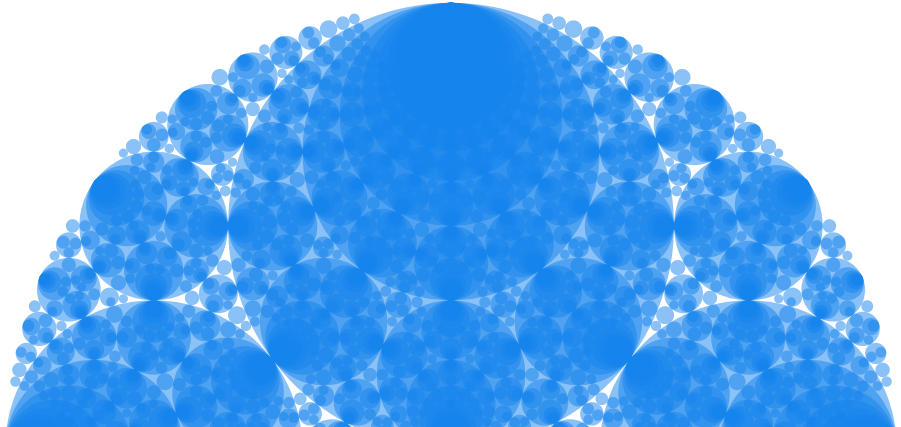
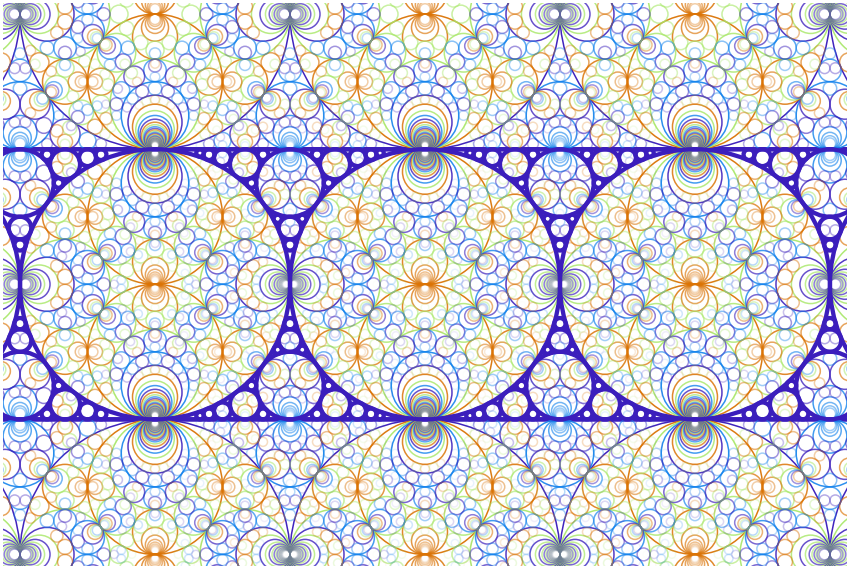
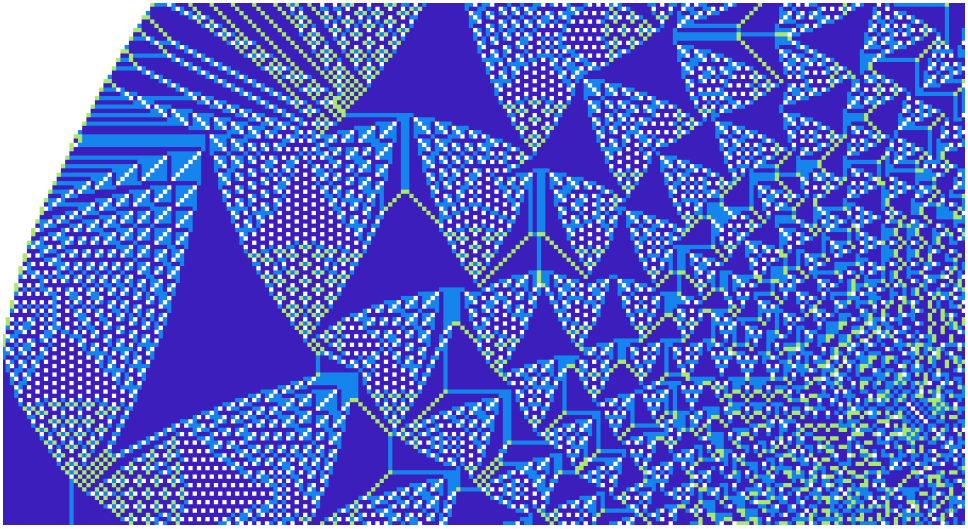
Katherine Stange
University of Colorado, Boulder

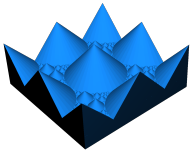


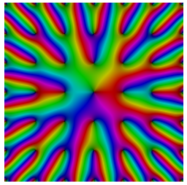
Arithmetic of Kleinian Groups, and Apollonian Circle Packings

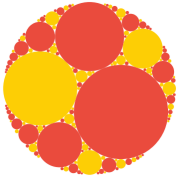


Abelian Sandpiles









My interests include…

- algebraic number theory
- quadratic & hermitian forms, class field theory
- Diophantine approximation and continued fractions
- Kleinian groups
- elliptic curves and modular curves
- cryptography
- quantum computing

Things I want to illustrate include…

- isogeny graphs of elliptic curves
- CM points
- Gauss sums
- heights on varieties
- …

Aaron Abrams

Washington and Lee University

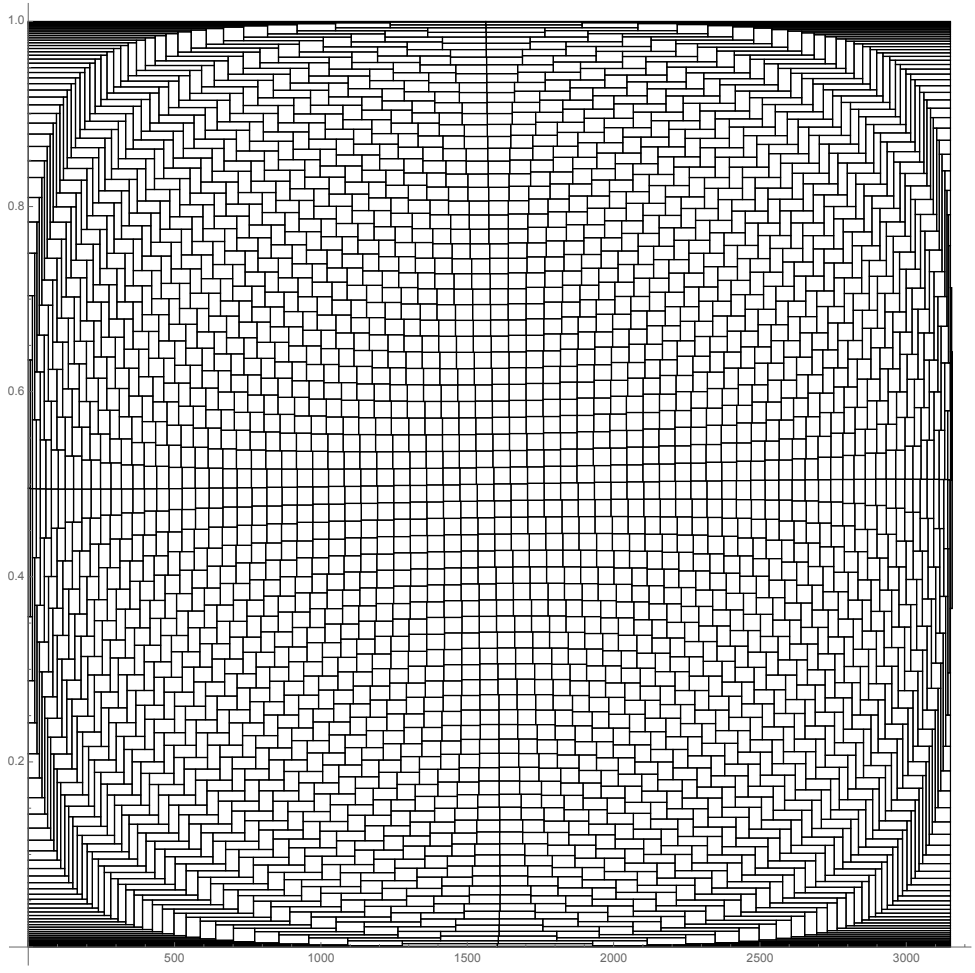
(A small liberal arts college in Virginia)

Mathematics

I am a mathematician with broad research interests.

Some topics that I like that are relevant to this program include:

I. Tilings



Equal areas
(Abrams–Kenyon 2017)

I. Tilings



Tiling course

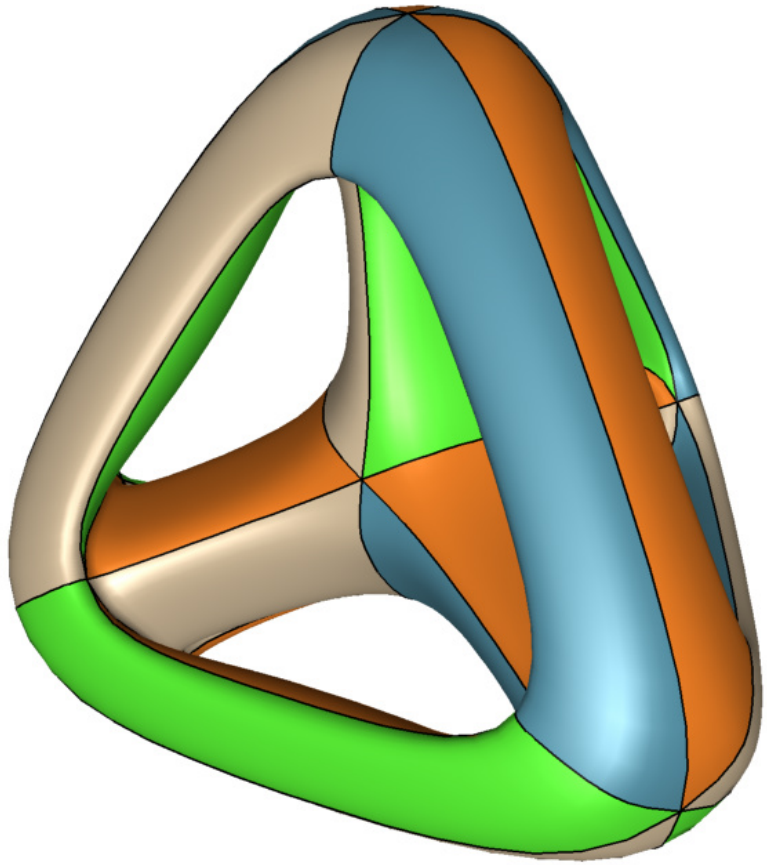
I. Tilings



I. Tilings



II. Configuration Spaces

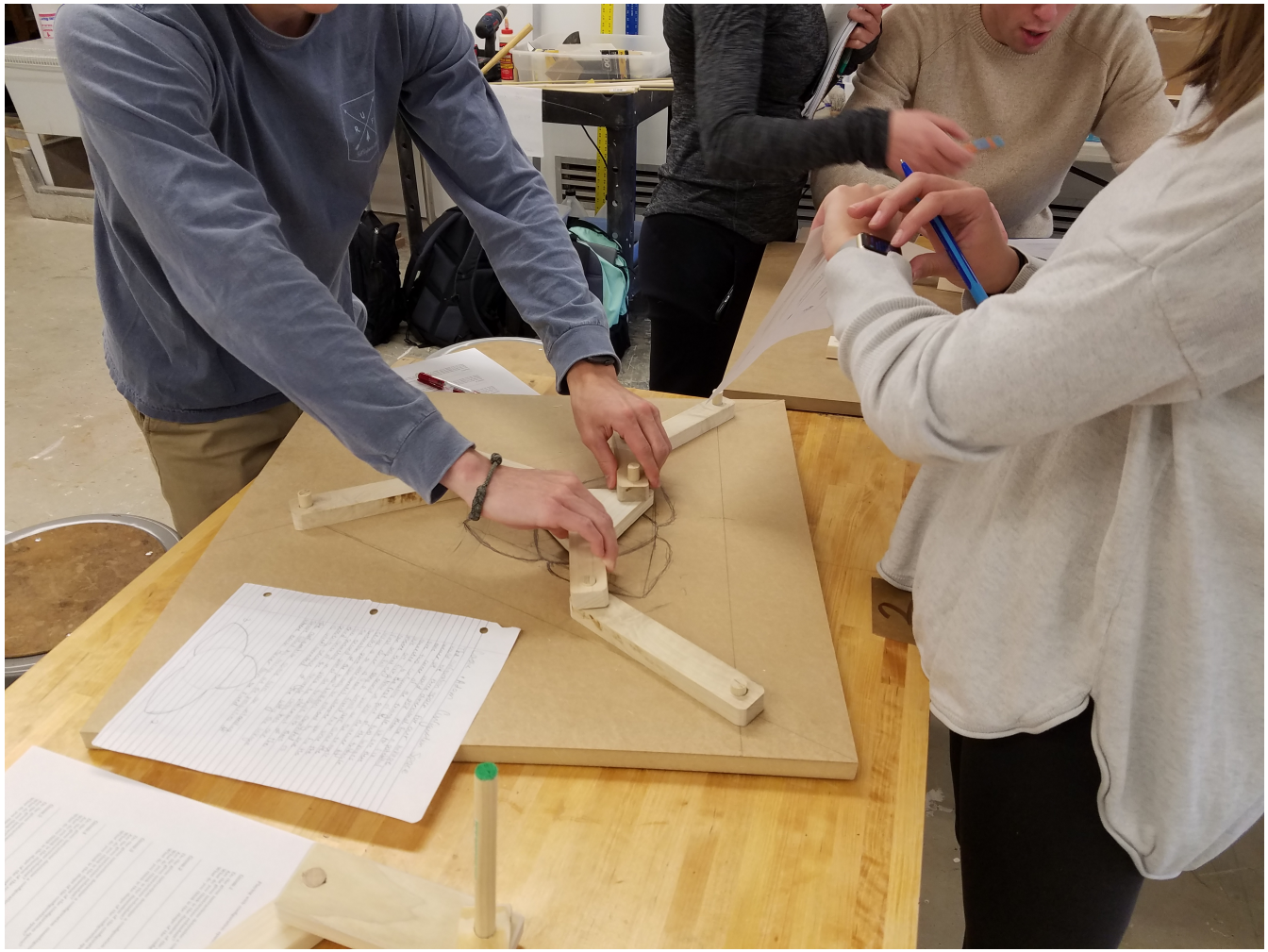


II. Configuration Spaces



Rotem Tamir, Sculpture Professor

II. Configuration Spaces



Math and Sculpture Course

II. Configuration Spaces

I am interested in creating
physical or virtual
interactive demonstrations,
that non-mathematicians can learn something from.

roger antonsen

Associate Professor, Department of Informatics, University of Oslo
Visiting Scholar, University of California, Berkeley

rantonse.no

rantonse

Berkeley

UNIVERSITY OF CALIFORNIA





Roger Antonsen

The Method of Variable Splitting

Faculty of Mathematics and Natural Sciences
University of Oslo
2008

The Method of Variable Splitting

Roger Antonsen

Thesis submitted to the Faculty of Mathematics and Natural Sciences at the University of Oslo for the degree of ***Philosophiae Doctor (PhD)***

Date of submission: ***June 30, 2008***
Date of public defense: ***October 3, 2008***

Supervisors

Prof. Dr. Arild Waaler, University of Oslo
Prof. Dr. Reiner Hähnle, Chalmers University of Technology

Adjudication committee

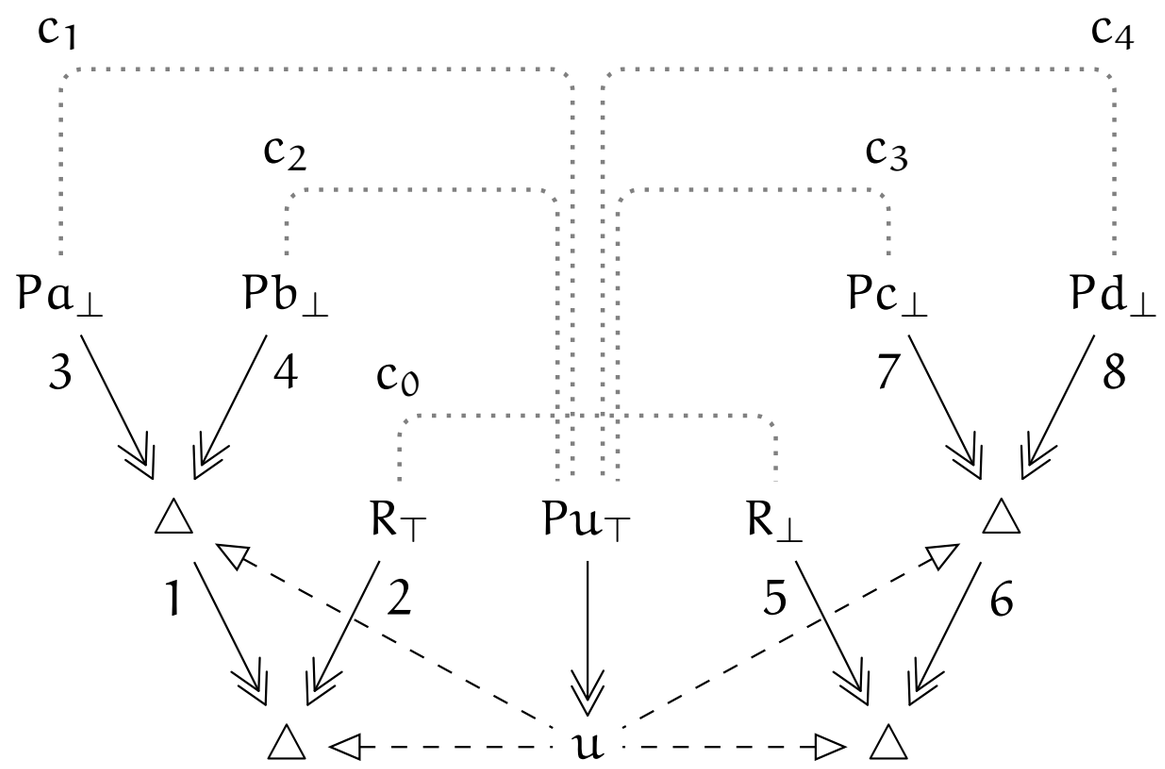
Prof. Dr. Matthias Baaz, Vienna University of Technology
Prof. emer. Dr. Wolfgang Bibel, Darmstadt University of Technology
Dr. Martin Giese, University of Oslo

$$\dfrac{\dfrac{\dfrac{\dfrac{}{\overline{Pu} \vdash \overline{Pa}}\,u^{13}/a\ 13 \quad \dfrac{}{\overline{Pu} \vdash \overline{Pb}}\,u^{14}/b\ 14}{Pu \vdash Pa \wedge Pb}\ \cdots \qquad \dfrac{\dfrac{}{\overline{R}, Pu \vdash \overline{R}}\ 25 \qquad \dfrac{\dfrac{}{R, \overline{Pu} \vdash \overline{Pc}}\,u^{267}/c\ 267 \quad \dfrac{}{R, \overline{Pu} \vdash \overline{Pd}}\,u^{268}/d\ 268}{R, Pu \vdash Pc \wedge Pd}}{R, Pu \vdash R \wedge (Pc \wedge Pd)}}{Pu, Pa \wedge Pb \to R \vdash R \wedge (Pc \wedge Pd)}}{\underset{u}{\forall x} \underset{0}{P} \underset{3}{x}, \underset{1}{P} \underset{4}{a} \wedge \underset{2}{P} \underset{5}{b} \to \underset{7}{R} \vdash \underset{6}{R} \wedge (\underset{8}{P} c \wedge P d)}$$

The splitting substitution is admissible due to the following, total, splitting relation.

$$\{(1 \triangle 2) \sqsubset u, (3 \triangle 4) \sqsubset u, (5 \triangle 6) \sqsubset u, (7 \triangle 8) \sqsubset u\}$$

A formula tree representation is given in Figure 8.3.





