tom denton, phd.

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Synopsis.

I work in the intersection of mathematics and computer science, building new algorithms and data structures to explore vast combinatorial structures in search of new theorems. As a researcher in mathematics, I've published scholarly articles and independently guided large projects to completion.

My research specialty is in algebraic combinatorics, which means that I am an expert with permutations, combinations, and representation theory. Representation theory has a long history of important applications in statistics; my current interest is in applying representation theory in machine learning problems.

On the software side, I am a contributor to the Sage computer algebra system, and also develop software independently for research, web publishing, and fun. I have familiarity with a full LAMP stack, including Django and ZeroMq.

As an educator, I've worked with e-learning and outreach as a Fulbright scholar in Kenya. While in Kenya, I co-founded a new technology hub and the first math camps for secondary students in Kenya and Ethiopia. The common thread in this work was showing people how to use cutting-edge mathematics to help in solving their problems.

Specialities:
Experimental Mathematics, Scholarly Research, Problem Solving, Combinatorics, Communicating Science, Python, Algorithms, and Software Development.

Grants and Fundraising

Fulbright Scholarship
E-learning and mathematics outreach, 2012-13.

US State Department Cultural Grant
2012 Maseno Math Camp, $10,000.
Supported over 100 students for the camp.

UC Davis Domes
Raised over $20,000 for preservation of the Davis Domes and was a lead coordinator for a two-year campaign to keep the Domes open.

VIGRE Summer Research Fellowship
University of California, Davis

Education and Work Overview.

The Fields Institute and York University
Joint Appointment, 2011-Present.
Postdoctoral Researcher in Mathematics
Faculty Mentors:
Nantel Bergeron and Mike Zabrocki

Fulbright Scholar, Maseno University, Kenya
US State Department, 2012-2013.
Researcher and project developer for mathematics e-learning and outreach.

University of California, Davis
Graduate student, 2006-2011
Thesis Advisors:
Prof. Anne Schilling and Prof. Nicolas Thiéry
Dissertation Title:
Excursions in Algebra and Combinatorics at q=0.
PhD accepted June, 2011.

Université Paris-Sud
Visiting Scholar, Spring 2010

University of Oregon
BSc Cum Laude, Awarded June, 2006

Teaching and Workshops.

Fields Institute and York University
Coordinator, Fields Algebraic Combinatorics Seminar
Math for Life and Social Sciences, 2013-14
Linear Algebra with Applications II, 2012

Mombasa Algebraic Geometry Workshop
University of Nairobi, 2013.
Two weeks on Sage and introductory Grobner bases.

African Institute of Mathematics
South Africa, January 2013, guest lecturer.
Three week course on problem solving with Sage.

Maseno University
Foundations of Pure Mathematics
Algebraic Structures

Strathmore University
Nairobi, Kenya, 2012-13
Faculty development workshop on e-learning.
One-week workshop on algebra and geometry.

University of California, Davis
Three calculus courses, 2009-11

Major Activities

Research mathematics can be roughly divided into two activities: Theory-building and problem-solving. Theory builders take existing tools and build large frameworks for finding the full extent of our understanding, while problem solvers explore the fringes of what is known, developing new tools to expand our space of possibilities. Overall progress in mathematics requires both of these activities, innovation and consolidation of knowledge.

I am a rather unabashed **problem-solver**.

My approach to research is to find hard, interesting problems, and employ computer exploration to develop new tools and find new solutions.

This approach has enabled the discovery of new formulas for multiplying k-Schur functions, finding idempotents in monoid algebras, and, recently, to new ways of counting rational lattice paths. My approach allows progress in areas where traditional combinatorial tools fail almost entirely.

Lately I have been interested in how we can automate the process of searching for patterns in large bodies of combinatorial data. I am investigating the use of Fourier transforms on groups as a method of 'cleaning' group-like data, as well as using machine learning tools to estimate solutions to combinatorial problems.

Selected Publications

Algebraic and Affine Pattern Avoidance.
Seminaire Lotharingien de Combinatoire,
B69c (2013), 40 pp.

Affine Permutations and an Affine Catalan Monoid.
To appear, proceedings of "Workshop on Group Embeddings and Algebraic Monoids."

Canonical Decompositions of Affine Permutations, Affine Codes, and Split k-Schur Functions.
Electronic Journal of Combinatorics,
Vol 19, Issue 4, 2012, P19, arxiv: 1204.2591

A Combinatorial Formula for Idempotents in the 0-Hecke Algebra of the Symmetric Group.
Electronic Journal of Combinatorics,
vol 18, Feb 2011, arxiv: 1008.2401.

Representation Theory of J-Trivial Monoids.
with Florent Hivert, Anne Schilling, Nicolas Thi\'ery.
Seminaire Lotharingien de Combinatoire,
B64d (2011), 44p, arxiv: 1010.3455

Linear Algebra in Twenty-Five Lectures.
Free textbook developed with Andrew Waldron.
http://math.ucdavis.edu/~linear

I have been a contributor to **Sage**, a massive open-source computer algebra system, for about five years. I develop code constantly for my own research projects, and occasionally integrate code back into Sage. Recently, I contributed a large package for affine permutations. This work led to much faster computation of non-commutative k-Schur functions, but is useful for a range of researchers.

