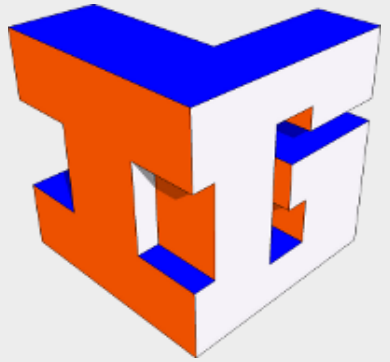


The Illinois Geometry Lab

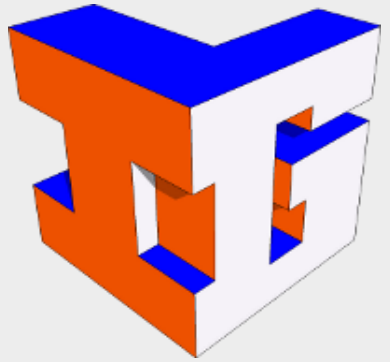
Fostering a culture of undergraduate research and community engagement in mathematics departments

Jeremy Tyson (Director, IGL, 2015-)

University of Illinois at Urbana-Champaign

March 6, 2018

MIT Electronic Mathematics Education Seminar



The Illinois Geometry Lab

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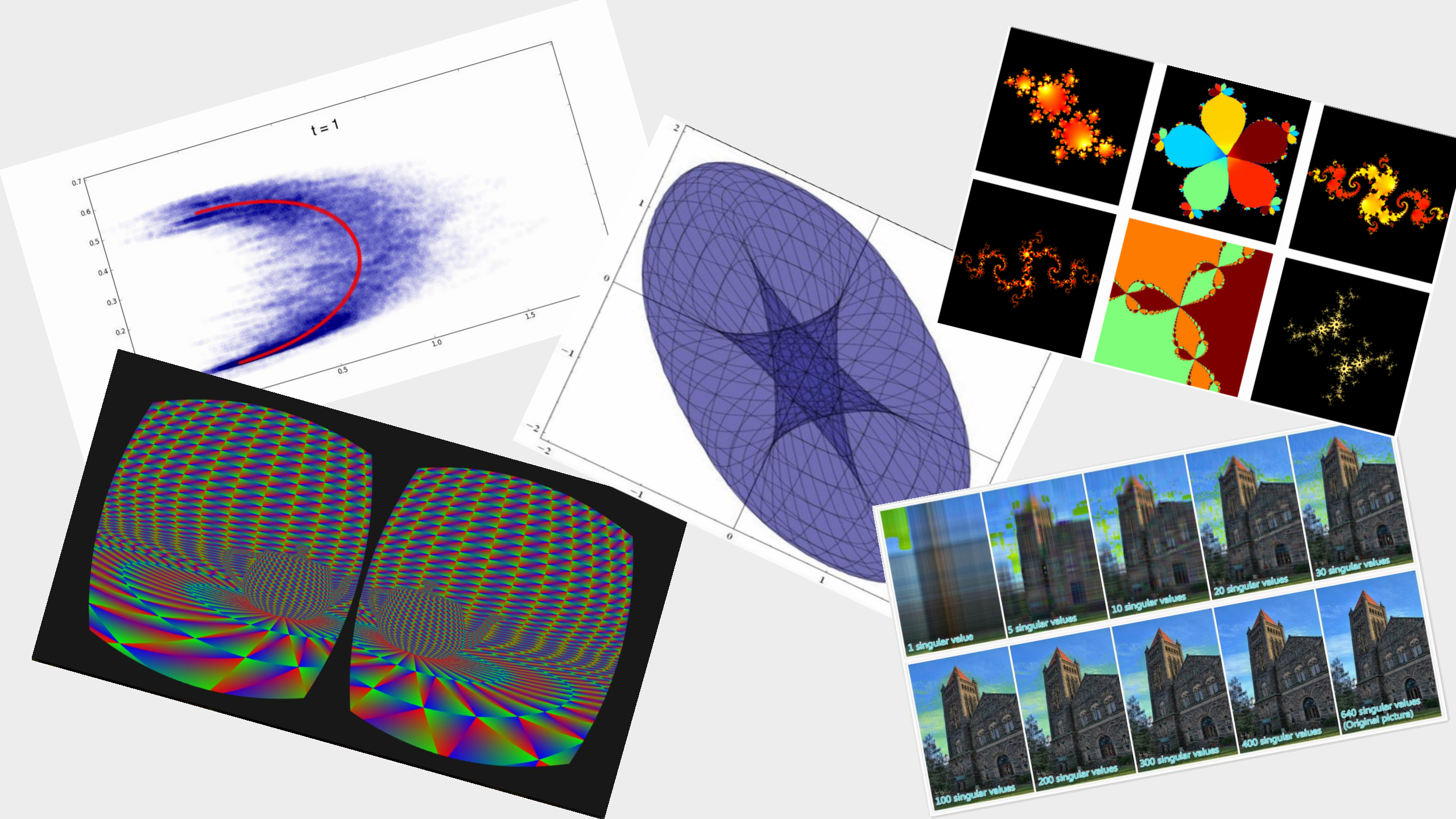
Jeremy Tyson (~~Director IGL, 2015-2017~~; Interim Department Chair, 2018-)

University of Illinois at Urbana-Champaign

March 6, 2018

MIT Electronic Mathematics Education Seminar


ILLINOIS GEOMETRY LAB
Department of Mathematics, University of Illinois at Urbana-Champaign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200 singular values
300 singular values
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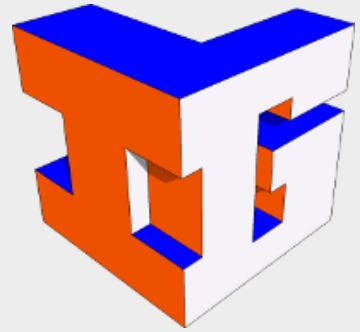
(Original picture)


Science at the Market:
Locally Grown
Cracked
GAP
GEMS 2015
Sonia Math Day for Girls:
Counting and Coloring

IGL Mission Statement



- Involve undergraduate students in genuine, contemporary research experiences in the mathematical sciences
- Provide mentoring experience and training for graduate students / postdocs / early career faculty
- Increase the visibility of mathematics within our communities

PCAST 2012 Report to the President

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Recommendation 2.

"Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.

Research courses can act as training for subsequent participation in research in faculty or industry laboratories, improving the skills that students bring to those positions.

Independent research on faculty projects is a direct way for students to experience real discovery and innovation and to be inspired by STEM subjects."