VINNER AV

Universitetsforlagets lærebokpris

Roger Antonsen

LOGISKE METODER

Kunsten å tenke abstrakt og matematisk

UNIVERSITETSFORLAGET

Roger Antonsen

Studiebok til LOGISKE METODER

UNIVERSITETSFORLAGET

Roger Antonsen:

Math is the hidden secret to understanding the world

TEDxOslo · 17:04 · **Filmed** Jan 2015

23 subtitle languages

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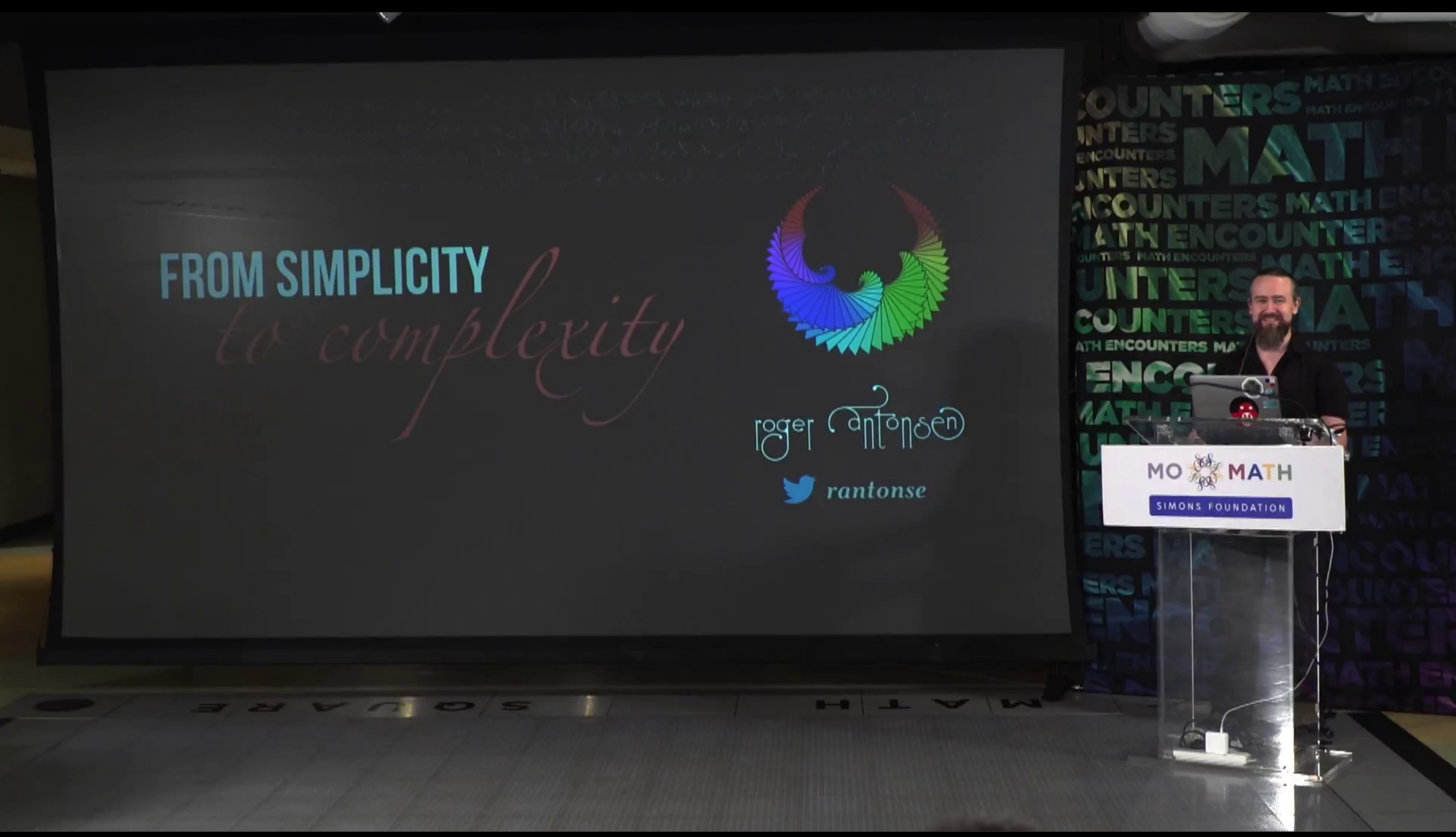
2,726,549

Unlock the mysteries and inner workings of the world through one of the most imaginative art forms ever — mathematics — with Roger Antonsen, as he explains how a slight change in perspective can reveal patterns, numbers and formulas as the gateways to empathy and understanding.



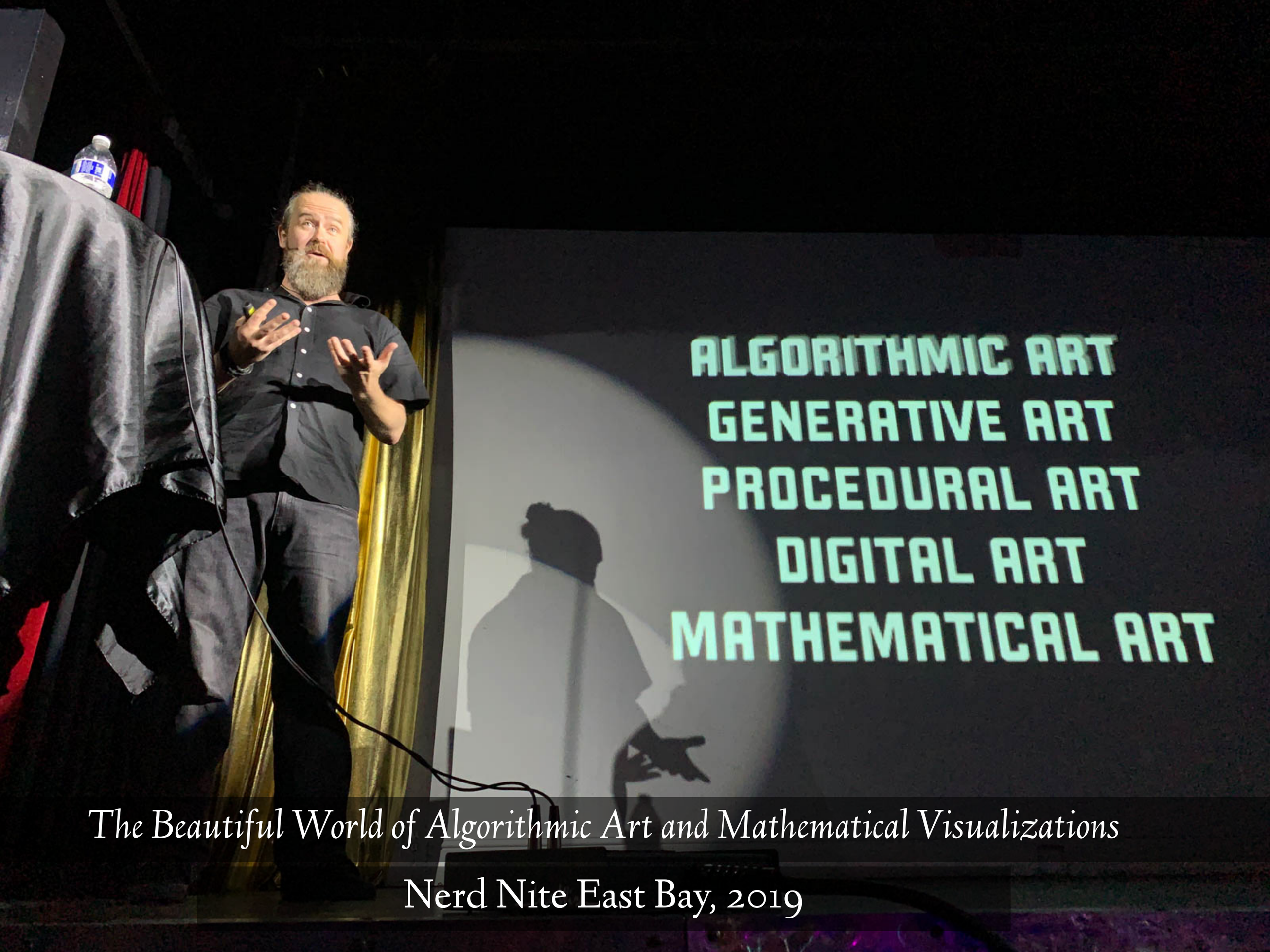
From Simplicity to Complexity

National Museum of Mathematics, New York City, 2018



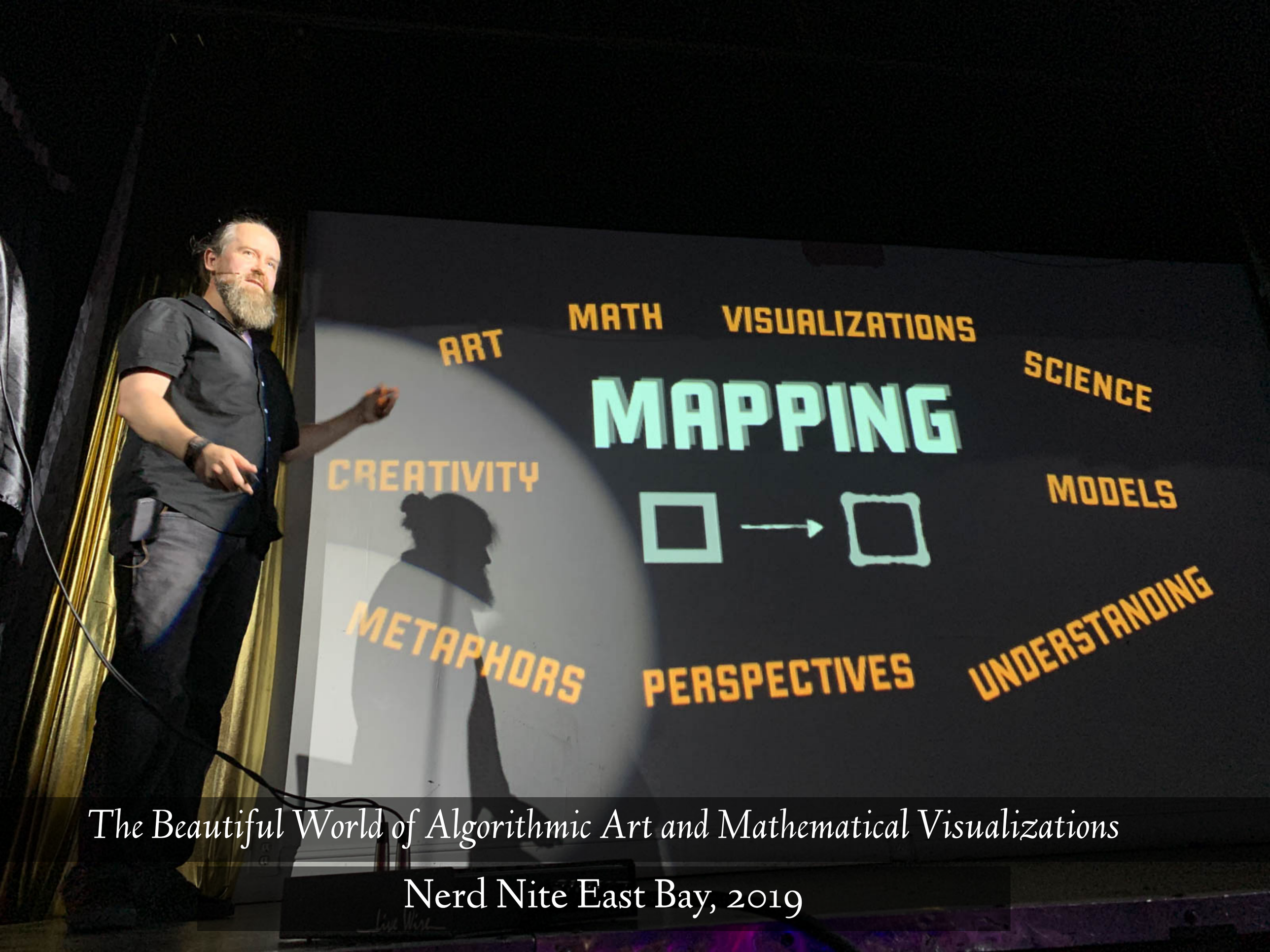
20 Mathematical Mysteries in 20 Minutes

Nerd Nite San Francisco, 2018



The Beautiful World of Algorithmic Art and Mathematical Visualizations

Nerd Nite East Bay, 2019



The Beautiful World of Algorithmic Art and Mathematical Visualizations

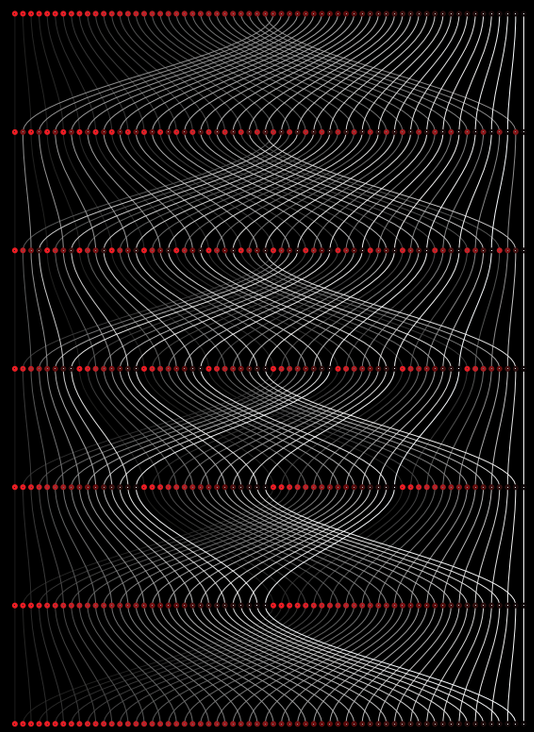
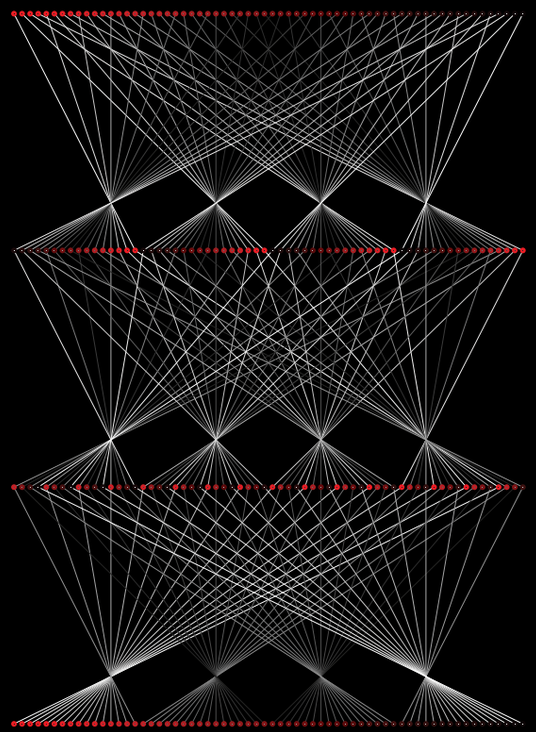
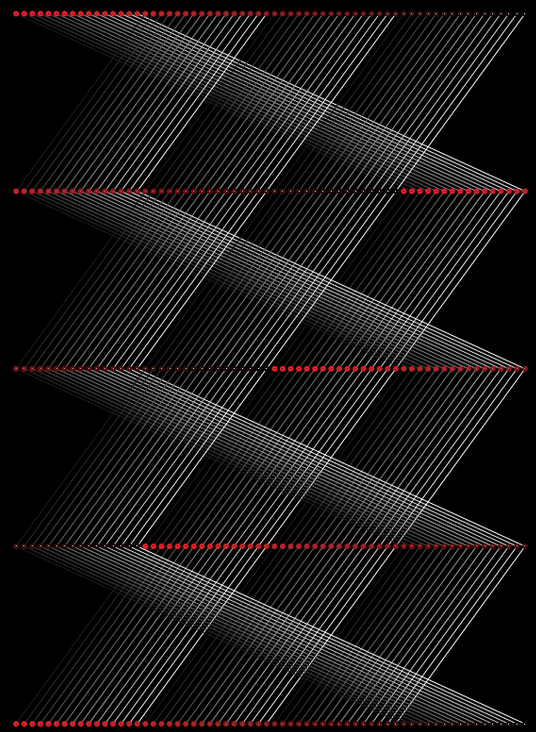
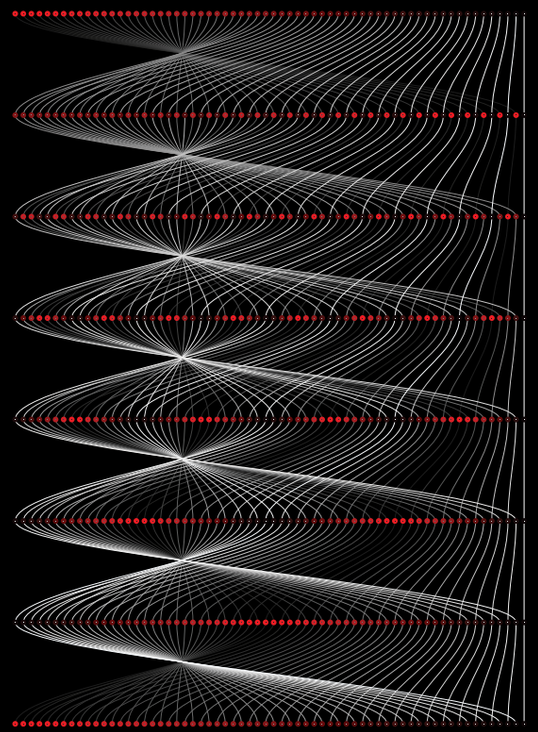
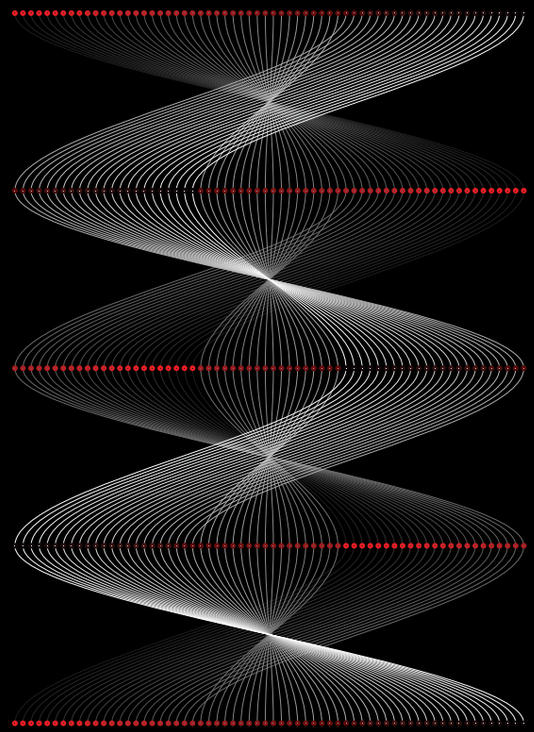
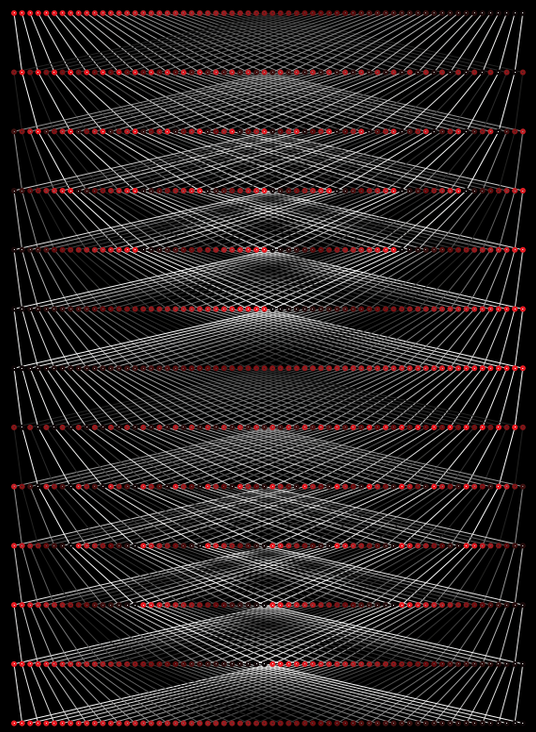
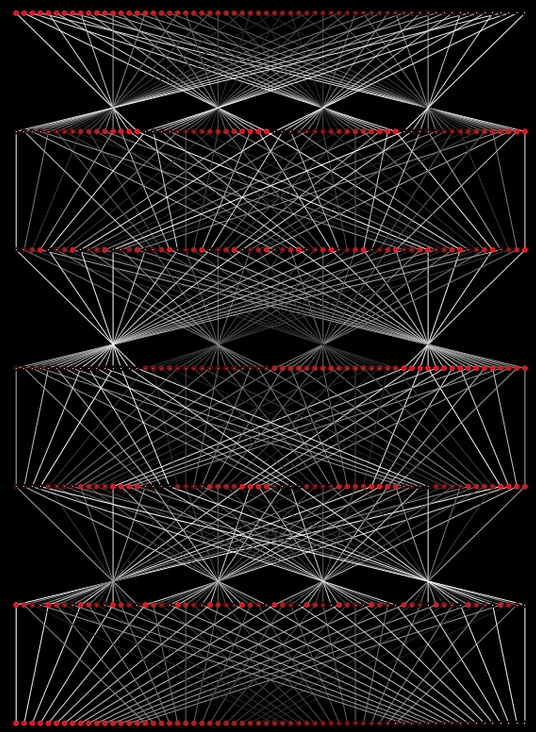
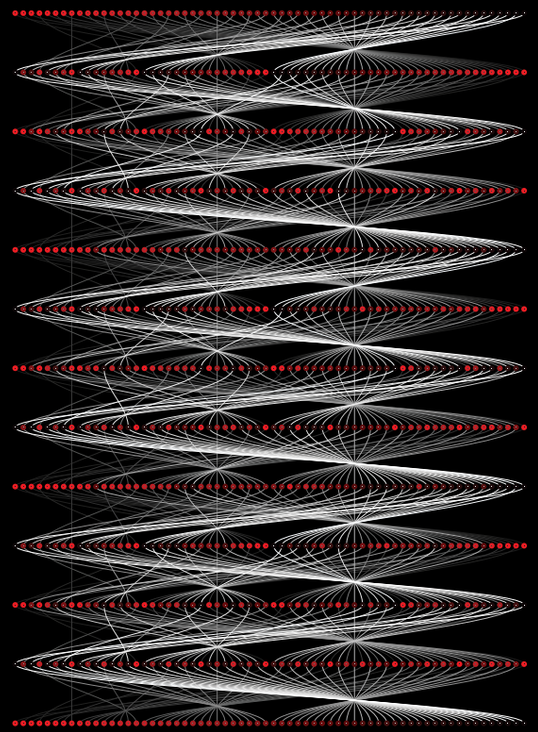
Nerd Nite East Bay, 2019

