter Hofstra

   Title: *Complexity classes, computation, and Turing categories*

   In my work on quantum computing, I have been focused on BQP and which algorithms can be assigned to this complexity class. As we build quantum computers over the next decade that go beyond the NISQ regime and approach the fault-tolerant-regime, this becomes more than just a theoretical question.

   Chapter five of my forthcoming textbook on Quantum Computing focuses on complexity classes and how we think about them in this context. I would be very interested to work with Pieter and the group on these issues.

   PS - my hobby is going through the complexity zoo website.

2. ## Miriam Backens

   Title: *Simplifying quantum circuits using the ZX-calculus*

   Also of great interest is the work that Miriam Backens has done on the ZX-calculus building on the work of Coecke and Duncan.

   This framework can be a powerful tool to both analyze, construct and simplify quantum circuits. I am also interested in connecting this line of inquiry with our work on tensor networks. In my group we collaborate with a range of labs that develop quantum computing hardware; each hardware realization has different constraints and parameters that dictate the kinds of quantum circuits one can build and run; this project provide additional tools in the theoretical framework for quantum circuit design and understanding.

My comments on the two groups of interest delineate why I believe this program will be very beneficial for my research. I also hope that I can contribute a useful and different perspective in that my group and I have been immersed at the forefront of quantum algo design and development and the implications for complexity class analysis.

Note: could use some advice on what to do about the recommendation letter. The faculty I work with are visiting faculty in my group that I lead and thus would be inappropriate to ask for a letter of recommendation (Lenny Susskind, Patrick Hayden and others...). If needed, the school could contact the head of mathematics at Springer who knows my work, as a reference.

In summary, I hope to join ACT2019 to both learn more about category theory, contribute to the group and attend the school and conference at Oxford.

Please email me at hidary@google.com with any questions.