SIAM 2012 Report on Mathematics in Industry

Section 5.2 Graduate Education

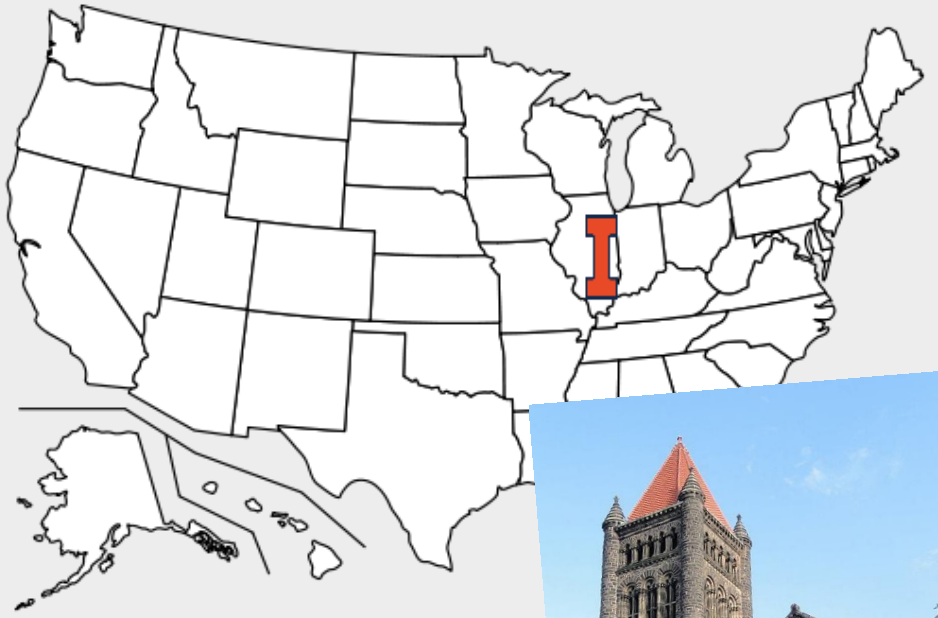
"Additional skills and experiences needed in industry

- **Exposure to a relevant application and real-world problem solving**
- **Expertise in programming**
- **High-Performance computing**
- **Communication and teamwork**

The ability to listen to and learn from other team members is just as important as the ability to generate your own ideas. You need leadership and presentation skills to get your ideas across, a strategic sense of the team's goals, and the drive, discipline, and energy to meet project deadlines."

ILLINOIS

- R1 large public university
- #52 U S News ranking of US universities
  (#14 among publics)
- 33K undergraduate students



Department of Mathematics

- #17 U S News ranking of graduate programs
- 66 faculty
- 200 graduate students
- 1200 math majors

IGL research model vs traditional REU model

IGL research model vs traditional REU model

Standard REU model

- Summer residential program
- Competitive application process
- Small number of participants, typically from other institutions
- Participants receive funding for travel, lodging
- Often NSF funded

IGL research model vs traditional REU model

Standard REU model

- Summer residential program
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- Small number of participants, typically from other institutions
- Participants receive funding for travel, lodging
- Often NSF funded

IGL model

- In-semester program
- Competitive application process
- Eligibility restricted to Illinois students
- Number of student participants limited only by number of projects
- Undergraduate students are unfunded; receive course credit
- Graduate student and faculty participants also unfunded

Structure of a typical IGL project

One or more faculty mentors

1-2 graduate students (project supervisors)

3 or more undergraduate students
(team members)

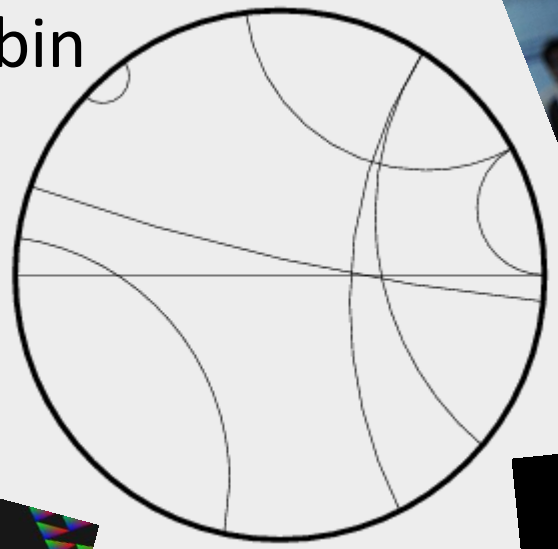
Timeline of an IGL semester

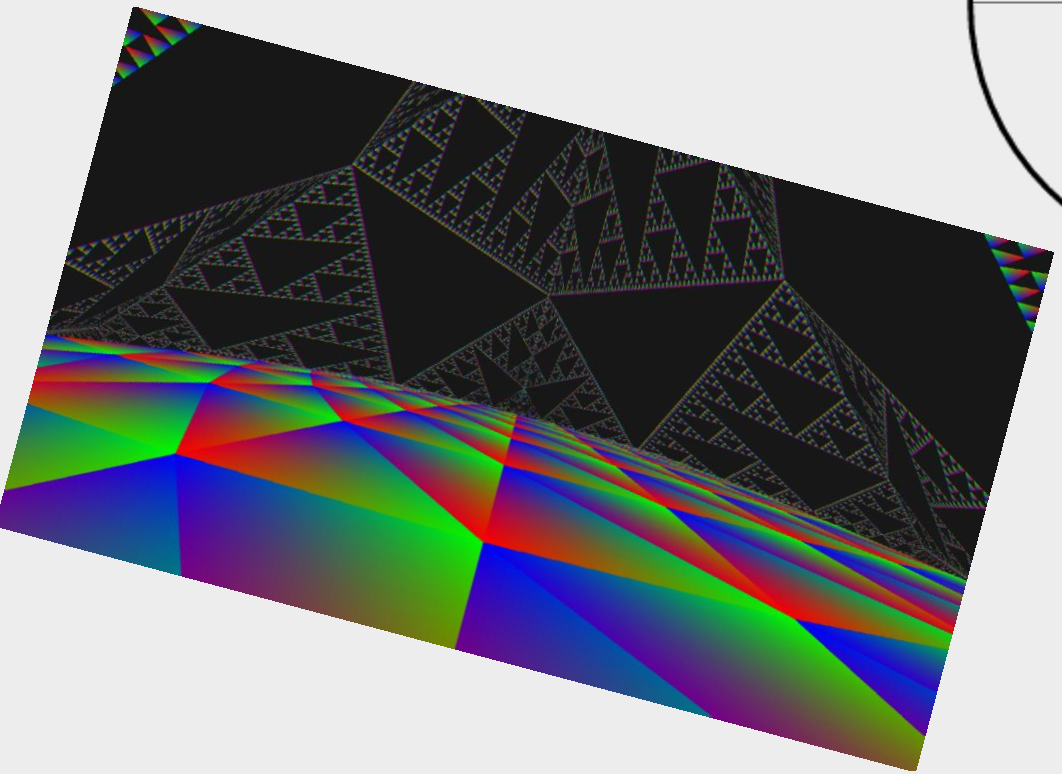
- Application window open from approx week 10 of prior semester until one week before start of current semester
- Staffing decisions made immediately prior to start of semester
- Week 1 / 2: Kickoff meeting, Research Plan due
- Week 7: Mid-semester meeting (5 minute progress reports by group)
- Week 13: Brochure material due
- Week 15: Brochures printed, end-of-semester poster session