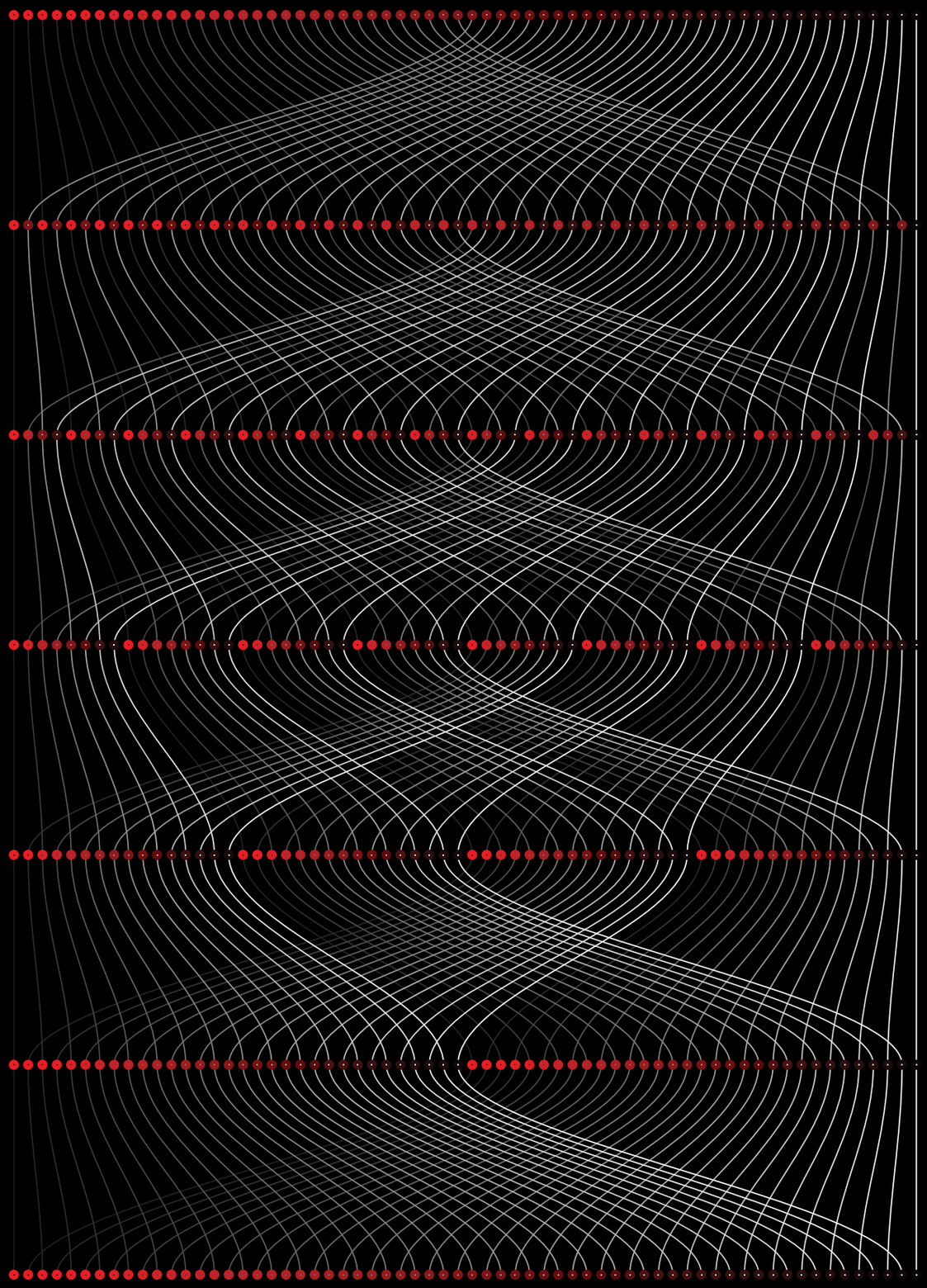

MAGISKE
MØNSTRE

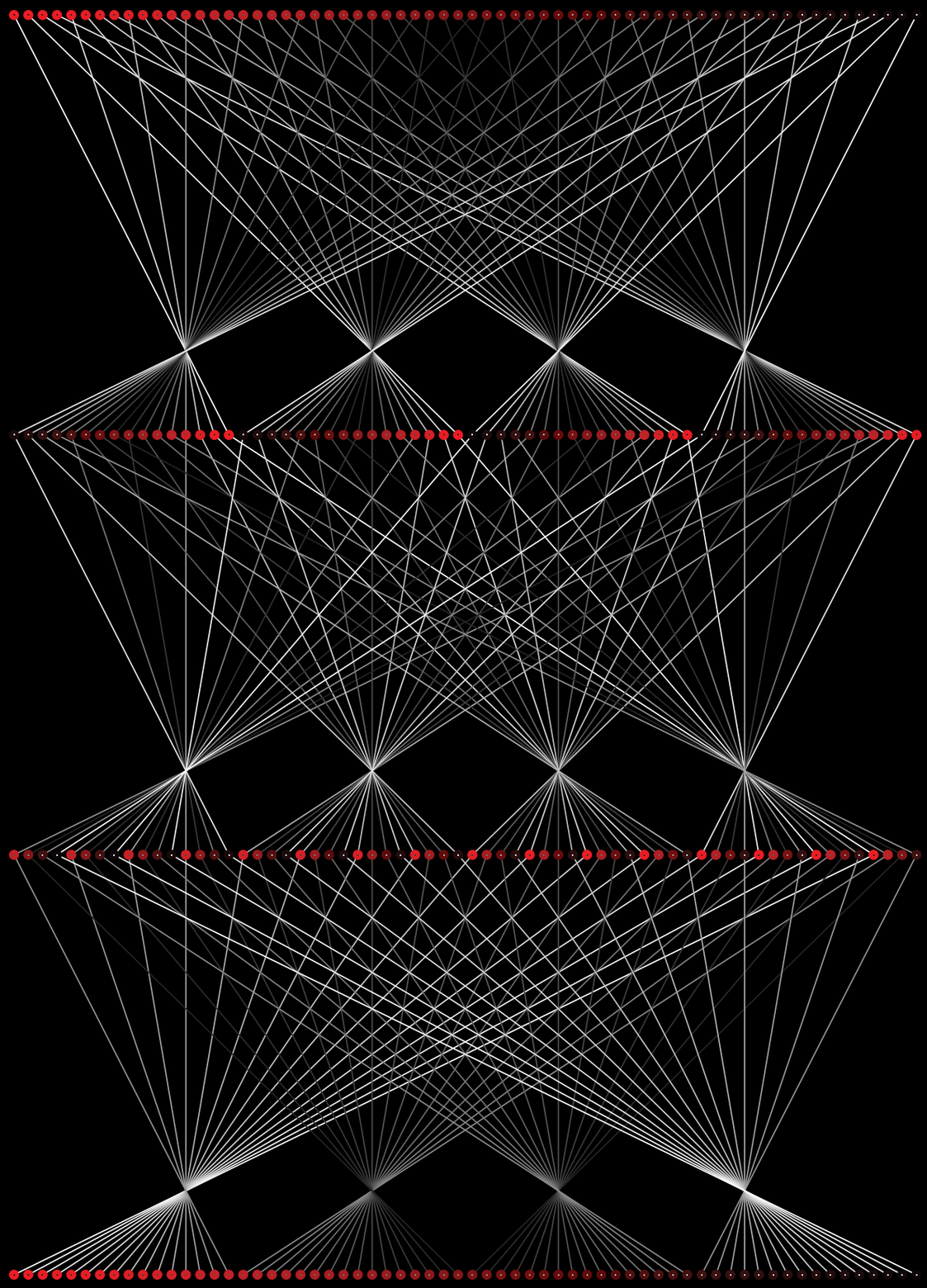
IKOSAEDER

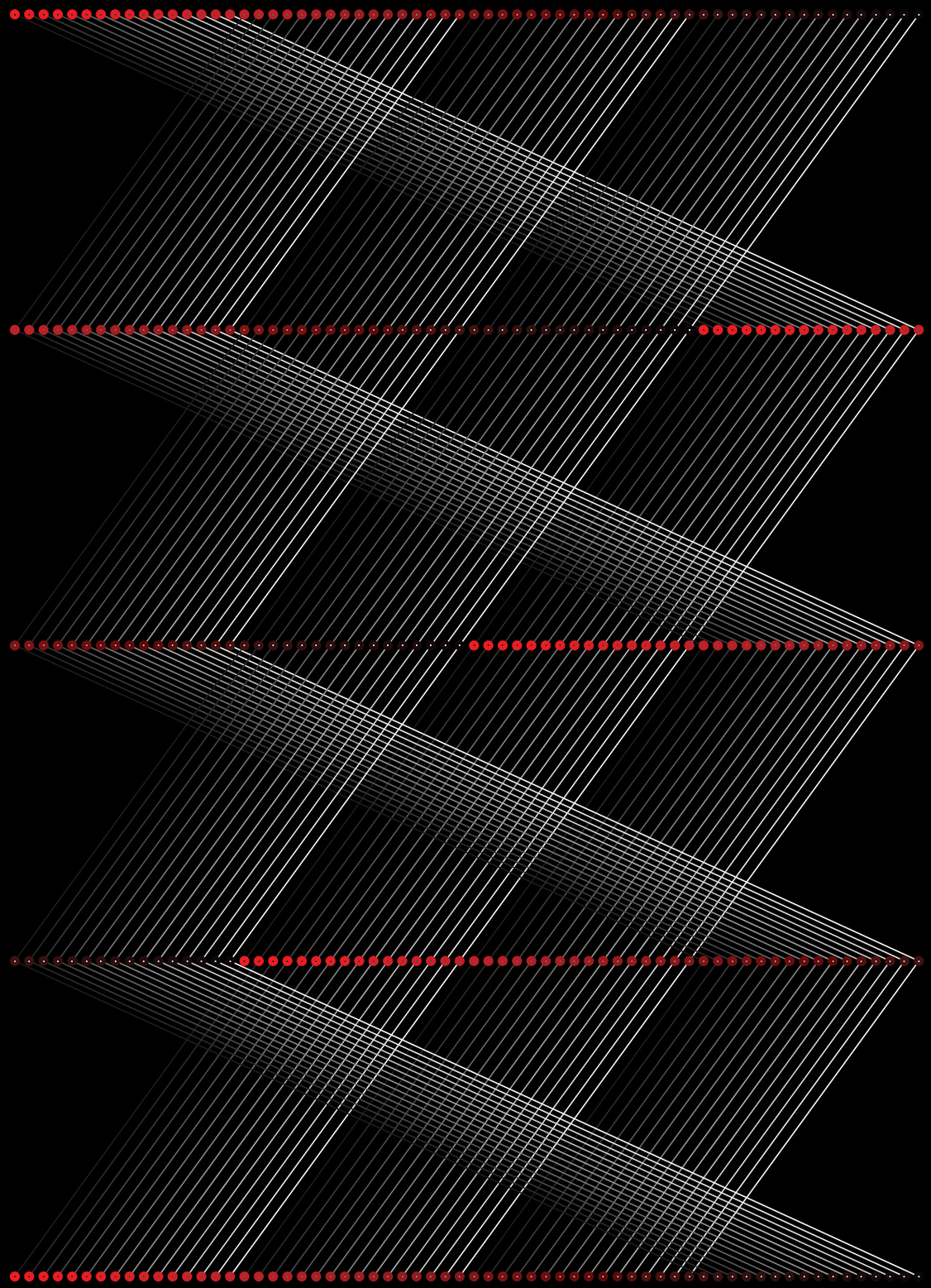
regulært polyeder med tjue likesidede trekanter