I have given numerous **demos and talks** on using Sage for experimental mathematics, including a short course at AIMS, South Africa, a course on Grobner bases at an algebraic geometry workshop in Mombasa, Kenya, and an introduction to Sage talk at the FPSAC 2013 conference in Paris.

I have strong foundations in **web technologies**. Last year, I developed online notes for a course in algebraic structures using Django. In addition to basic database set-up, this project also involved extending MarkDown to include special boxes for theorems, as well as a good helping of jQuery to make the site responsive for people accessing the site from their phones. Lately I've also been building a Django-based interface for a Raspberry Pi camera project.

http://garsia.math.yorku.ca/~sdenton/algstruct

Communicating science is an essential part of being a scientist. I have worked extensively on making math and science accessible for the general public, through math camps in Kenya and Ethiopia, seminars on math for computer scientists at LakeHub, teaching robotics with the COSMOS outreach program, and writing a blog at inventingsituations.net about math, hacking, and my experiences as a scientist in rural Africa.

I believe strongly in the importance of creative communities in fostering innovation.

While working in Wesern Kenya, I co-founded **LakeHub**, a new technology hub in Kenya's third-largest city, Kisumu. Technology hubs in Africa provide informal educational spaces for developers, networking opportunities, and spaces for business incubation. Lakehub is the first African technology hub outside of a capital city, and thus provides a platform for developing new technlogical solutions in rural Kenya, where 80% of Kenyans live.

Selected Projects: 2013-14

PiLapse, 2013-14

A timelapse camera built with a Raspberry Pi and Legos. While working in Kenya, I piloted the use of Raspberry Pis for teaching programming in rural areas; on returning to Canada, I was eager to actually build something. The camera has been used for documenting a local farmer's market, and in late December a camera was placed on Lake Huron for a six-month shot.

The camera uses an online gradient descent algorithm to maintain a near-constant image brightness over a long period of time. More recently, I've been using a pair of cameras connected by ZeroMQ to enable panoramic or 3D timelapses. I am also collaborating with John Mardlin of CoinForest on a web interface for previewing and easily setting the parameters of a shot.

Sample Video:
http://www.youtube.com/watch?v=fz6PFiHOPaw

Blog Posts:
http://inventingsituations.net/category/pilapse/

GitHub Repository:
https://github.com/sdenton4/pipic

RoShamBot, 2014

Rock paper scissors (RPS) is a well-known game used for various kinds of decision-making. The optimal strategy against an optimal opponent is to play uniformly at random. But often we play against humans; therefore we can improve our chances by finding and exploiting patterns in the ways that people play.

This project was a proof-of-concept for using methods from statistical group theory for machine learning. The RoShamBot analyzes thousands of distinct move combinations in an iterated RPS game. Identifying past actions as elements of a product of cyclic groups, it then applies a Fourier transform on the appropriate finite group to measure distance from the opponent's moves to the uniform distribution. In other words, it uses group theory to find and exploit patterns of play.

An additional bot uses a database of over 200,000 human games and Bayesian inference to model human play.

Blog posts:
http://inventingsituations.net/tag/rps/

East African Math Camps, 2011-14

In 2011 I co-organized the launch of the first math camp for secondary students in East Africa, with Zach Mbasu, David Stern, and others at Maseno University. The week-long camp hosts students and secondary teachers from all over Kenya, and is executed by a Maseno graduate students, professors, and innovative secondary math teachers from the UK. I've personally developed sessions on the mathematics of games, research methods, algorithm design, hash functions, and more.

As of 2014, we have run the Maseno camp three times, along with numerous one-day "mini-math camps" at secondary schools around Kenya. In July 2013, we piloted a week-long camp at Bahir Dar University in Ethiopia, and we expect future camps to be held in Ghana, Uganda, and Cameroon.

The goal of the camp is to bring modern mathematics to schools, and to demonstrate that math is a creative art with great relevance to the world, not just an exercise in rote learning.

Video and Website:
www.youtube.com/watch?v=pLQpuAR8quw
http://www.africanmathsinitiative.net/mmc/

Affine Permutations, 2012-13

Affine permutations are special permutations of the full collection of integers, subject to certain periodicity constraints. They arise whenever you have finite mixing process occuring regularly over time, for example in a juggling pattern or a braid. Like the usual permutations, they have a group structure. They can also be realized as the Weyl group of affine type A_n.

While working on multiplying k-Schur functions in 2012, I developed an extensive library for working with affine permutations in the Sage computer algebra system. After finishing the research paper, I expanded the code to other Weyl types and integrated the code into Sage.

As a major open-source software project, integrating code into Sage requires rigorous adherence to a style guide, fully documented code with unit tests and usage examples, and must pass a peer-review process.

Documentation:
http://www.sagemath.org/doc/reference/combinat/sage/combinat/affine_permutation.html