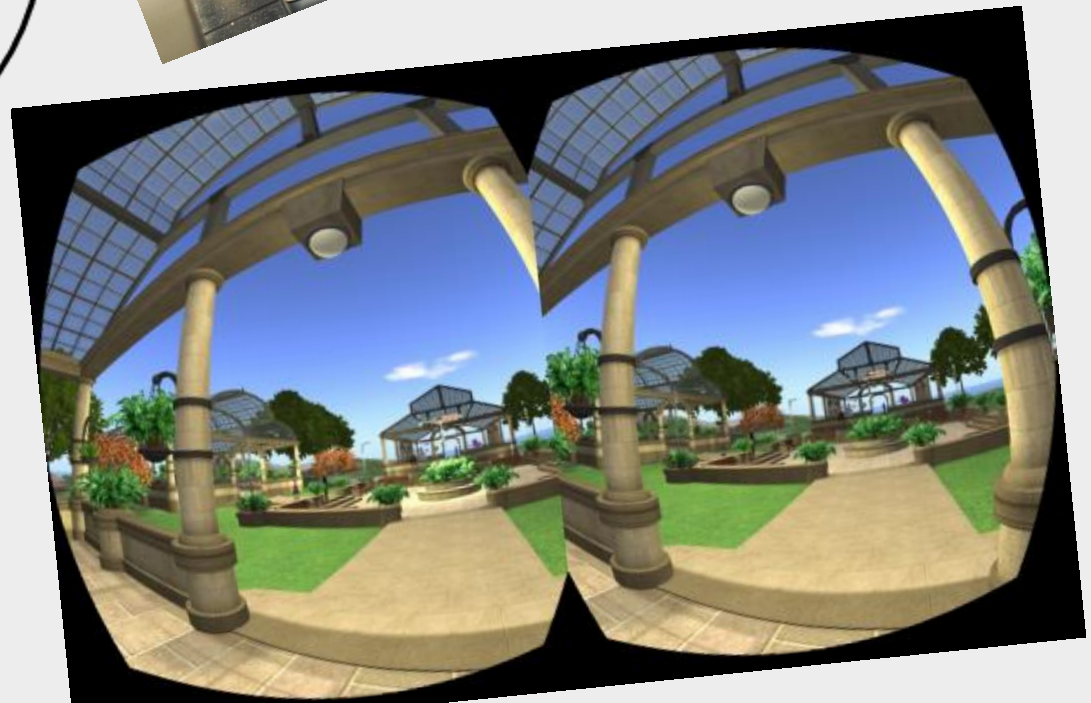

GEAR

Hyperbolic space on the Oculus Rift (Fall 2014)

Faculty mentor: Pierre Albin

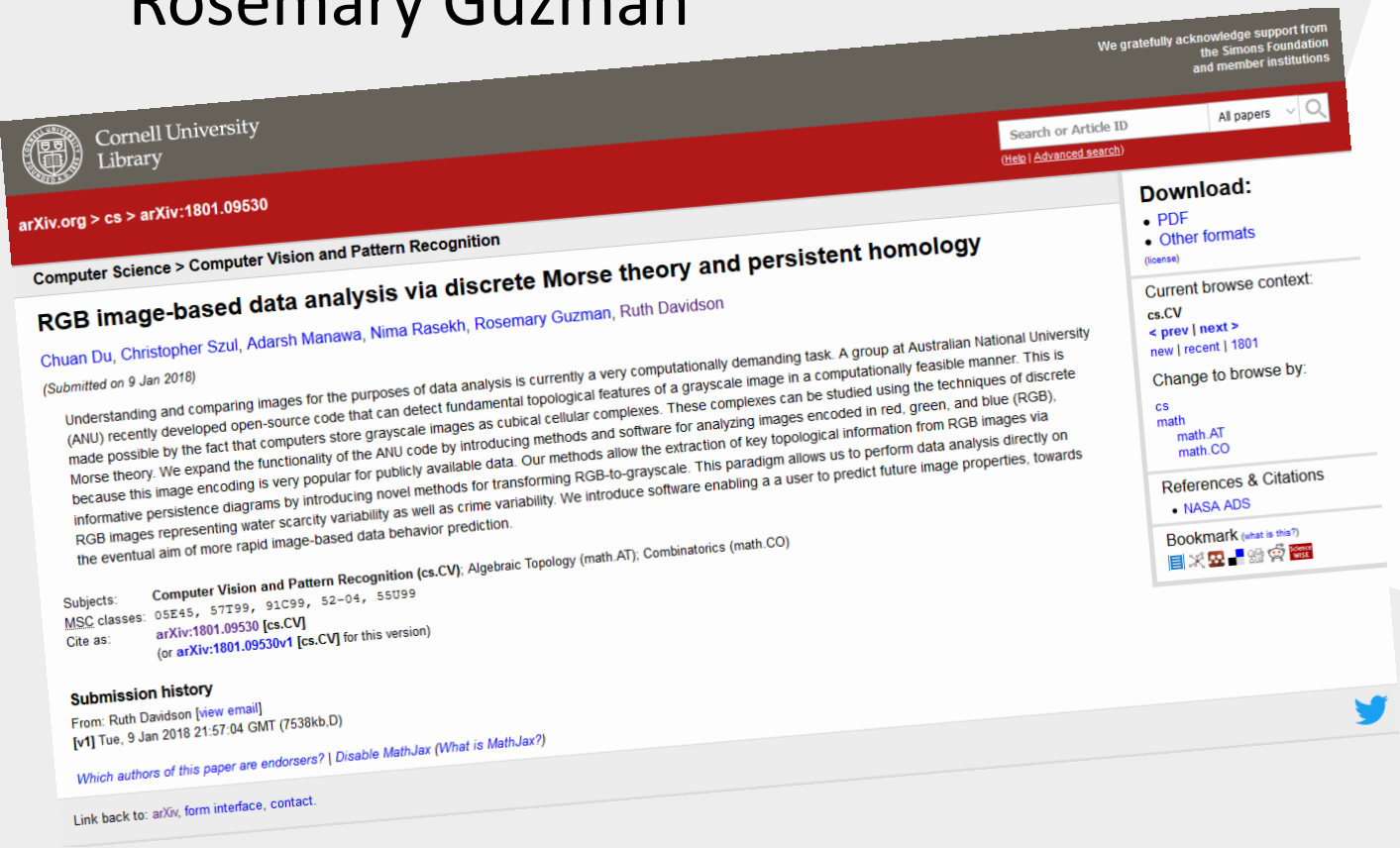






Discrete Morse theory, vector fields, and materials science (Spring 2016 / Fall 2016)

Faculty mentors: Ruth Davidson and Rosemary Guzman



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arXiv.org > cs > arXiv:1801.09530

Computer Science > Computer Vision and Pattern Recognition

RGB image-based data analysis via discrete Morse theory and persistent homology

Chuan Du, Christopher Szul, Adarsh Manawa, Nima Rasekh, Rosemary Guzman, Ruth Davidson

(Submitted on 9 Jan 2018)

Understanding and comparing images for the purposes of data analysis is currently a very computationally demanding task. A group at Australian National University (ANU) recently developed open-source code that can detect fundamental topological features of a grayscale image in a computationally feasible manner. This is made possible by the fact that computers store grayscale images as cubical cellular complexes. These complexes can be studied using the techniques of discrete Morse theory. We expand the functionality of the ANU code by introducing methods and software for analyzing images encoded in red, green, and blue (RGB), because this image encoding is very popular for publicly available data. Our methods allow the extraction of key topological information from RGB images via informative persistence diagrams by introducing novel methods for transforming RGB-to-grayscale. This paradigm allows us to perform data analysis directly on RGB images representing water scarcity variability as well as crime variability. We introduce software enabling a a user to predict future image properties, towards the eventual aim of more rapid image-based data behavior prediction.