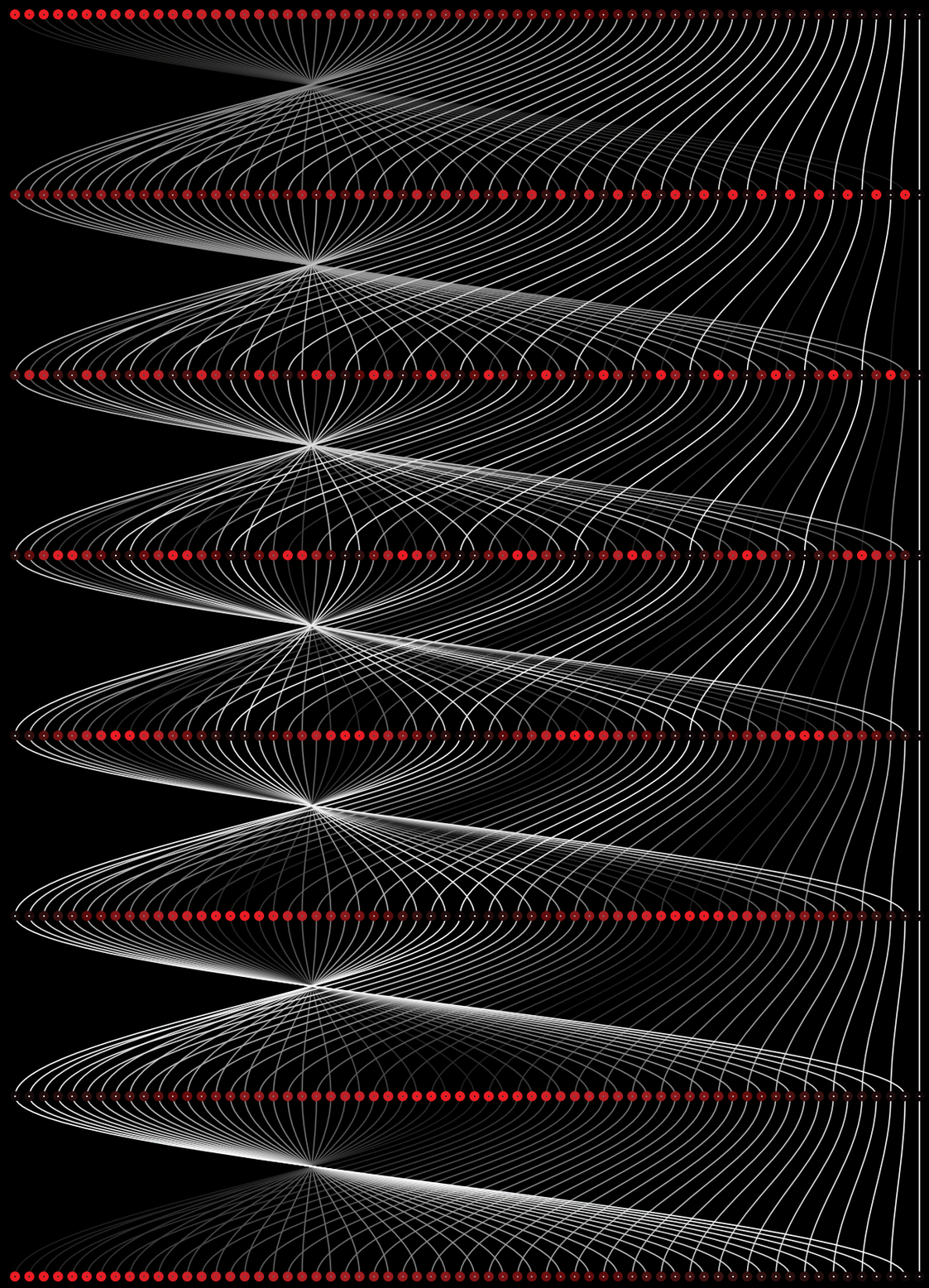


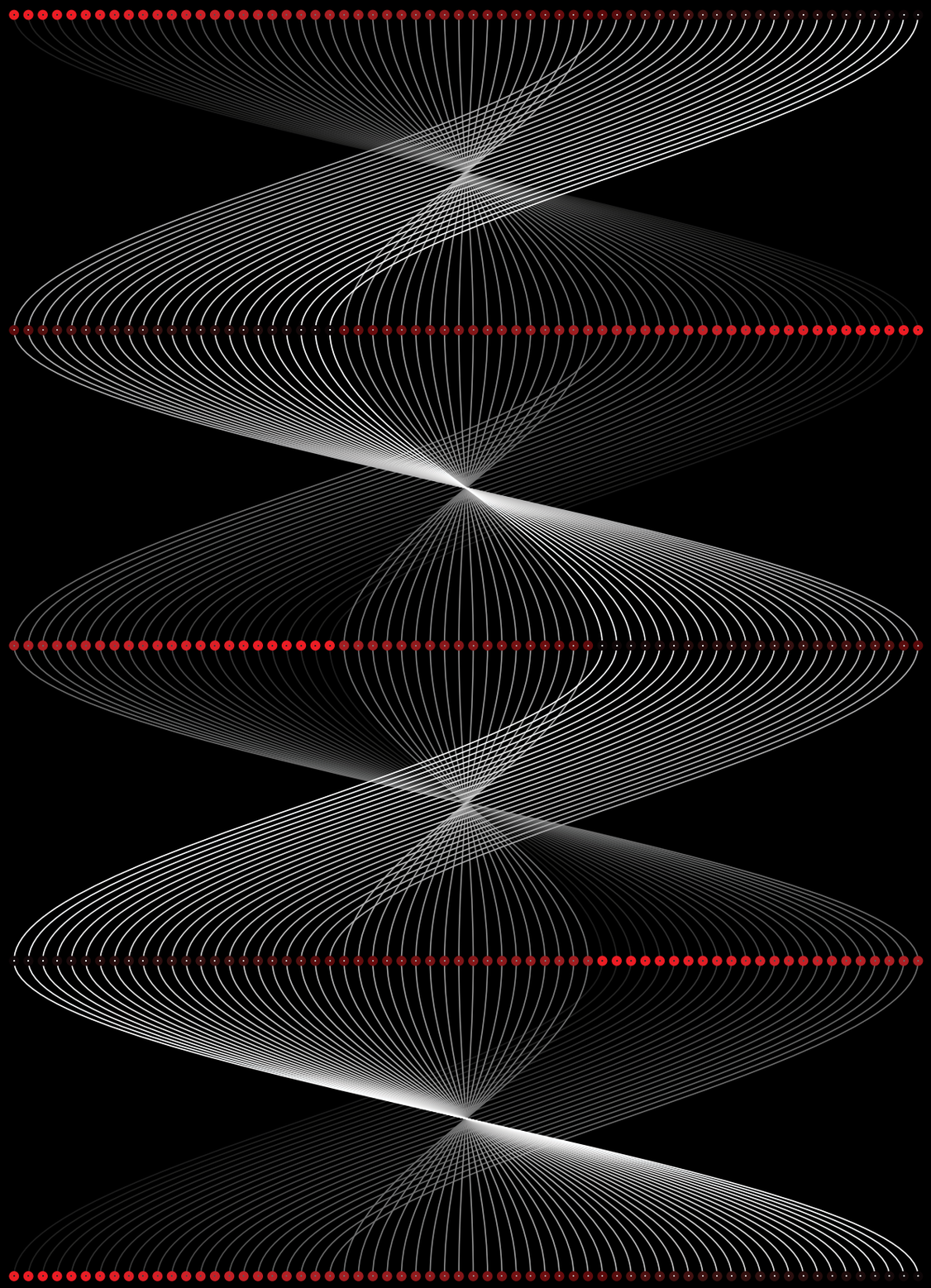









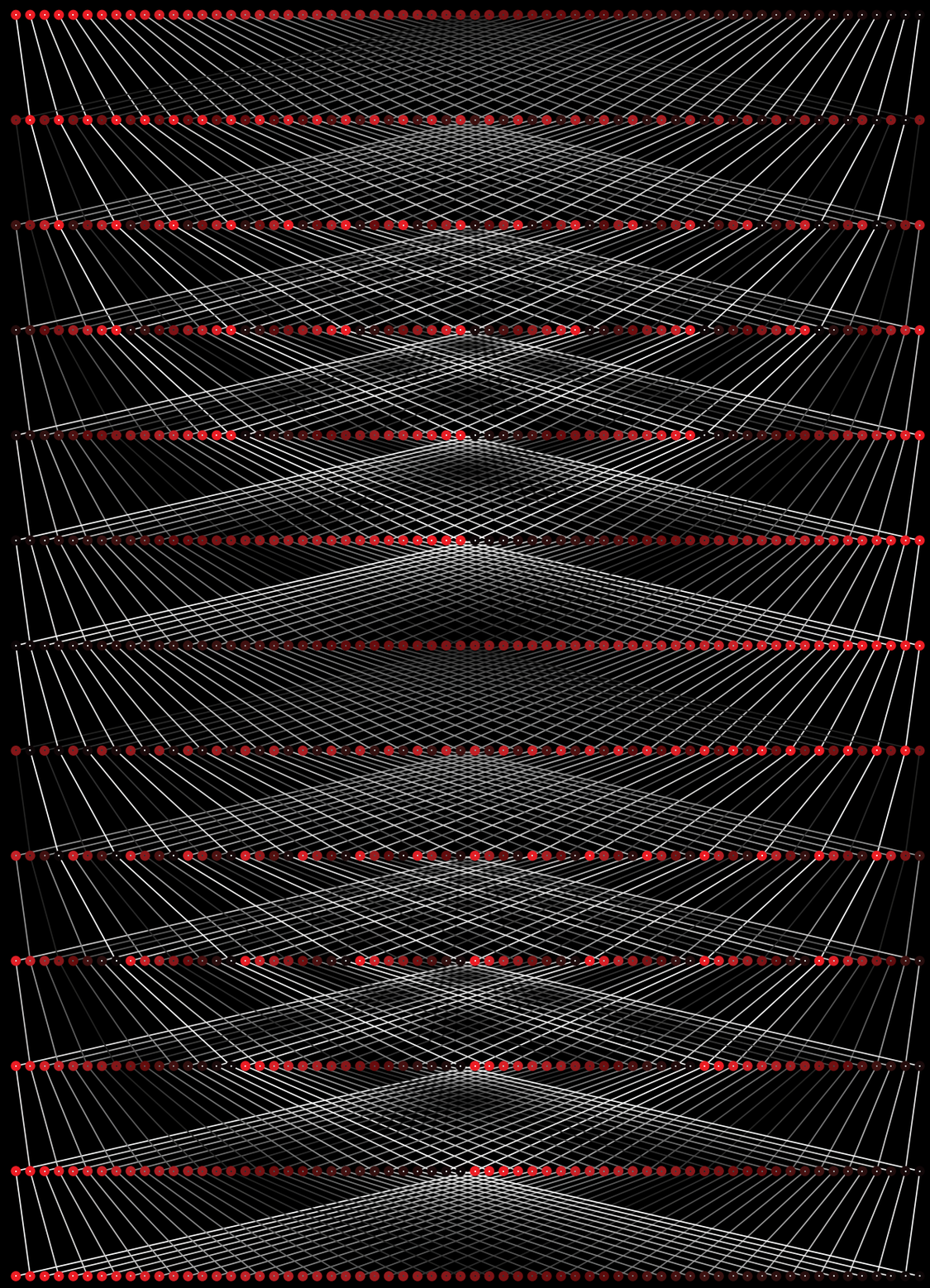


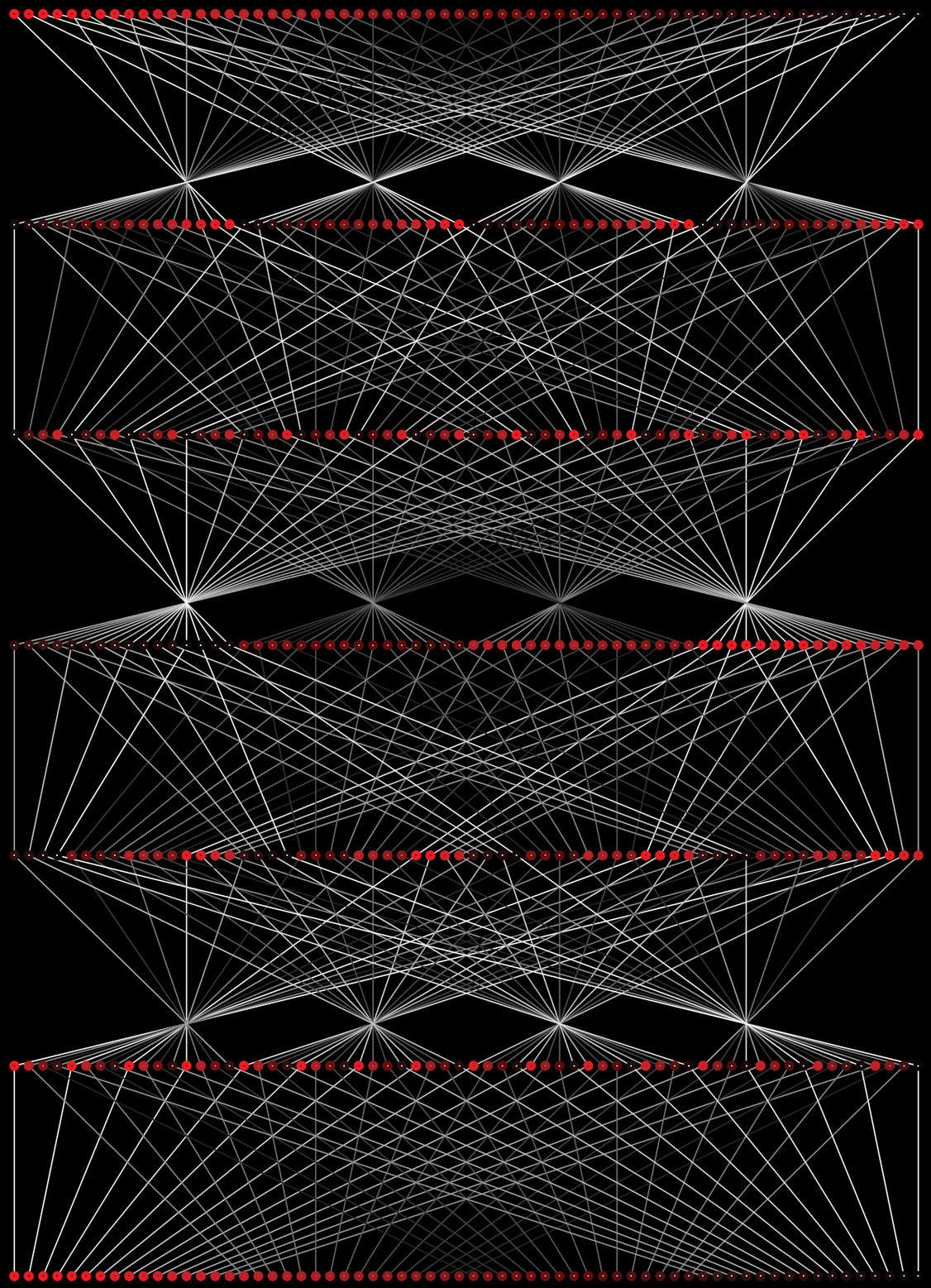


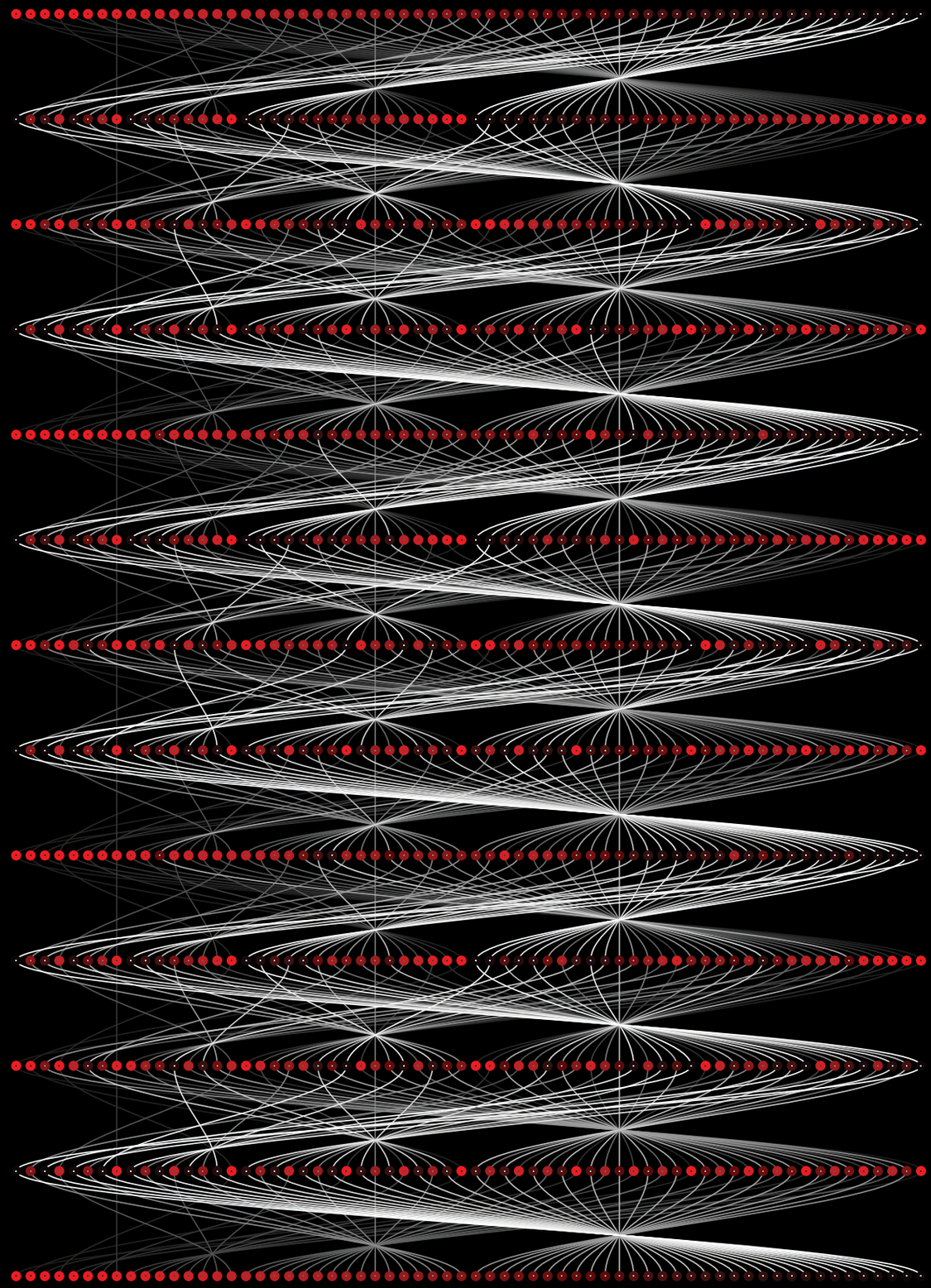


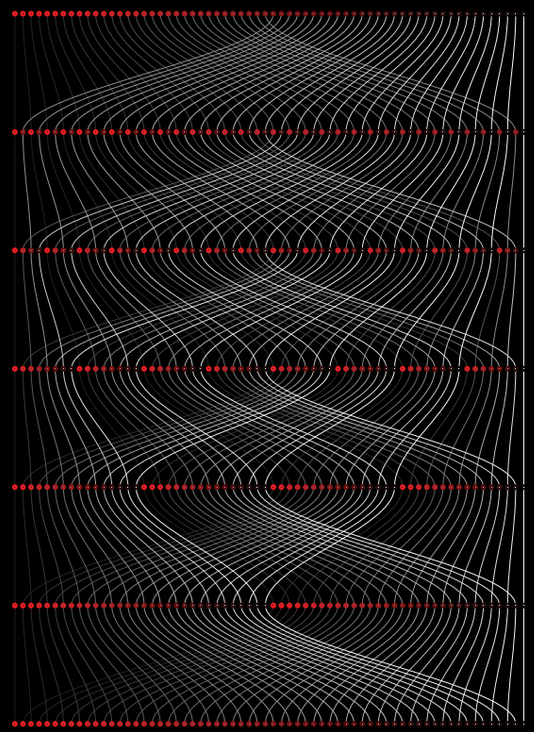
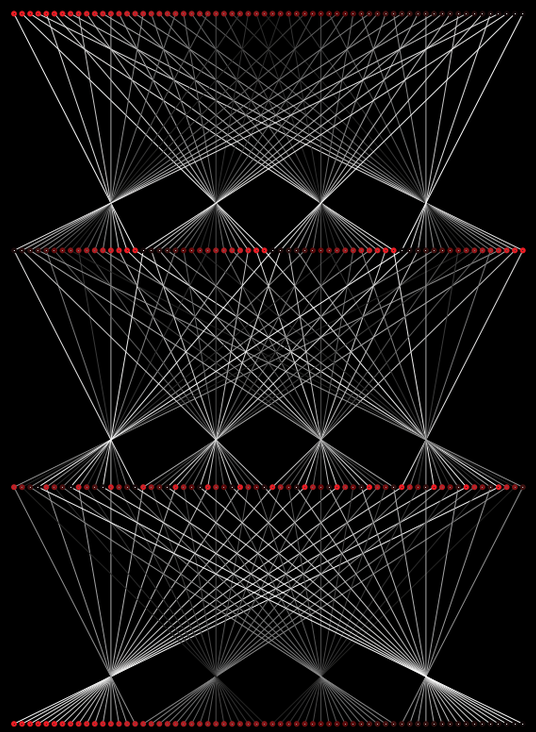
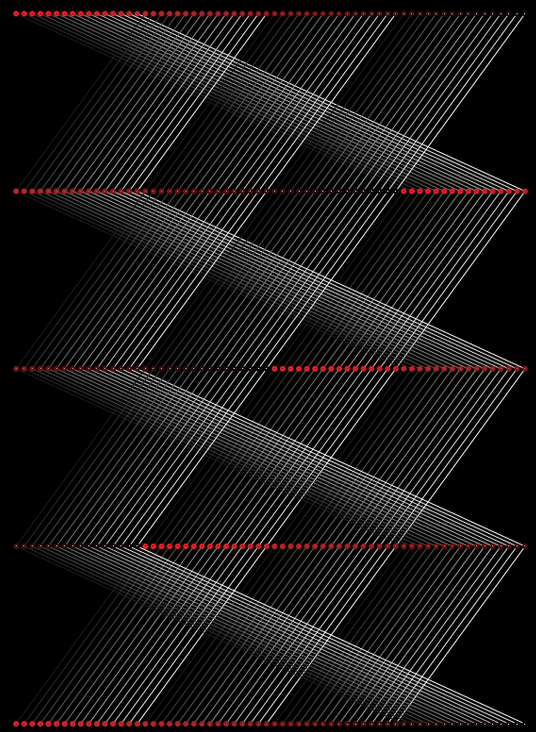
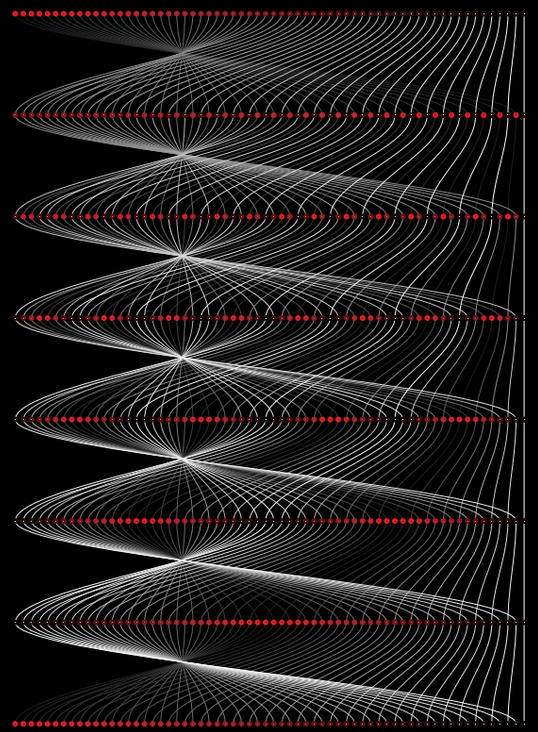
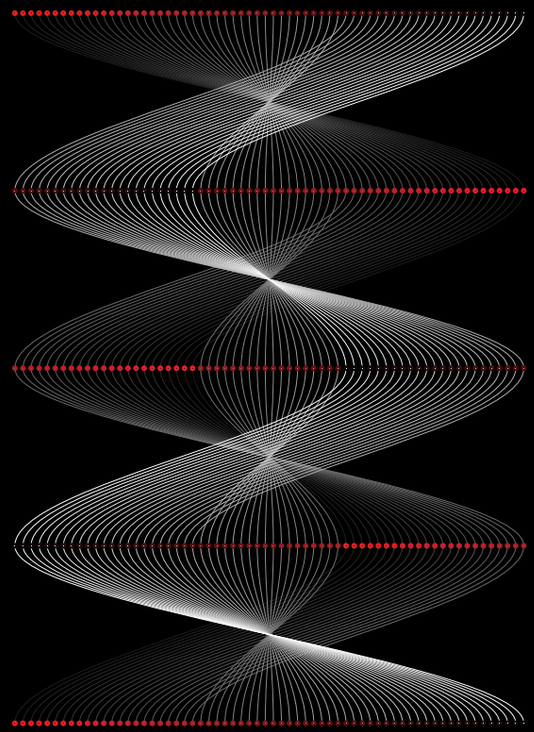
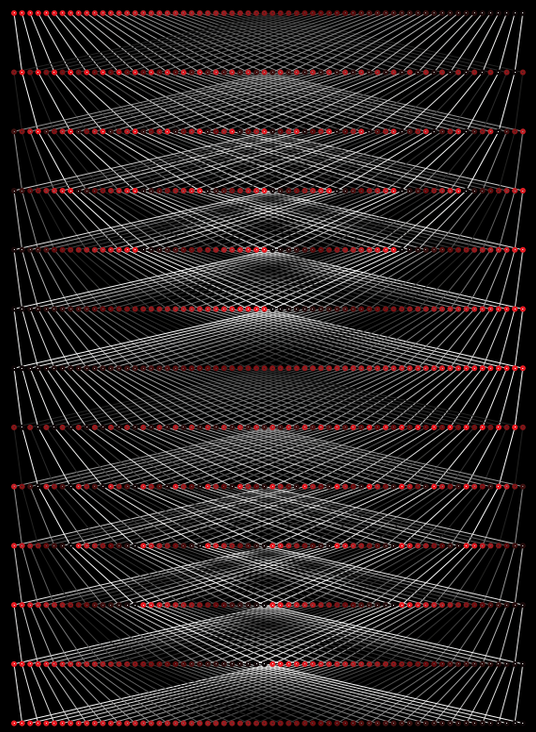
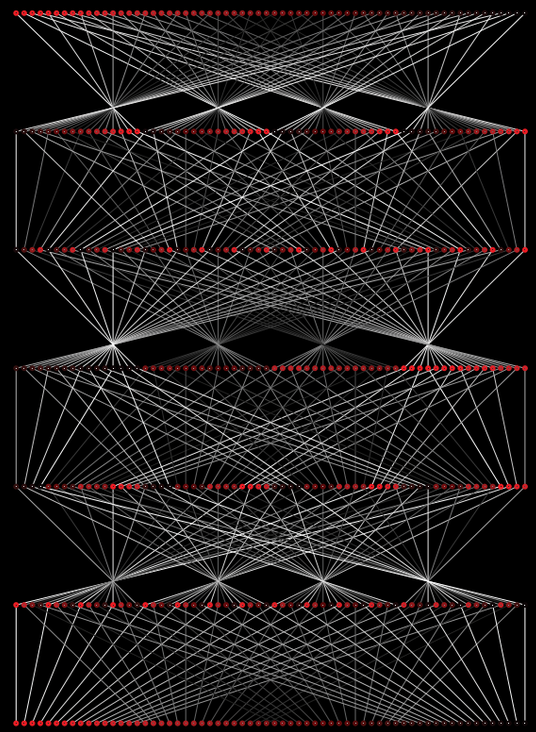
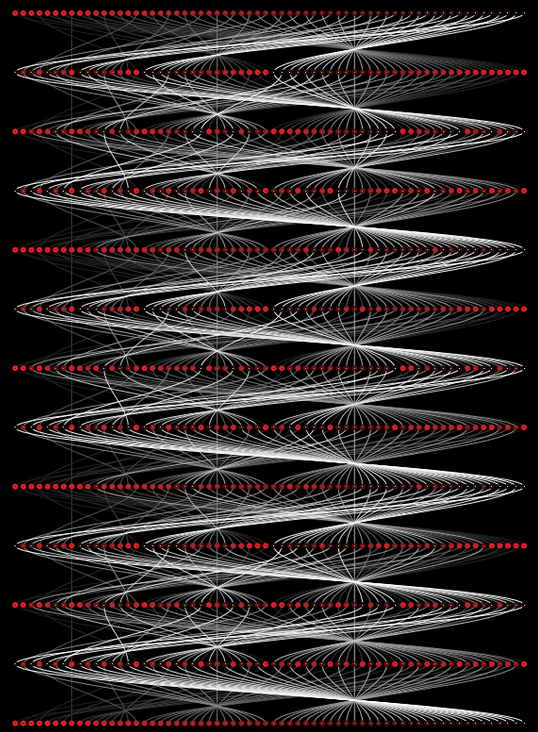






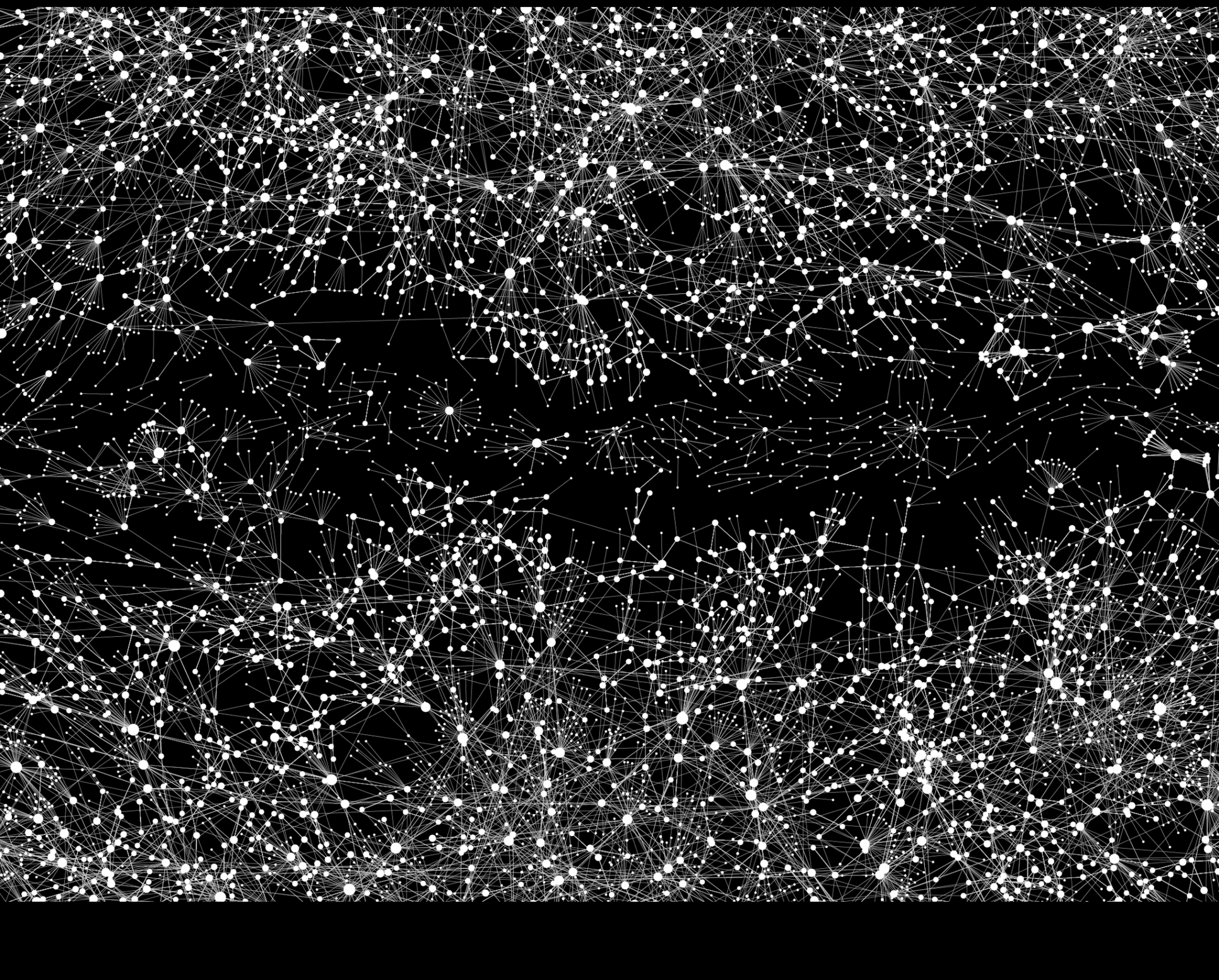


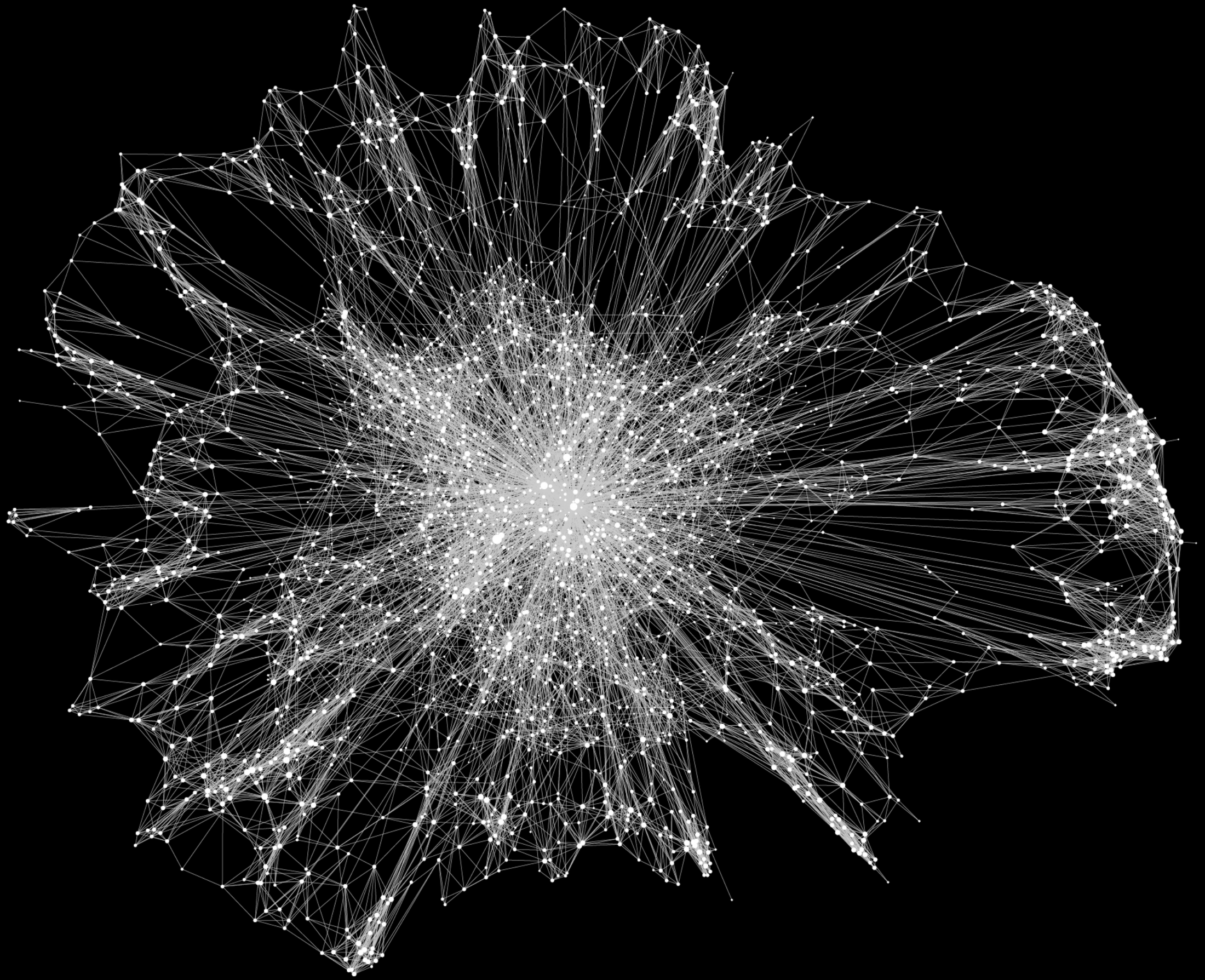


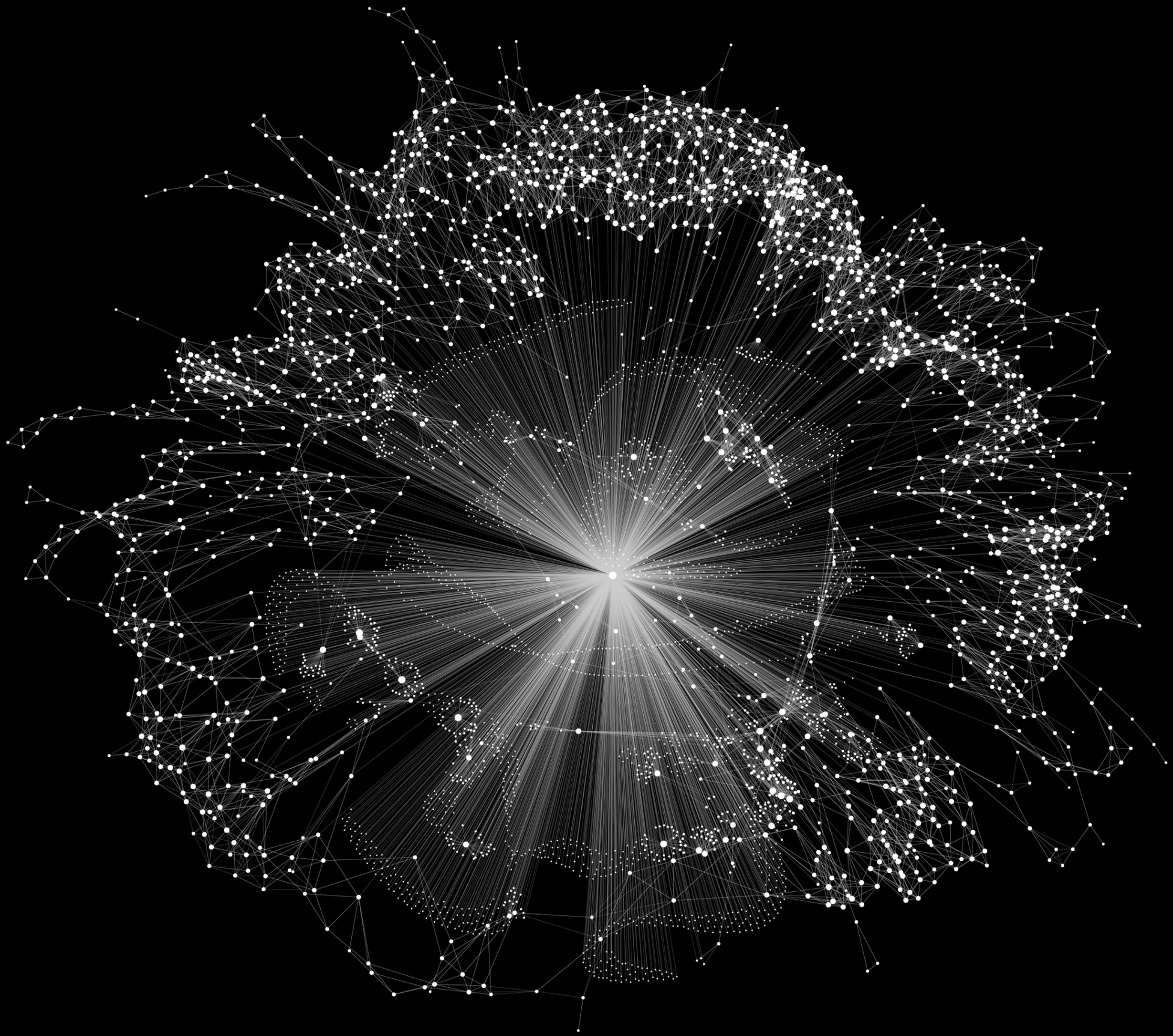









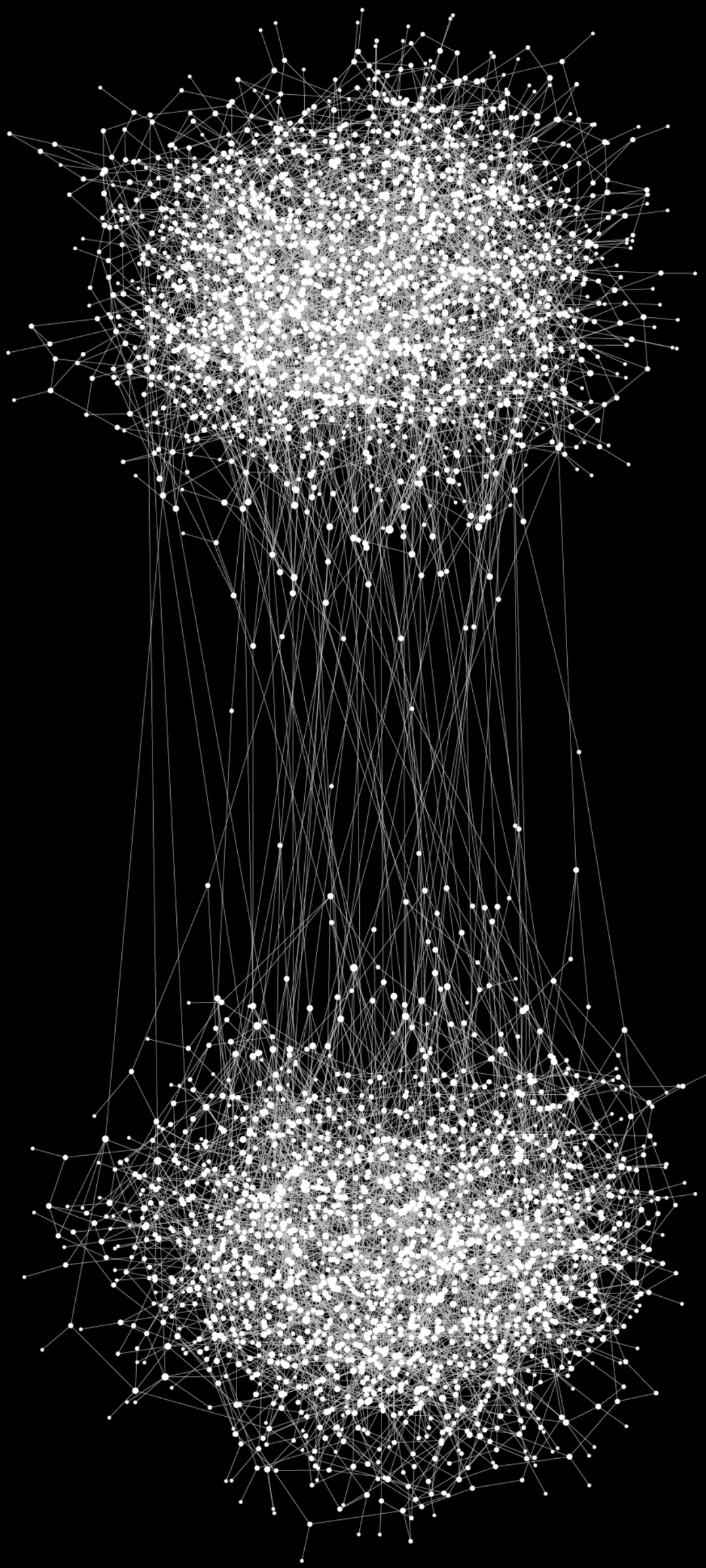


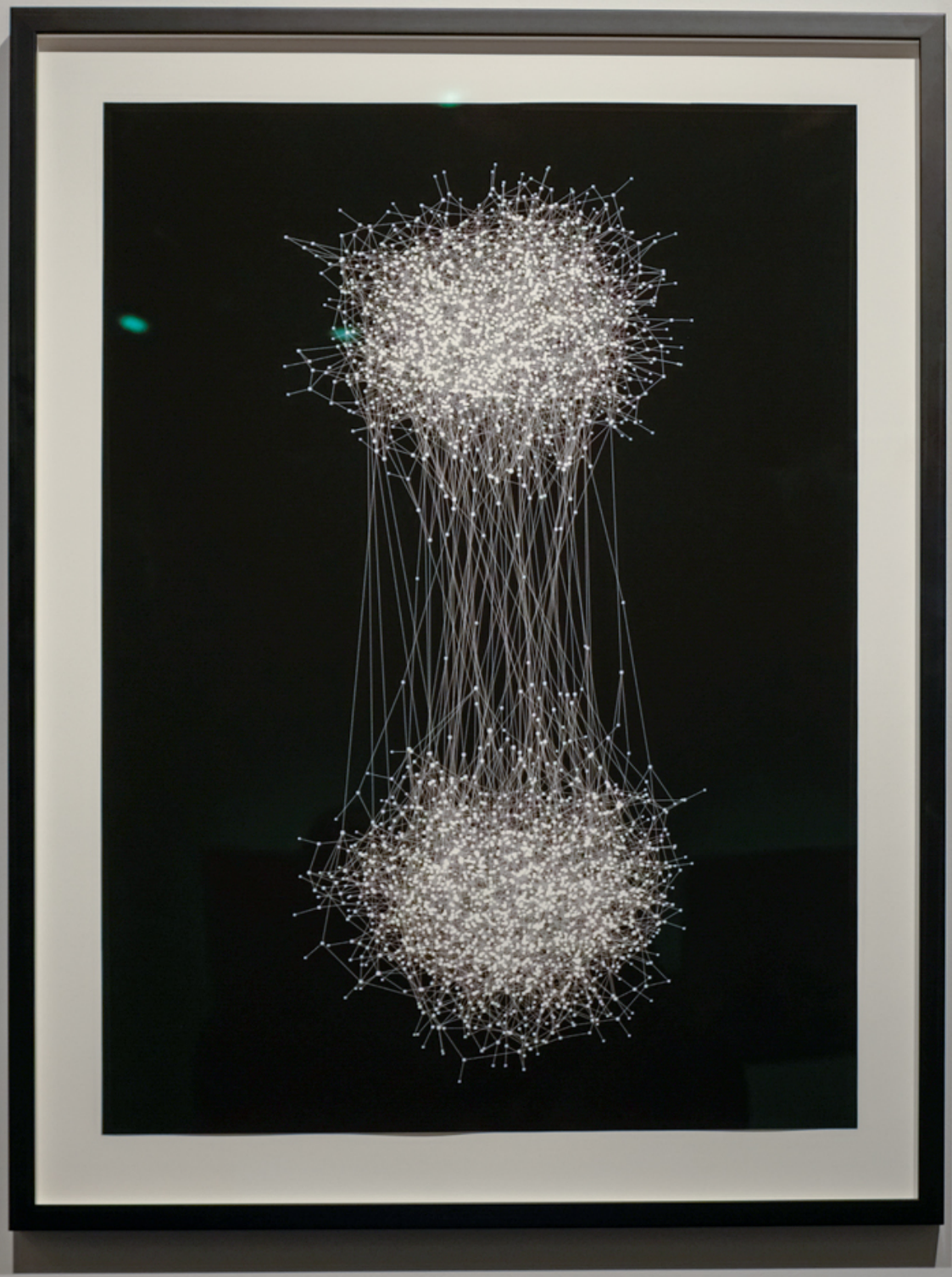




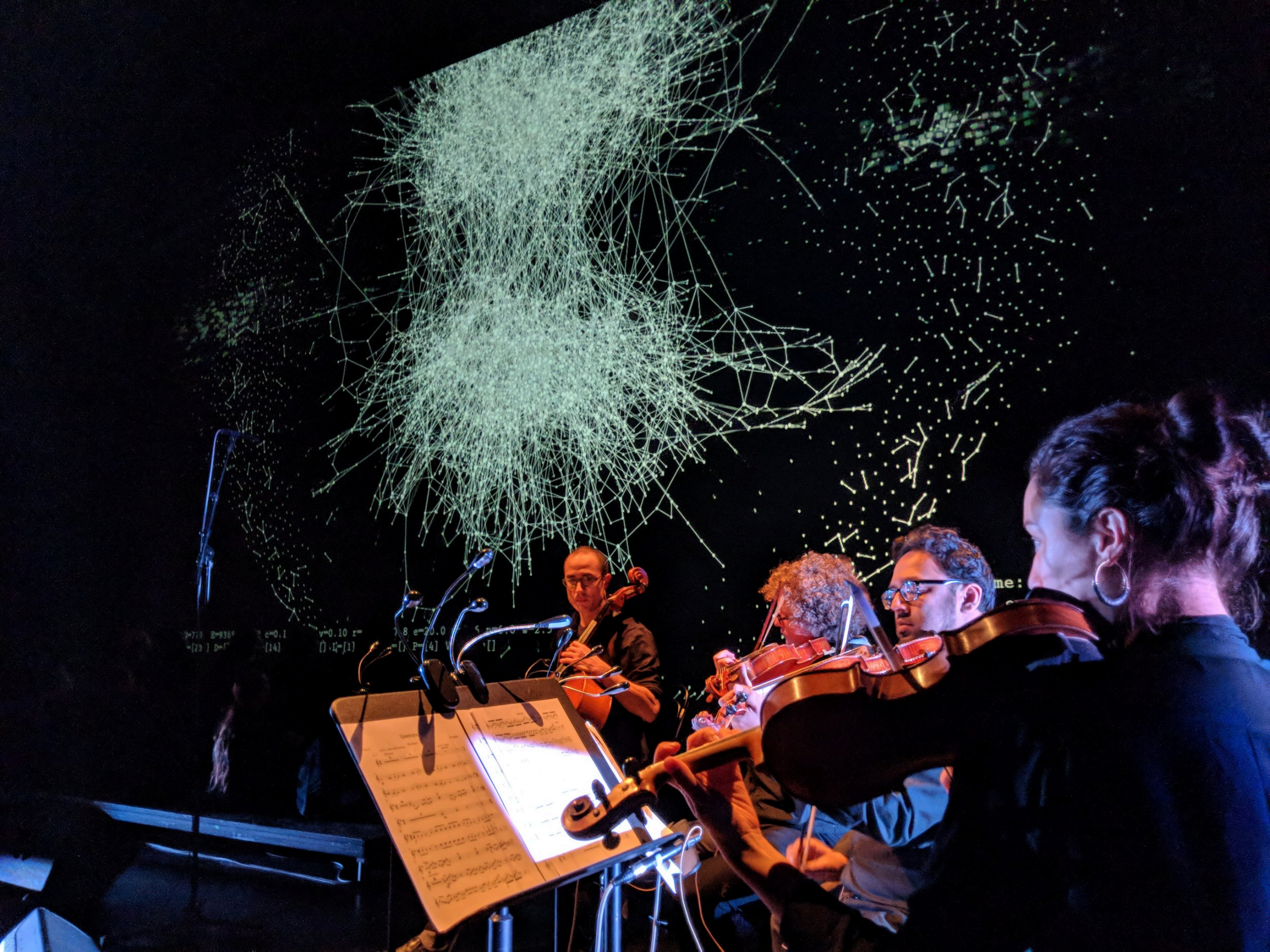


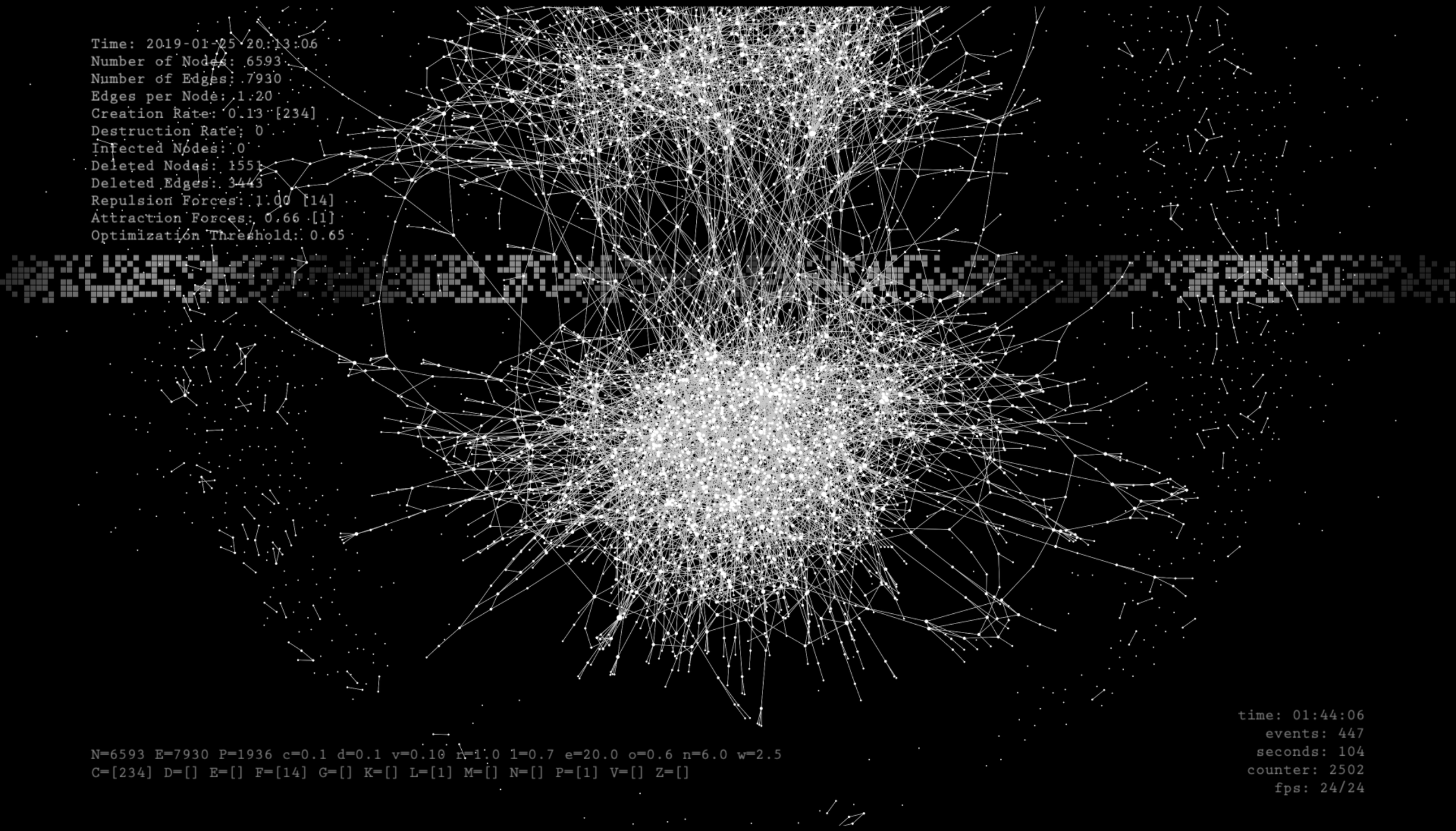






QUANTOPIA
THE EVOLUTION OF THE INTERNET
DJ SPOOKY

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Number of Edges: 7930
Edges per Node: 1.20
Creation Rate: 0.13 [234]
Destruction Rate: 0