Subjects: **Computer Vision and Pattern Recognition (cs.CV)**; Algebraic Topology (math.AT); Combinatorics (math.CO)
MSC classes: 05E45, 57T99, 91C99, 52-04, 55U99
Cite as: arXiv:1801.09530 [cs.CV]
(or arXiv:1801.09530v1 [cs.CV] for this version)

Submission history
From: Ruth Davidson [view email]
[v1] Tue, 9 Jan 2018 21:57:04 GMT (7538kb,D)

Which authors of this paper are endorsers? | Disable MathJax (What is MathJax?)

Link back to: arXiv, form interface, contact.

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References & Citations
- NASA ADS

Bookmark (what is this?)

Discrete Morse Theory, Vector Fields, and Materials Science

Faculty Mentors: Dr. Ruth Davidson, Dr. Rosemary Guzman

Team Leader: Nima Rasekh

Scholars: Chuan Du, Adarsh Manawa, Christopher Szul, Titan Wibowo

A key task of of data science is the ability to analyze big collections of data with the goal of understanding its behavior and possibly predicting patterns. Yet this type of inquiry traditionally requires a lot of experimental data, time, and financial resources. Discrete Morse Theory provides a toolkit for studying key qualitative properties of shapes. A team of Australian scientists has successfully applied this toolkit in order to extract information about digital images. We have adapted their ideas for use in the comparison of heat maps of certain data sets. Concretely, we applied these techniques to analyze water scarcity maps of certain countries (Kazakhstan) and are using it to predict water levels for the coming years.

(a) World Water Risk Variability

(b) Kazakhstan Water Risk Variability

Figure 1: Open-Source Images obtained from the Aqueduct Water Risk Analysis Atlas at http://bit.ly/2fEoU7Q

(a) Discrete Vector Field: Cell Complex

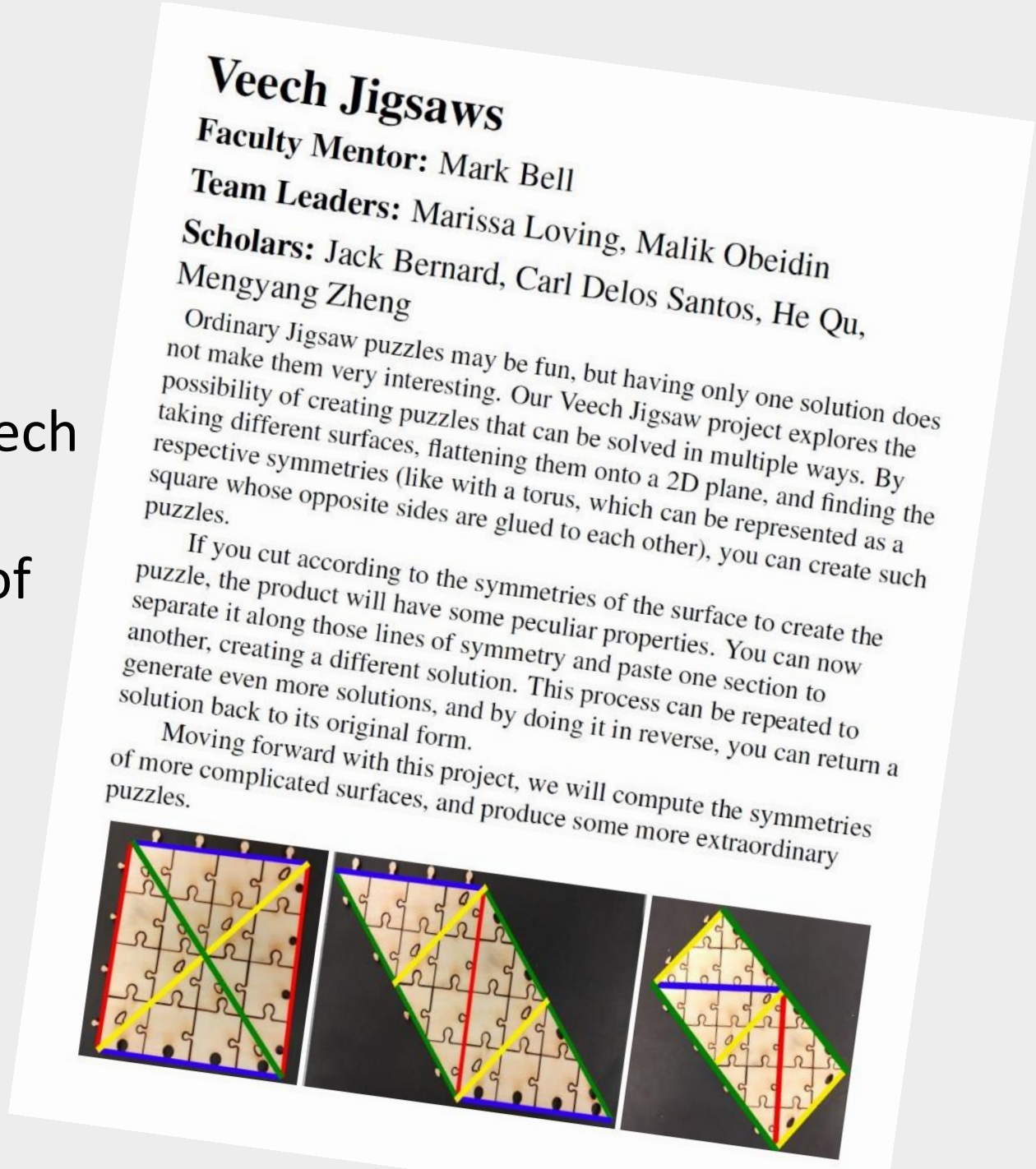
(b) Underlying Topology

Figure 2: Topological Image Compression via Discrete Morse Theory

Veech Jigsaws (Spring 2017)

Faculty mentor: Mark Bell

- Investigate a class of highly symmetric translation surfaces studied by Veech
- Compute symmetries and generators of the corresponding affine group
- Generate corresponding jigsaw puzzles in Python
- Laser cut final puzzles



Veech Jigsaws

Faculty Mentor: Mark Bell

Team Leaders: Marissa Loving, Malik Obeidin

Scholars: Jack Bernard, Carl Delos Santos, He Qu, Mengyang Zheng

Ordinary Jigsaw puzzles may be fun, but having only one solution does not make them very interesting. Our Veech Jigsaw project explores the possibility of creating puzzles that can be solved in multiple ways. By taking different surfaces, flattening them onto a 2D plane, and finding the respective symmetries (like with a torus, which can be represented as a square whose opposite sides are glued to each other), you can create such puzzles.