Infected Nodes: 0
Deleted Nodes: 1551
Deleted Edges: 3443
Repulsion Forces: 1.00 [14]
Attraction Forces: 0.66 [1]
Optimization Threshold: 0.65
N=6593 E=7930 P=1936 c=0.1 d=0.1 v=0.10 r=1.0 1=0.7 e=20.0 o=0.6 n=6.0 w=2.5
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events: 447
seconds: 104
counter: 2502
fps: 24/24


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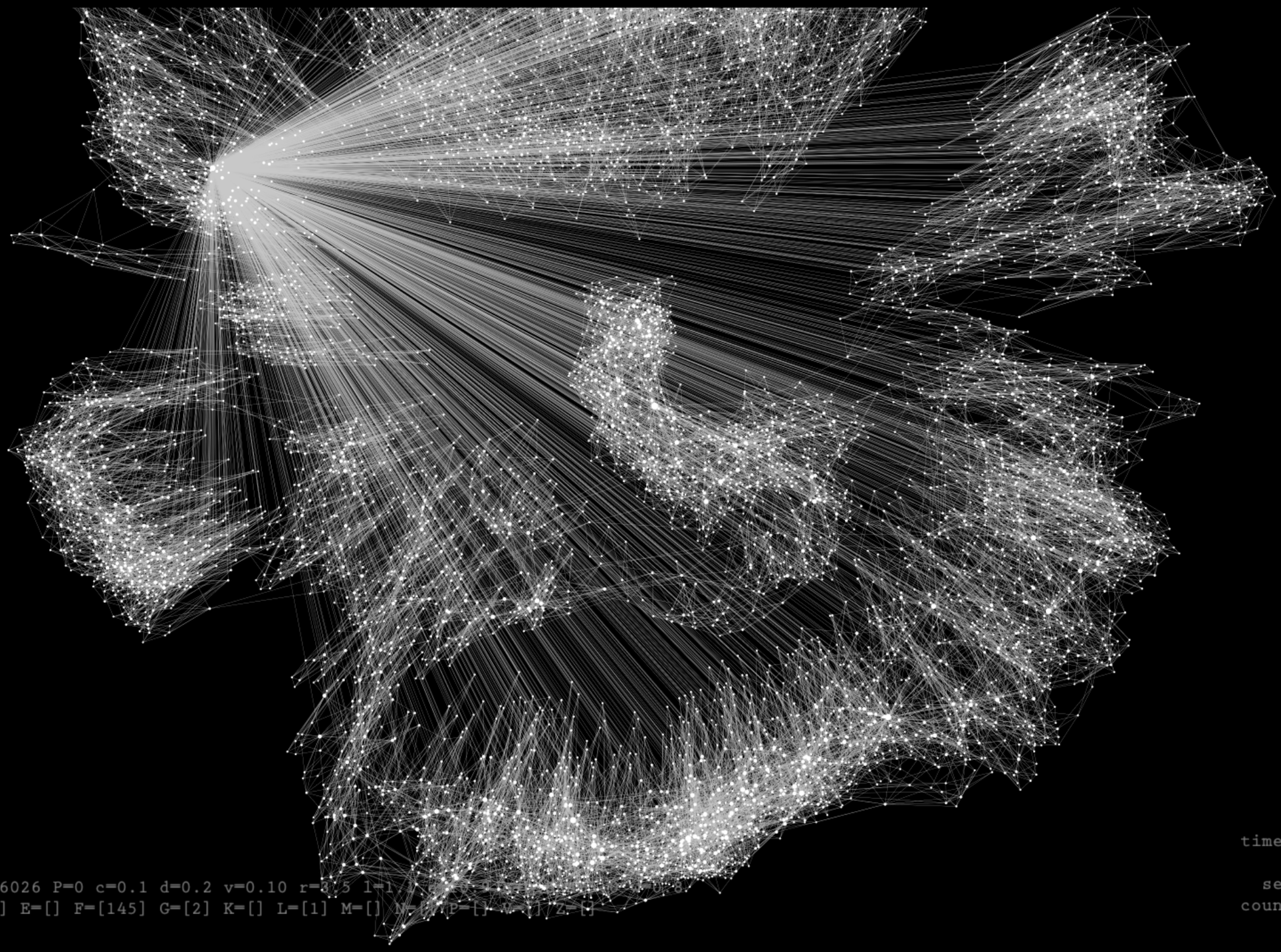

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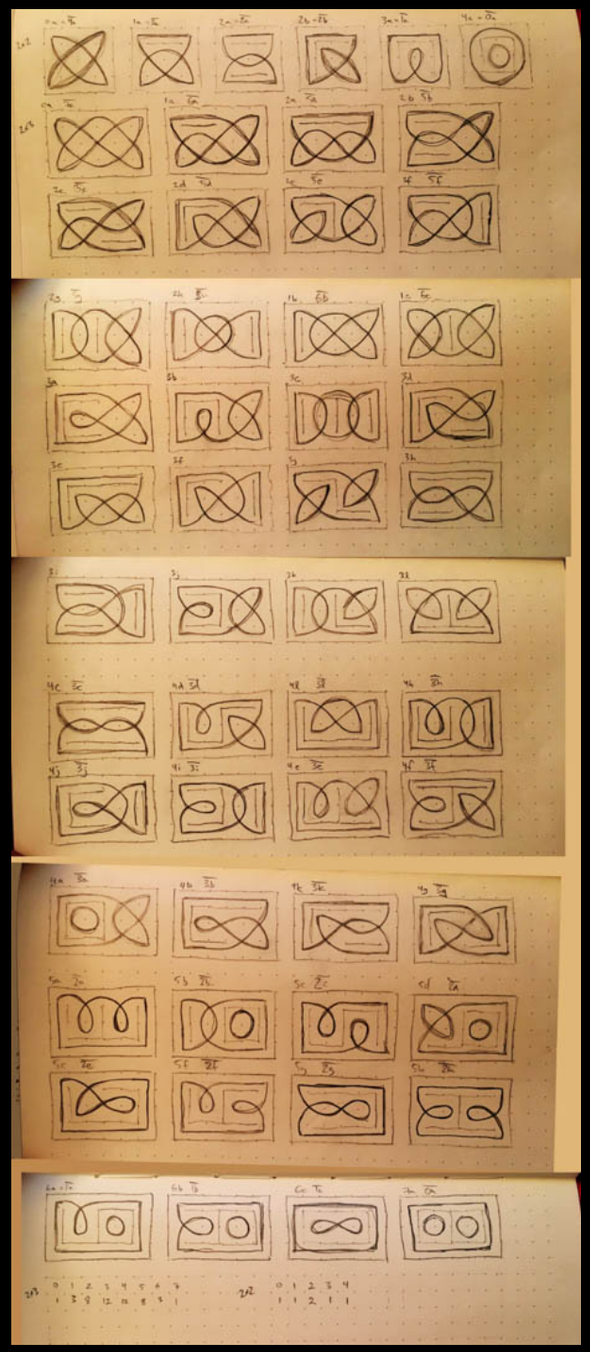

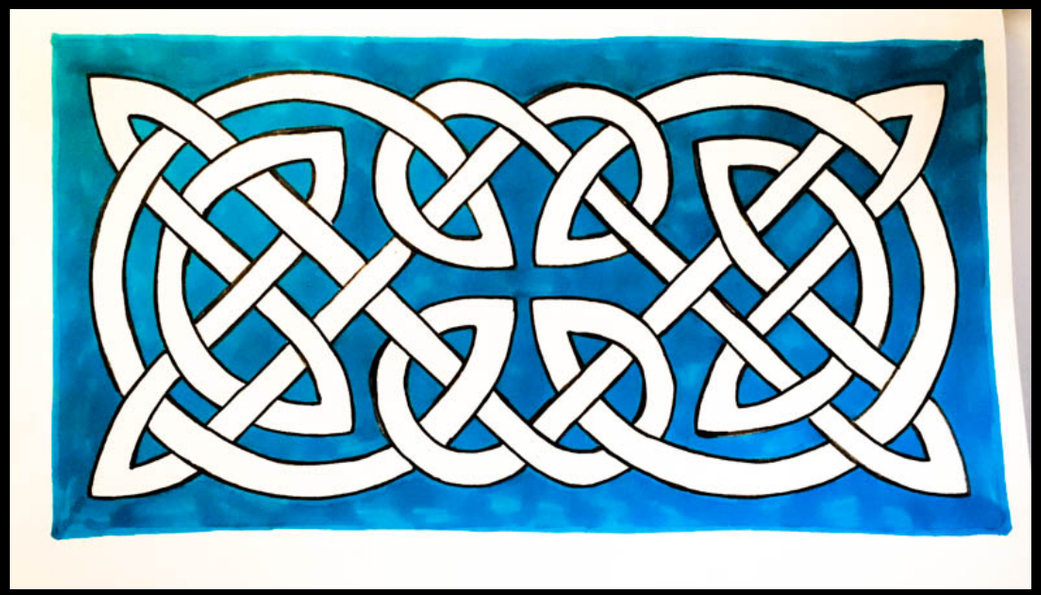

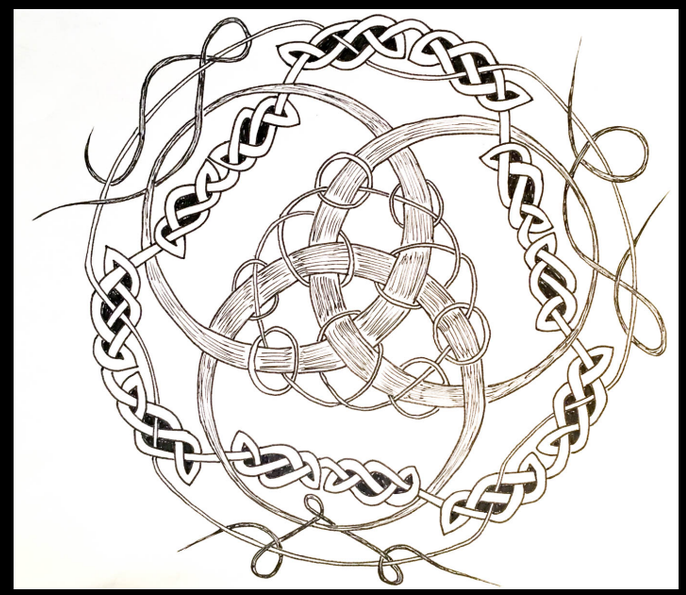



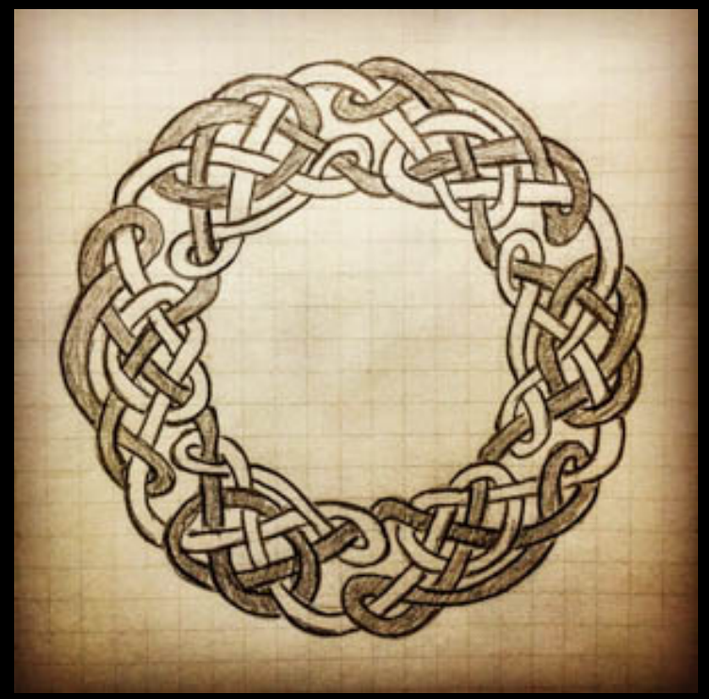





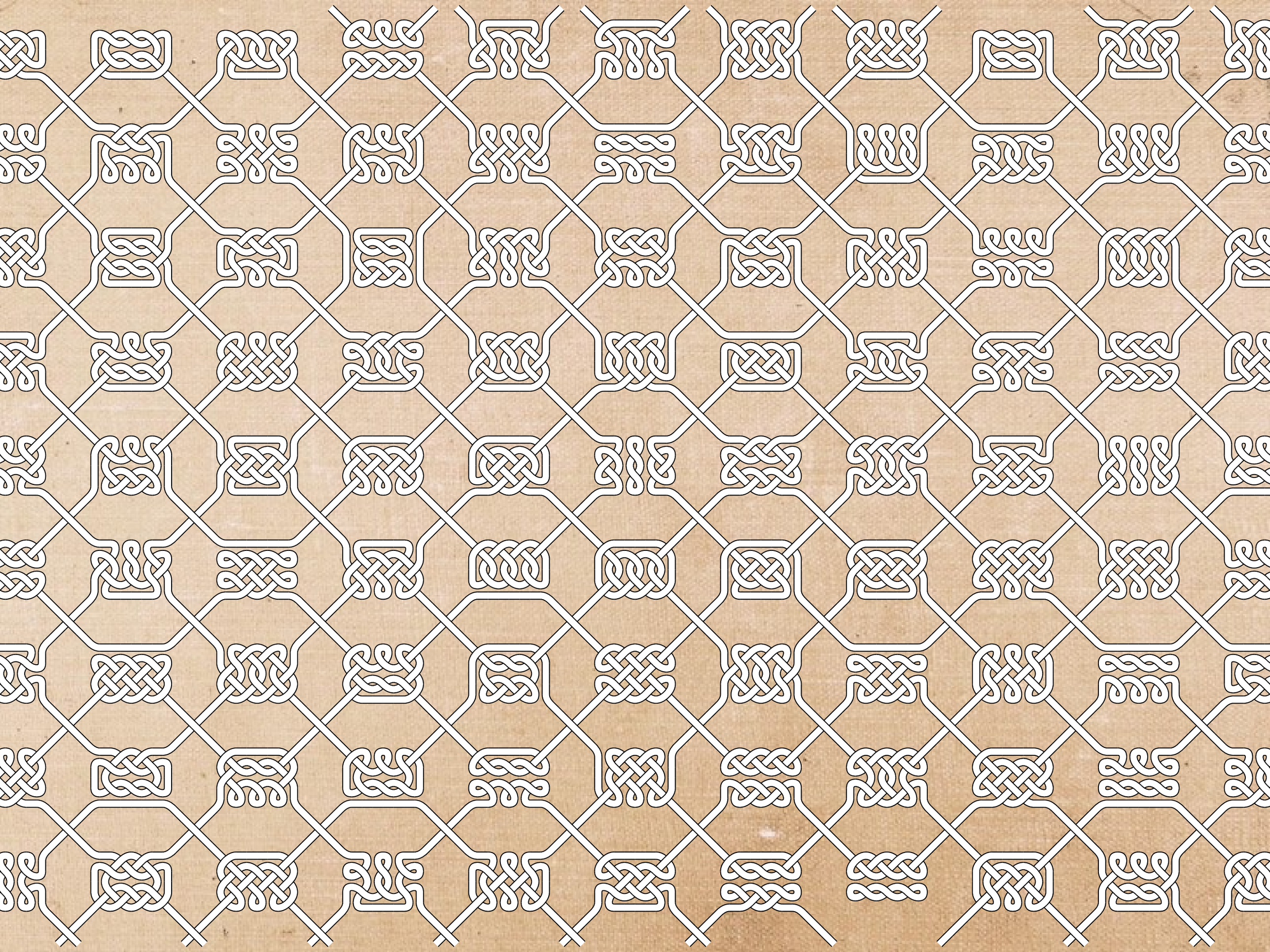

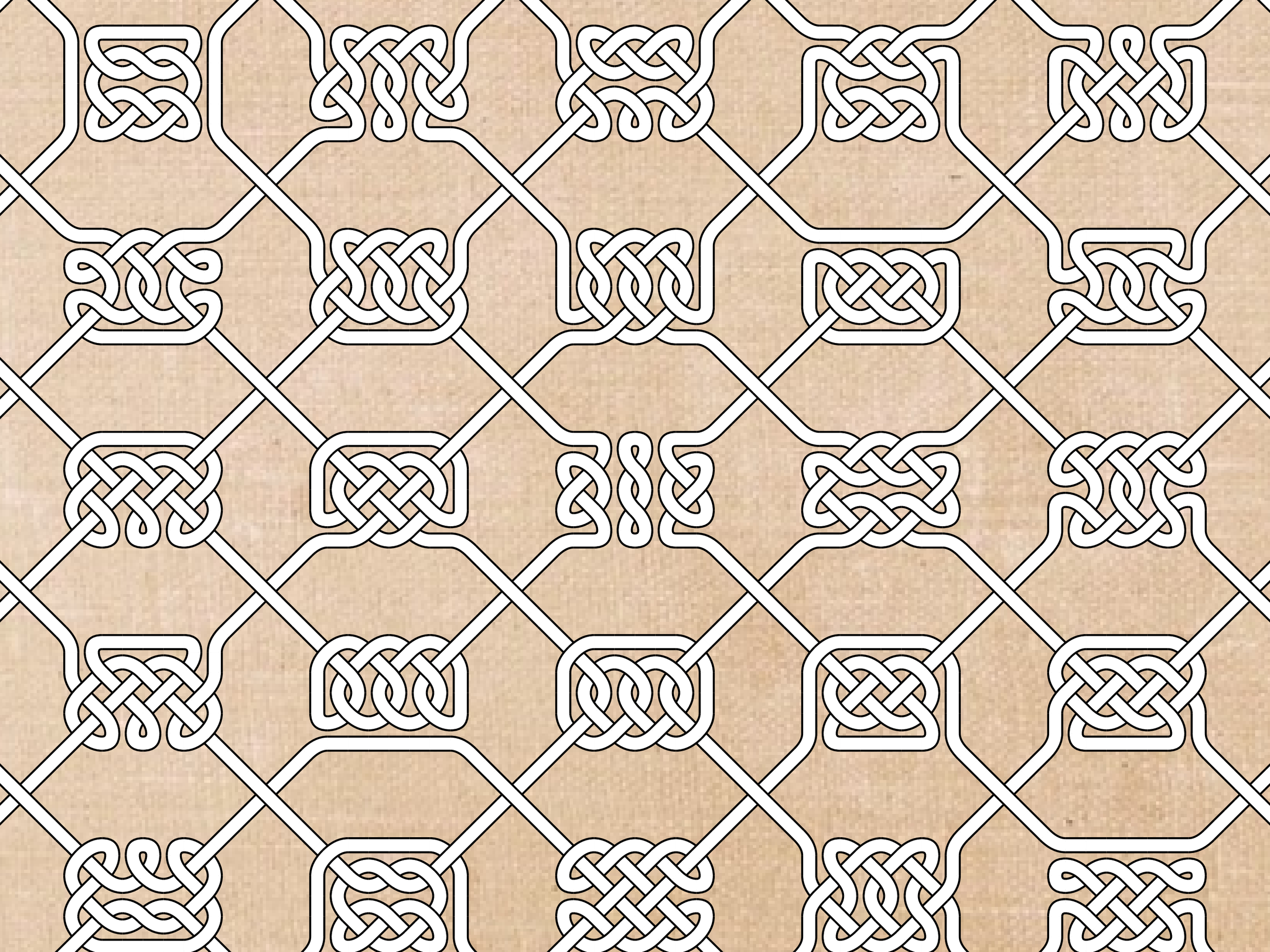

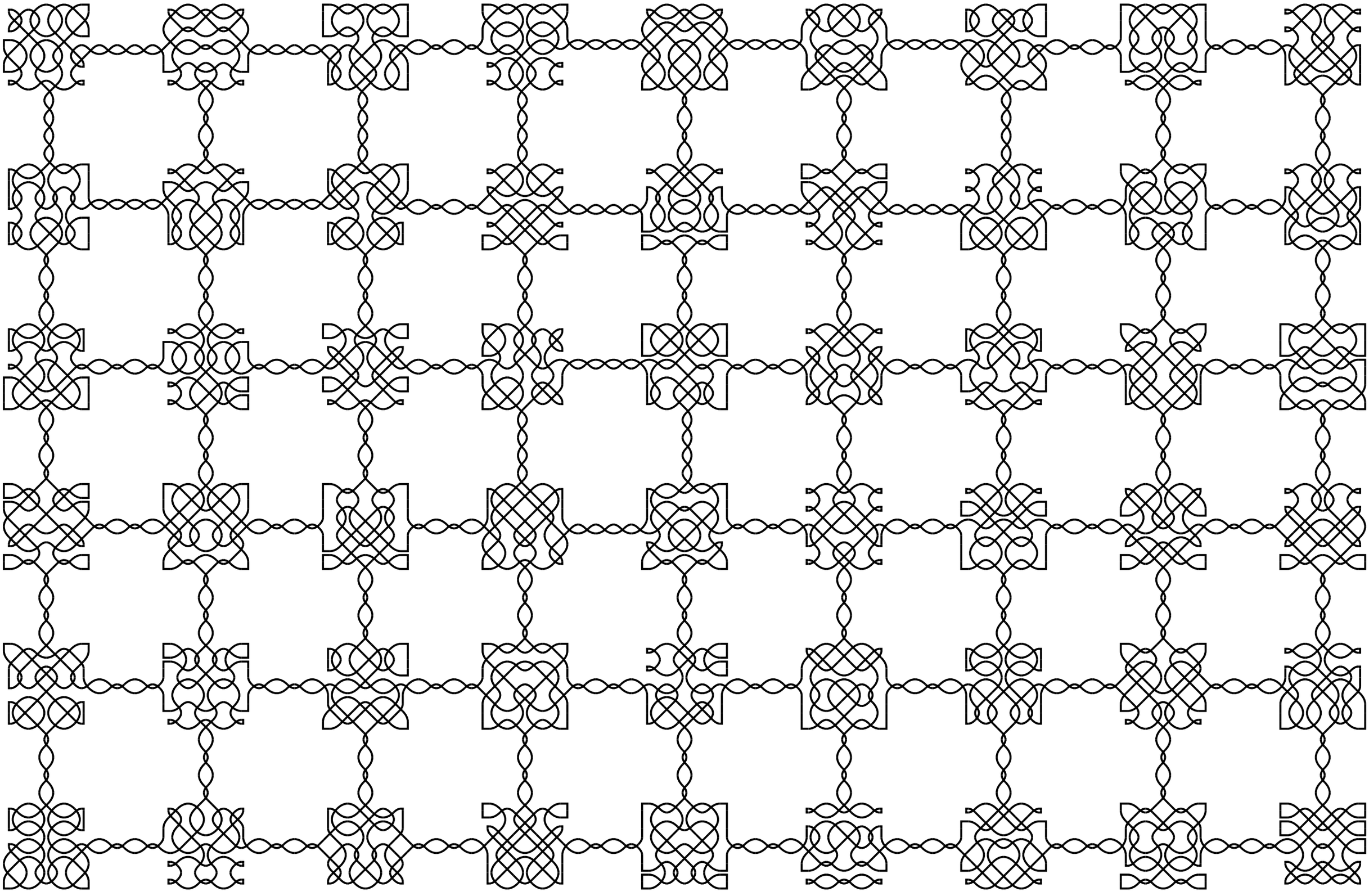

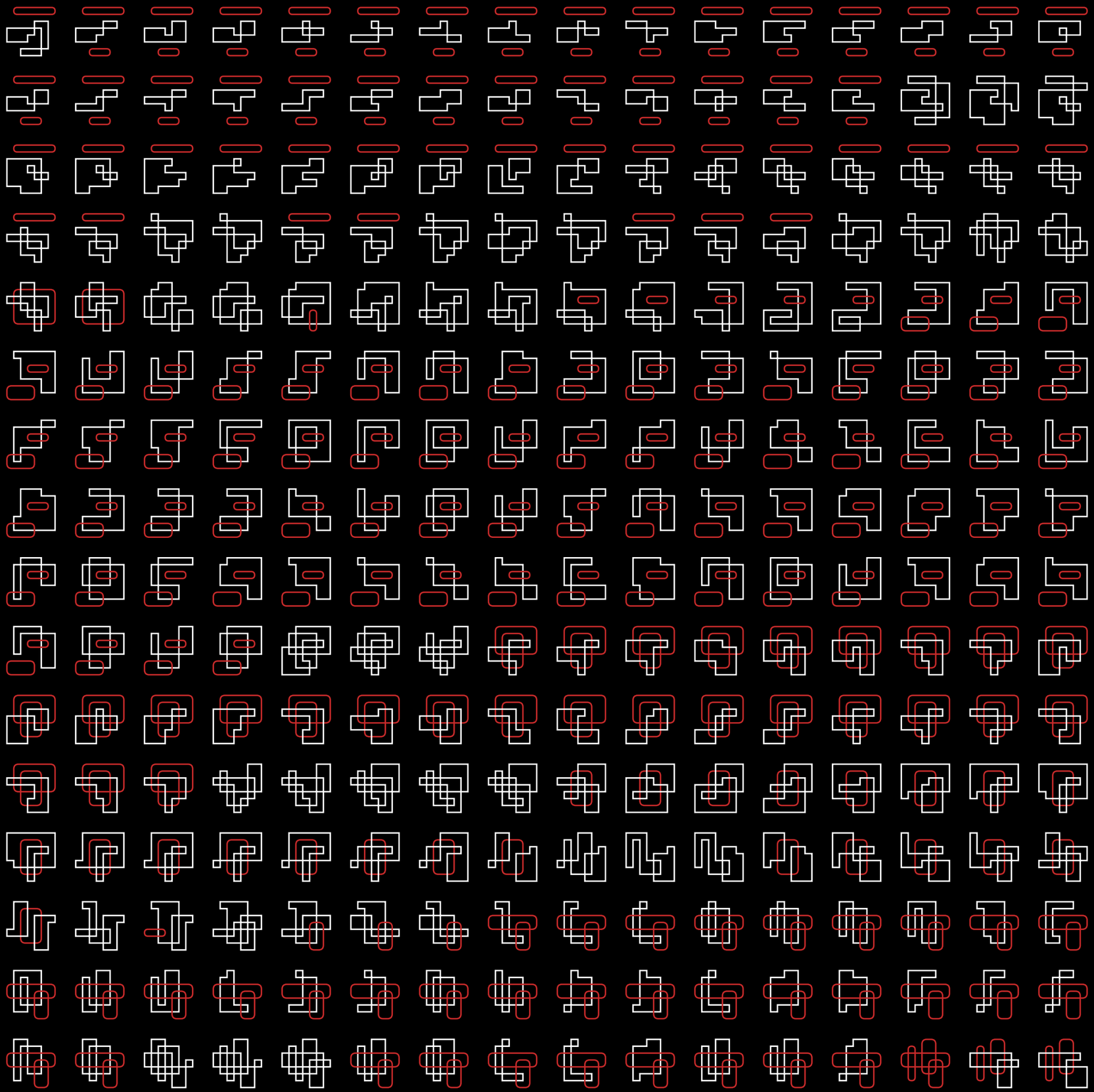



LLRR | 155,699,400 | 10,000,000x

U: 25.0000%
R: 25.0000%
D: 25.0000%
L: 25.0000%

U-1: 12.5105%
U+1: 12.4895%
R-1: 12.5105%
R+1: 12.4895%
D-1: 12.5105%
D+1: 12.4895%
L-1: 12.5105%
L+1: 12.4895%

0: 33.497%
1: 17.802%
2: 33.794%
3: 14.907%



LLRR | 155,382,700 | 1,000,000x

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L: 25.0000%

U-1: 12.5105%
U+1: 12.4895%
R-1: 12.5105%
R+1: 12.4895%
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D+1: 12.4895%
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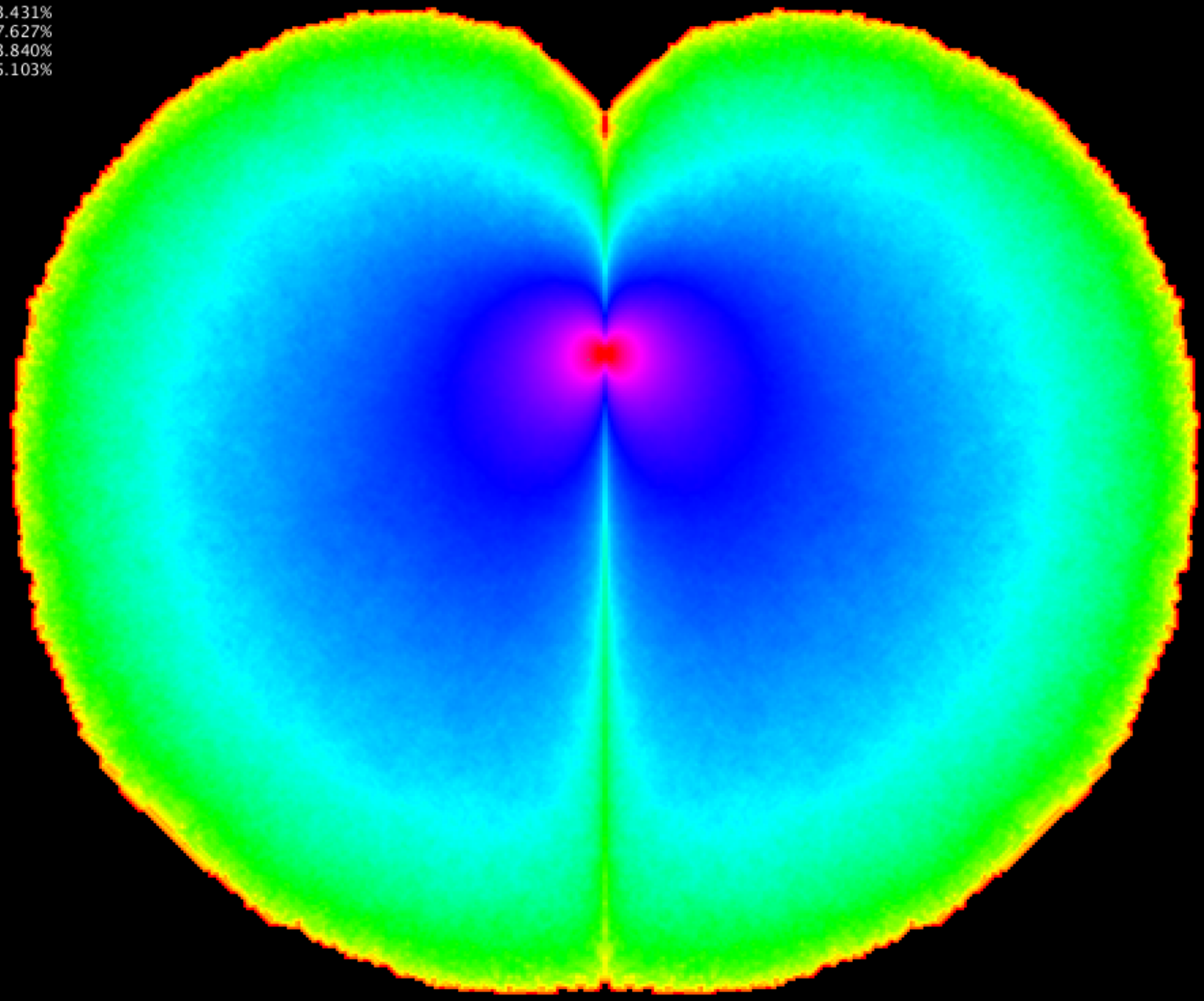
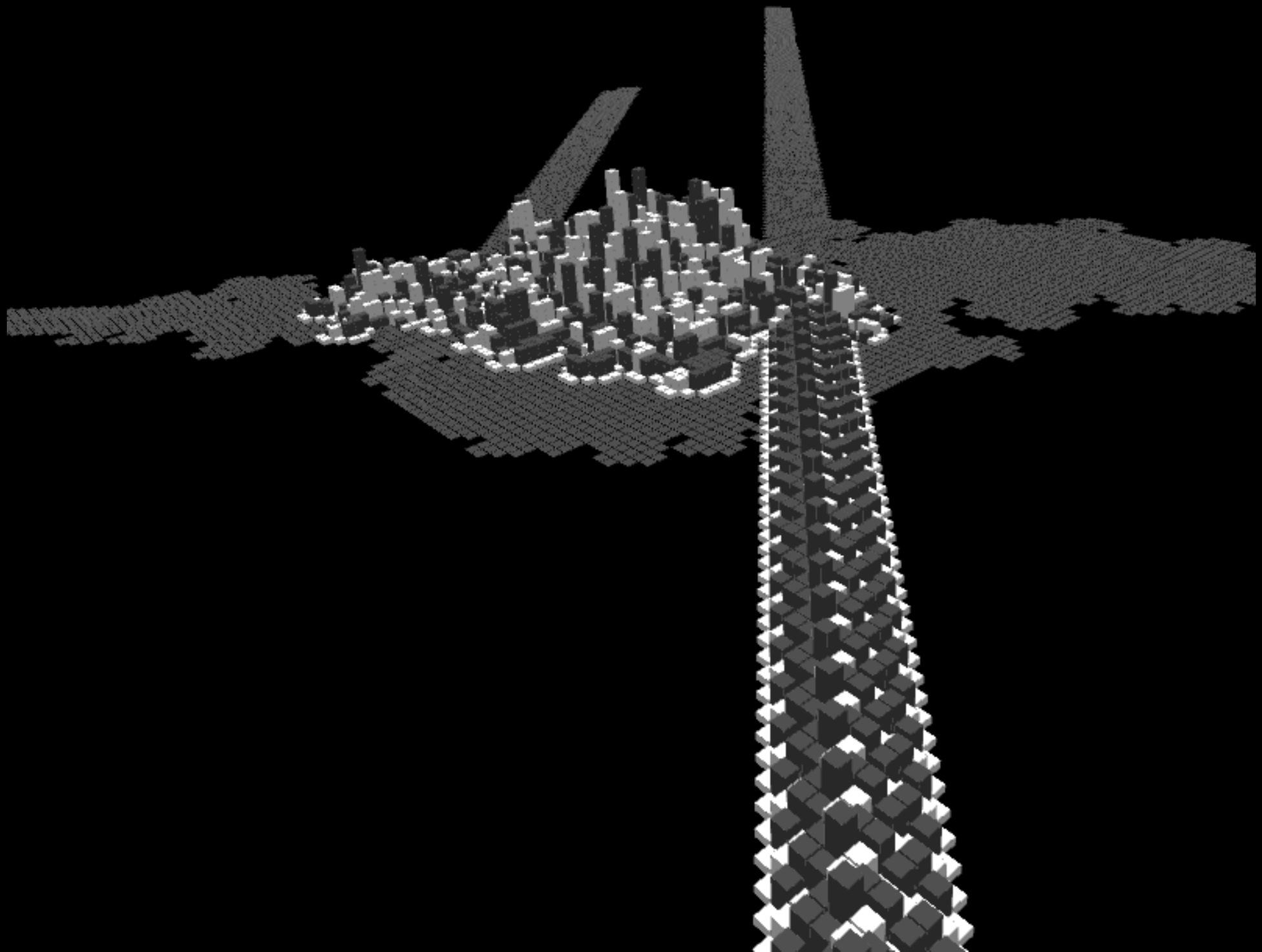
1: 17.627%
2: 33.840%
3: 15.103%