If you cut according to the symmetries of the surface to create the puzzle, the product will have some peculiar properties. You can now separate it along those lines of symmetry and paste one section to another, creating a different solution. This process can be repeated to generate even more solutions, and by doing it in reverse, you can return a solution back to its original form.

Moving forward with this project, we will compute the symmetries of more complicated surfaces, and produce some more extraordinary puzzles.

Video as a Sensor (Spring 2017 – Fall 2017 – Spring 2018)

Faculty mentors:

Professor Rich Sowers (Math and Industrial and Systems Engineering)

Professor Daniel Work (Civil and Environmental Engineering)

Recent initiatives

Recent initiatives

- IGL Research Award – awarded to one or more IGL projects in a given calendar year which best exemplify the IGL mission

Recent initiatives

- IGL Research Award
- IGL Seminar series – one speaker per semester, visits Illinois to give a research seminar/colloquium as well as an “IGL seminar” for undergrads

DEPARTMENT OF MATHEMATICS

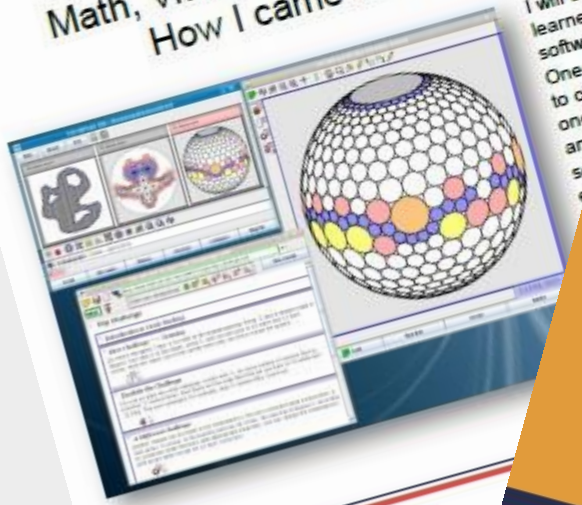
IGL SEMINAR

UNIVERSITY OF ILLINOIS AT URBANA–CHAMPAIGN

Ken Stephenson

University of Tennessee

Math, Visualization, and Experimentatio
How I came to love computing



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4:00 p.m., 245 Altgeld Hall
Friday, February 16, 2018

Department of Mathematics, University of Illinois at Urbana-Champaign

mathematics
IN SCIENCE & SOCIETY

Clayton Shonk

Colorado State University

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that the more basic questi
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Carroll's question

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4:00 p.m.

This lectu
Department of Mathematics

Department of Mathematics

Co-sponsored by the Illinois Geometry Lab and
the Association for Women in Mathematics

Special Undergraduate Seminar

Loredana Lanzani

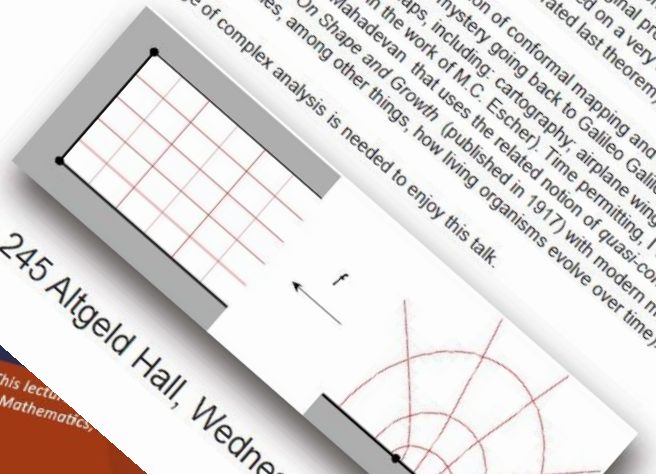
Syracuse University

Practical Uses of Complex Analysis

The notion of conformal mapping is of fundamental importance in complex analysis. Conformal maps are used by mathematicians, physicists and engineers to change regions with complicated shapes into much simpler ones, and to do so in a way that preserves shape on a small scale (that is, when viewed up close). This makes it possible to 'transpose' a problem that was formulated for the complicated-looking region into another, related problem for the simpler region (where it can be easily solved)—then one uses conformal mapping to "translate" the solution of the problem over the simpler region, back to a solution of the original problem (over the complicated region). The beauty of conformal mapping is that its governing principle is based on a very simple idea that is easy to explain and to understand (much like the statement of Fermat's celebrated last theorem).

In the first part of this talk I will introduce the notion of conformal mapping and will briefly go over its basic properties and some of its history (including a historical mystery going back to Galileo Galilei). I will then describe some of the many real-life applications of conformal maps, including: cartography; airplane wing design (transonic flow); art (in particular, the so-called 'Droste effect' in the work of M.C. Escher). Time permitting, I will conclude by highlighting a 2013 paper by MacArthur fellow L. Mahadevan that uses the related notion of *quasi-conformal mapping* to link D'Arcy Thompson's iconic work *On Shape and Growth* (published in 1917) with modern morphometric analysis (a discipline in biology that studies, among other things, how living organisms evolve over time).

No previous knowledge of complex analysis is needed to enjoy this talk.



3 pm, 245 Altgeld Hall, Wedne

Recent initiatives

- IGL Research Award
- IGL Seminar series
- Programming Workshop (“IGL Computational Bootcamp”) – two week evening workshop for first-time IGL students focused on basics of programming in the context of mathematical research

Recent initiatives

- IGL Research Award
- IGL Seminar series
- Programming Workshop (“IGL Computational Bootcamp”)
- IGL-Merit partnership – pipeline from *Merit Program for Emerging Scholars* to IGL, targeted research-type activities in first- and second-year calculus courses

Recent initiatives

- IGL Research Award
- IGL Seminar series
- Programming Workshop (“IGL Computational Bootcamp”)
- IGL-Merit partnership
- Morisato IGL Research Scholarship – competitive scholarship program for IGL graduate student mentors, provides six weeks of summer funding to pursue PhD thesis research

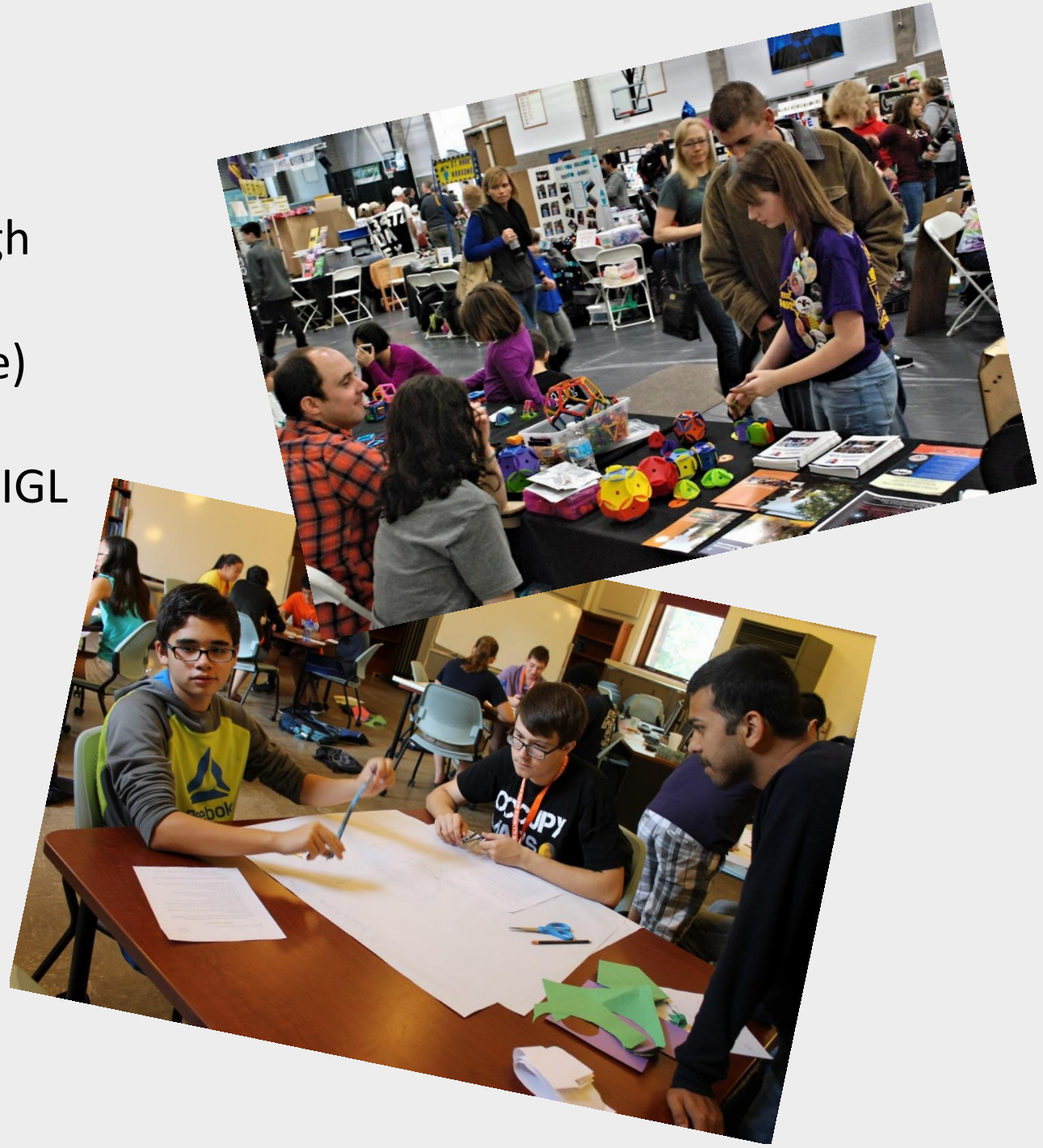
Outreach Activities

- Saturday workshops for middle and high school students, e.g. Sonia Math Days, GEMS (Girls Engaged in Math and Science)

- K-12 class visits to Altgeld Hall and the IGL

- Activity tables at local events

- Summer Illinois Math camp



Outreach Activities

- MoSAIC, Fall 2014

MoSAIC
Mathematics of Science, Art, Industry, Culture

University of Illinois presents

A Festival of Math & Art

FREE and open to the public

Come experience the beauty and excitement of math and art!

University of Illinois, 1409 W Green St., Urbana, IL
Friday, Nov 21, 2014, 10-8:30 pm
Saturday, Nov. 22, 2014, 9:30 am-6 pm

Fun Activities

- Hands-on Workshops
- Engaging Talks
- Math Art Exhibit
- Short Films
- Informal Exchange

Notable Presenters

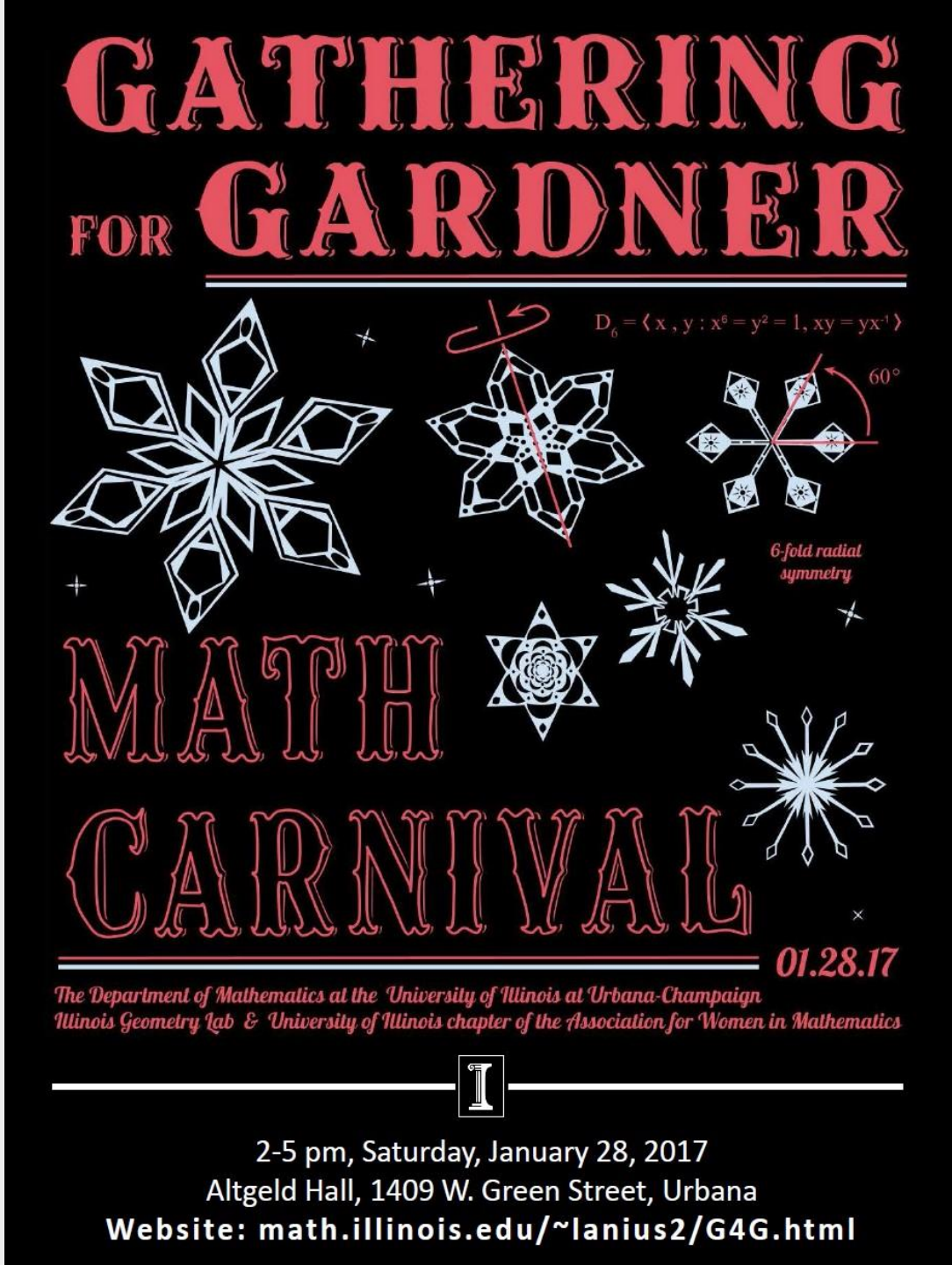
- Bob Bosch, natural science professor
- Christopher Carlson, Wolfram Research interface designer
- Judy Holdener, math professor
- Reza Sarhangi, math professor
- and more!

For more information, visit
www.mosaicmathart.org/events/illinois_urbana

Sponsored by: MSRI Mathematical Sciences Research Institute · The Bridges Organization · SIMONS FOUNDATION · JOHN DEERE

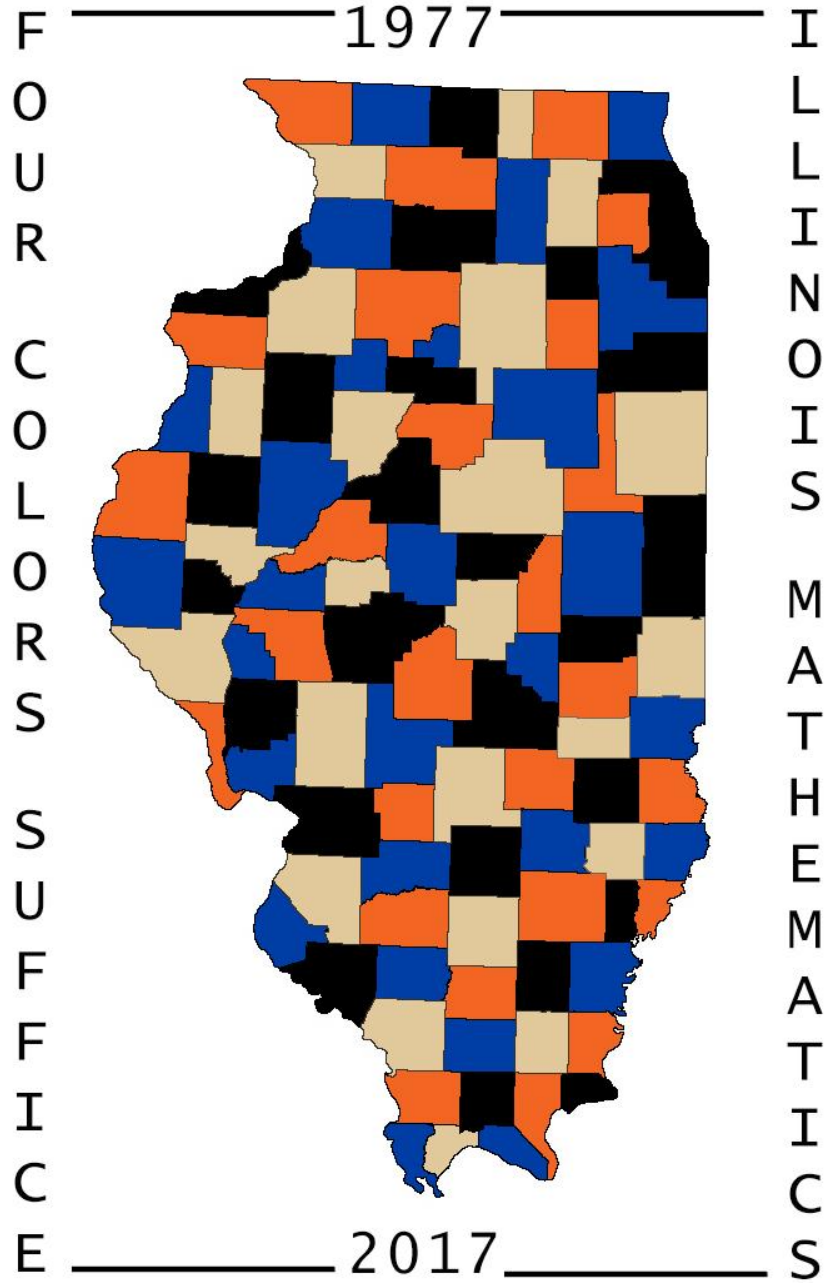
Outreach Activities

- MoSAIC, Fall 2014
- Winter Carnival, January 2017



Outreach Activities

- MoSAIC, Fall 2014
- Winter Carnival, January 2017
- Four Color Fest, Fall 2017



Outreach Activities

- MoSAIC, Fall 2014
- Winter Carnival, January 2017
- Four Color Fest, Fall 2017

FOUR COLOR FEST OPEN HOUSE

hosted by the Illinois Geometry Lab

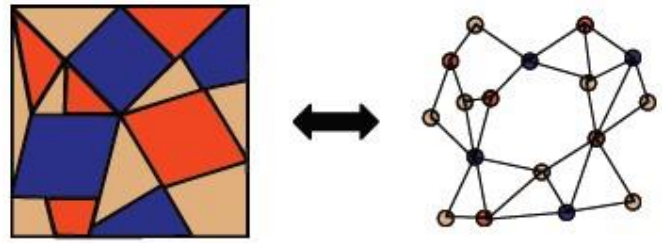
Saturday, November 4, 2017

10 am - noon

Ballroom, Alice Campbell Alumni Center

601 S. Lincoln Avenue, Urbana, IL 61801

- the event is free and open to the public, suitable for all ages
- themes will relate to the Four Color Theorem, especially graphs and networks, maps, coloring problems, algorithms, etc
- a variety of activities (guided and unguided) for all ages



The open house is being held in celebration of the 40th anniversary of the proof of the Four Color Theorem. In 1976, two mathematicians at the University of Illinois, Kenneth Appel and Wolfgang Haken, announced the solution to the Four Color Problem. Originally posed by Francis Guthrie in 1852, the Four Color Problem conjectures that four is the smallest number of colors needed to color the regions of an arbitrary map in such a manner that any two adjacent countries are painted with different colors. Appel and Haken's resolution of the Four Color Problem was remarkable both for its mathematical and historical significance as well as for the method of proof: this was the first mathematical proof to rely in an essential fashion on the use of computing technology.

ILLINOIS

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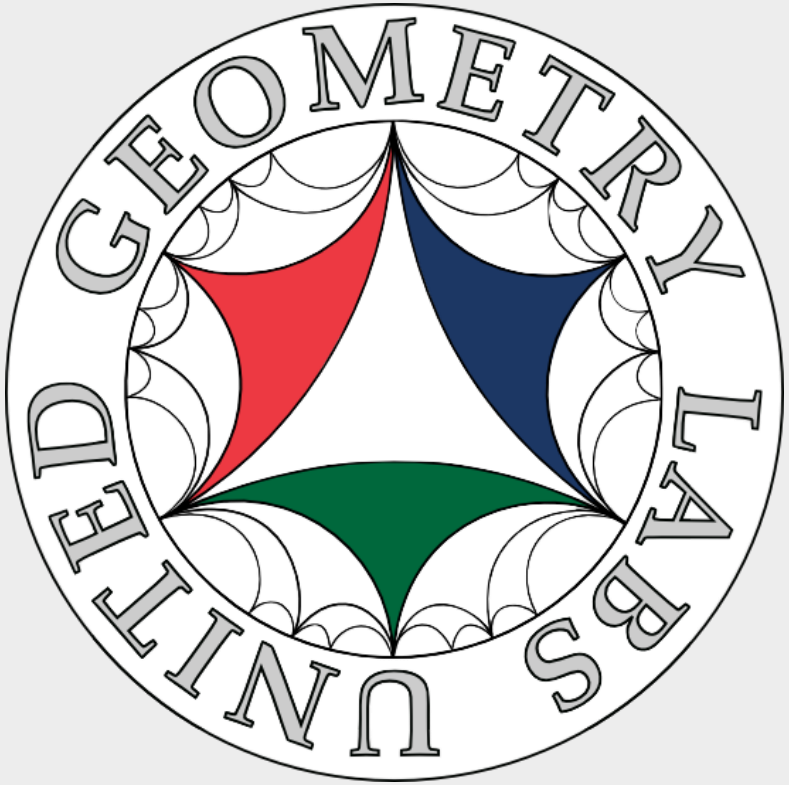
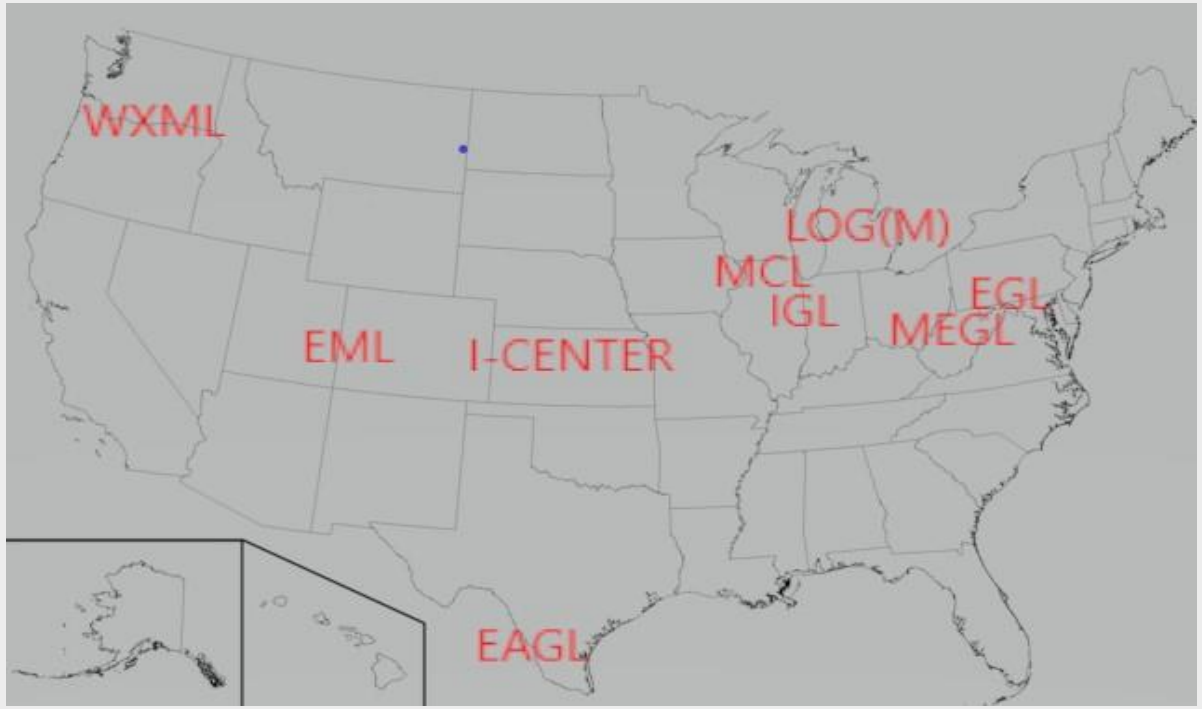
ILLINOIS GEOMETRY LAB, DEPARTMENT OF MATHEMATICS, UNIVERSITY OF ILLINOIS

math.illinois.edu/fourcolorfest

Geometry Labs United



- Experimental Geometry Lab (Maryland)
- Experimental Algebra and Geometry Lab (U Texas Rio Grande Valley)
- Mason Experimental Geometry Lab (George Mason)
- Illinois Geometry Lab (U Illinois Urbana-Champaign)
- Mathematical Computing Lab (U Illinois Chicago)
- Washington Experimental Mathematics Lab (U Washington)
- I-Center (Kansas State)
- Laboratory of Geometry at Michigan (U Michigan)
- Experimental Mathematics Lab (U Colorado Boulder)



Geometry Labs United Conferences

GLU I (Illinois, Summer 2015)

GLU II (Washington, Summer 2017)

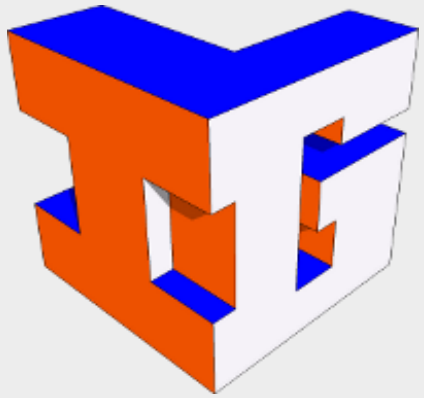
Some final thoughts

- Demand for quality research experiences at the undergraduate level is off the charts
- Vertically integrated research teams provide opportunities at all levels for hands-on experience and training in mentoring and leadership
- Departmental support is crucial: monetary as well as in-kind commitments by faculty, grad students, and staff
- Research and outreach feed off of each other
- This educational model provides excellent opportunities to showcase and advertise what we do

Funding

- University of Illinois Department of Mathematics
- NSF, "**CAREER: Randomness in Geometry and Dynamics",** PI: J. Athreya, DMS-1559860
- NSF, **"Mathways",** PIs: J. Athreya, M. Ando, J. Tyson DMS-1449269
- University of Illinois Public Engagement Office
- MAA, Dolciani Mathematics Enrichment Grants (2015-2016, 2016-2017)
- Susan C. Morisato

Thank you!



For more information, visit

www.math.illinois.edu/research/igl

www.geometrylabs.net