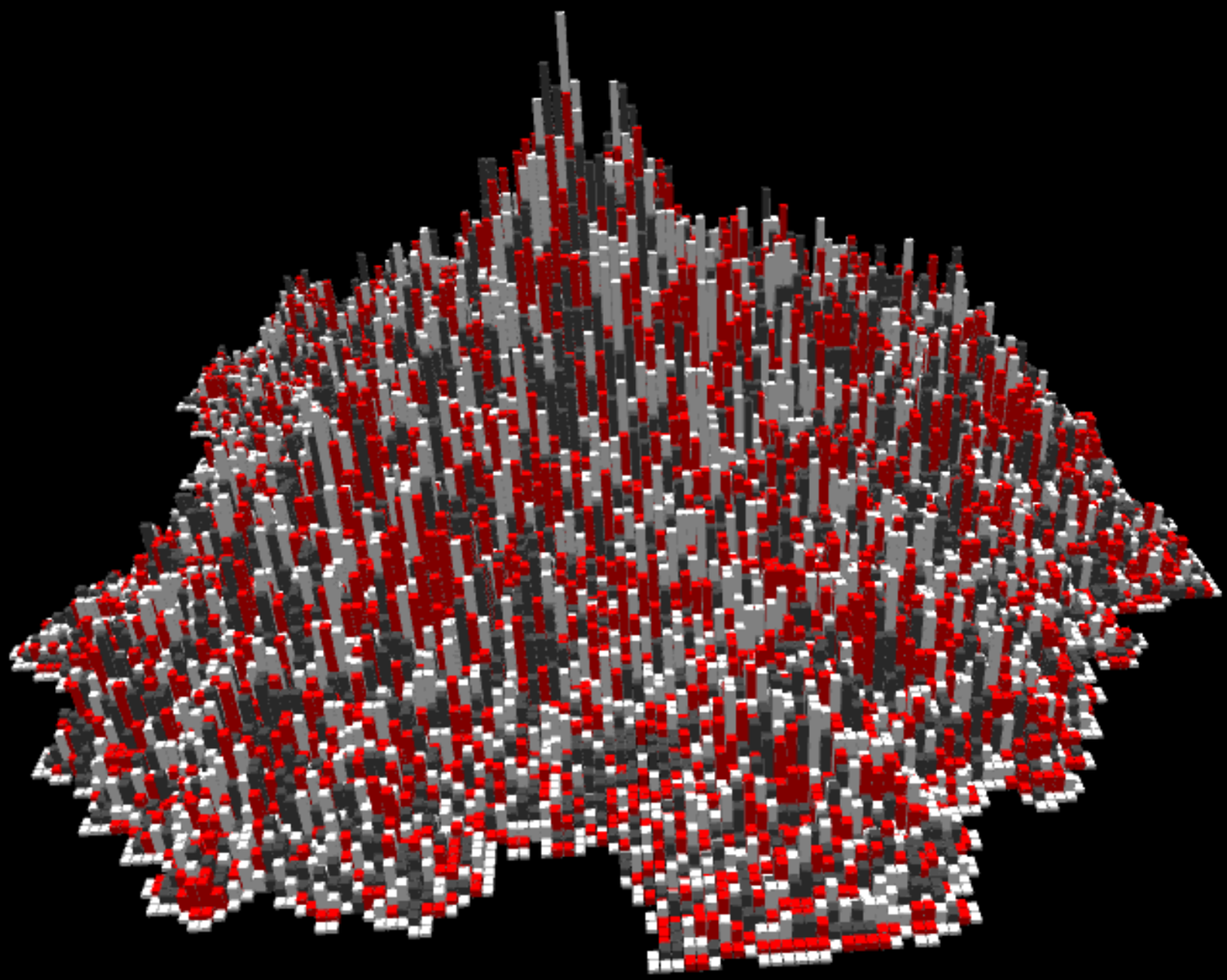


LR | 12583





LFR | 364265



roger antonsen

Associate Professor, Department of Informatics, University of Oslo
Visiting Scholar, University of California, Berkeley

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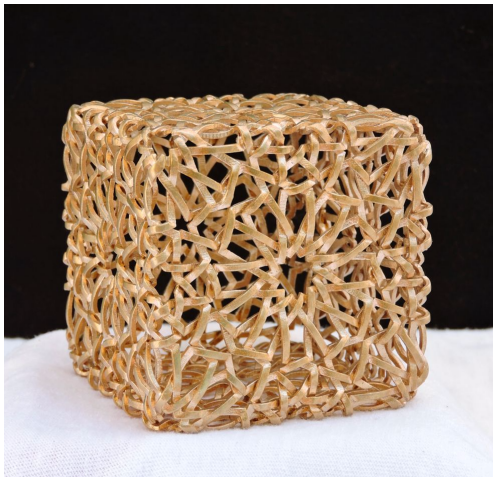
rantonse

David Bachman

Pitzer College

College: pzacad.pitzer.edu/~dbachman/
Art: davidbachman.org

Past Work

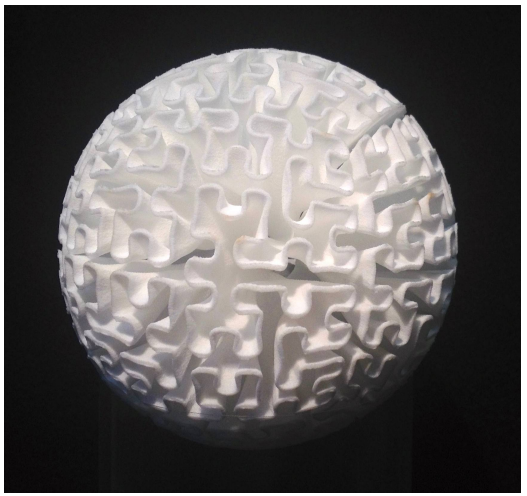






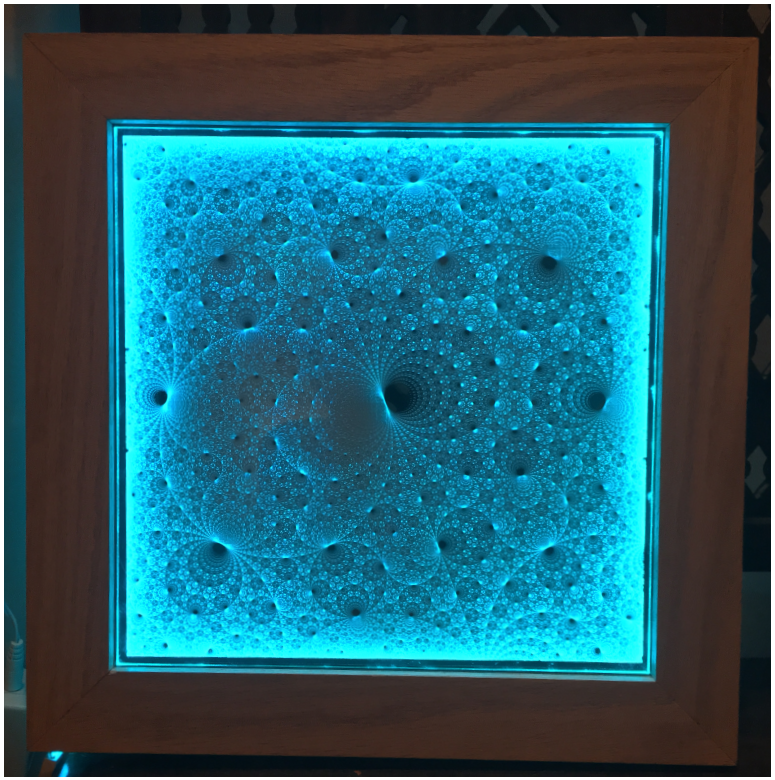


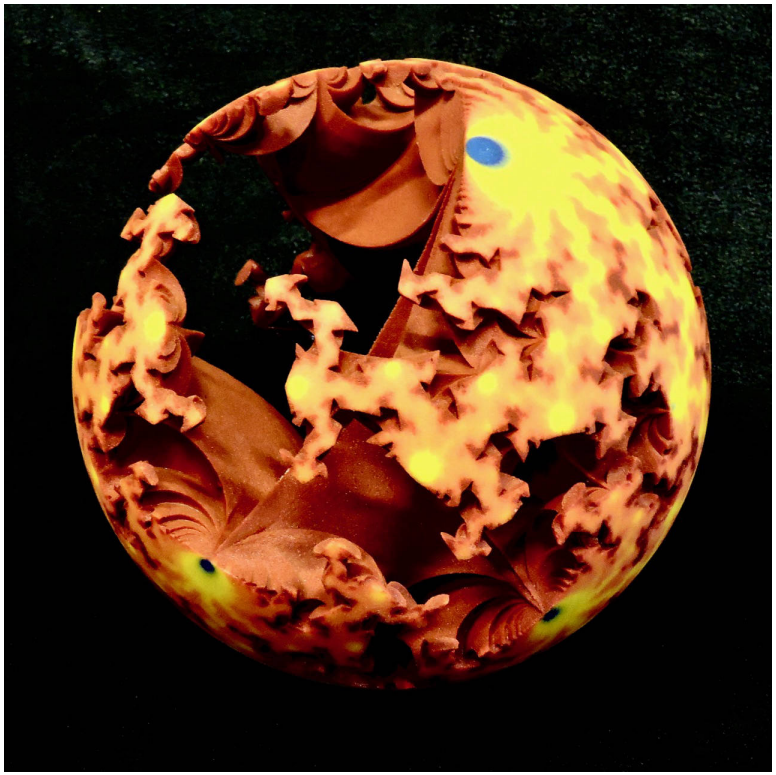




Current Work

(with Saul Schleimer and Henry Segerman)





Tools

Software

- Rhino 3D
  - Grasshopper ***
    - Kangaroo
    - T-Splines
    - Anemone
- Python
- SageMath/Mathematica
- Meshmixer

Hardware

- Many 3D printers
- Glowforge Lasercutter
- Some CNC milling
- Analog:
  - Lots of woodworking
  - Some casting
    (glass, ceramic, resin)

Hello, I'm Sebastian.

Sebastian Bozlee

University of Colorado, Boulder

Between September 5th and 6th.

Interests and skills

- I am a PhD candidate in mathematics at the University of Colorado, Boulder
- My research area is algebraic geometry, especially algebraic curves, log geometry, and tropical geometry
- Some experience with Photoshop, Inkscape, Blender scripts, 3D Printing with a Lulzbot machine, Python, C/C++, Mathematica, OpenGL, p5.js, OpenVR, CUDA

Some old work

- 3D Printing
- p5.js
- Projective curve viewer: Video link
- Projective surface viewer: Video link

Some thoughts for the future

- Polish projective viewer projects
- Complex points of planar curves

Danielle Amethyst Brake

University of Wisconsin-Eau Claire
danielleamethyst.org
danielleamethystbrake@gmail.com

University of Wisconsin Eau Claire



The Power of AND

Research

Interests

- Numerical algebraic geometry – solving systems of polynomials numerically
- Algebraic curves and surfaces
- Replicating the Herwig Hauser gallery of algebraic surfaces

Software projects

- Bertini 2 – for numerical algebraic geometry
- Bertini_real – for real algebraic sets
- Paramotopy – for parameterized polynomial systems

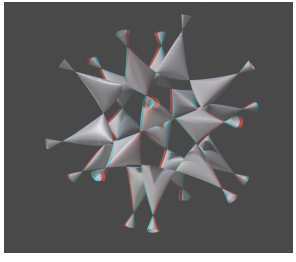
Skills and hobbies

Computer programming:

- C++ <I heart templates>
- Matlab
- Python

Visualization:

- Blender



3D printing:

- FFF 3D printing
- OpenSCAD
- Algebraic surfaces using Bertini_real
- Printing earrings and pendants in TPU

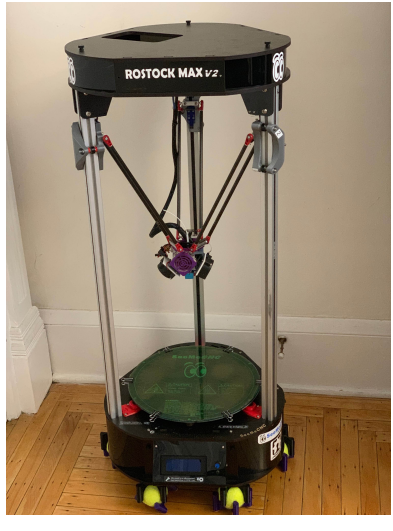
Electronics:

- Arduino-based

Things I brought with me to ICERM

- A 3D printer –
  I can print with most materials, including abrasive materials like steel and carbon fiber PLA.
  build volume: 270mm-diameter cylinder, $\approx$ 250mm tall

- Tools –
  for making wire jewelry and cleaning 3D prints, as well as a caliper, scale, hot glue gun, ...



Goals

- start to make a pop-up book – looking for a collaborator!
- fuse my interest in algebraic surfaces with novel ideas
- help others with 3D printing and electronics
- learn about machine embroidery
- learn how to knit
- Find something completely new to work on



Diagrammatic Algebra

J. Scott Carter
de-institutionalized[1]

ICERM Fall 2019

Diagrammatic Algebra

J. Scott Carter
de-institutionalized[1]

ICERM Fall 2019
1. I learned this joke from Lee Rudolph.

Goals and Aspirations

- Thanks to the Organizers

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- Diagrammatic Algebra really is a thing

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- I have some facility with Illustrator and Tikzpicture

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- I hope to gain better exposure and technical skill for computer assisted drawings/animations

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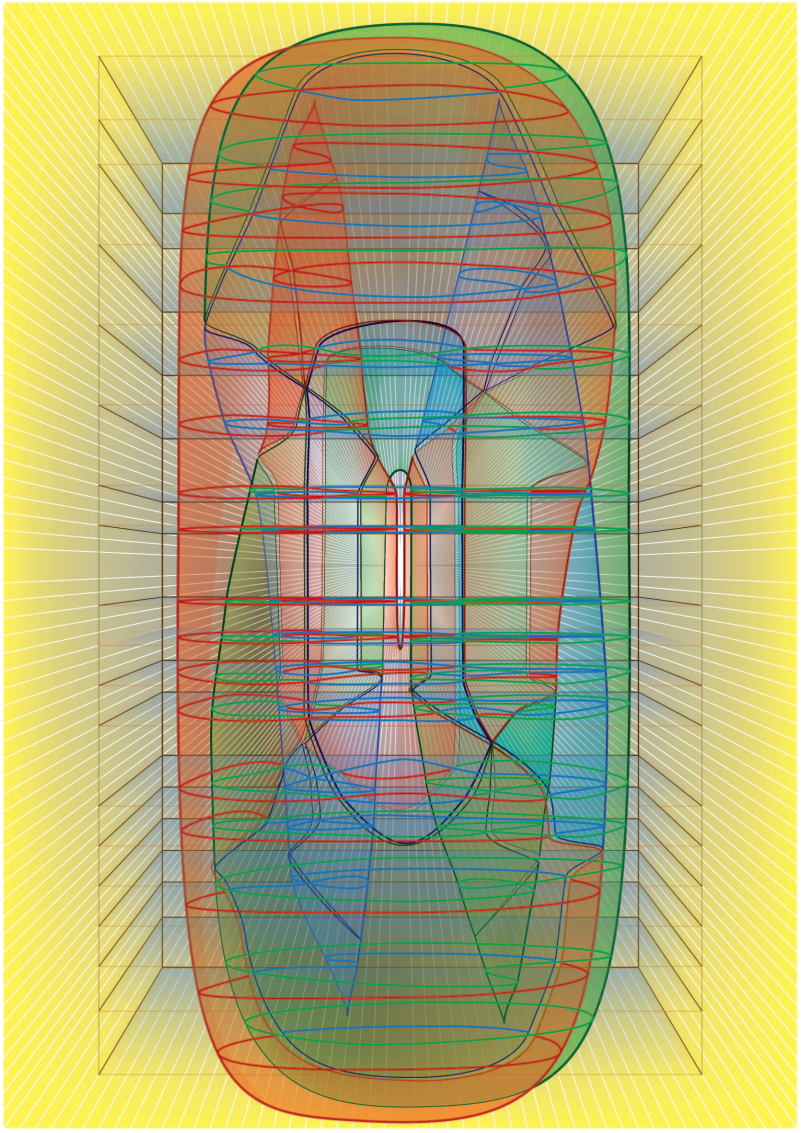
- I hope to learn Rhino (cost!/discounts?)
- I hope to co-develop 3-D pieces of Reid. moves for snap together buildings of surface braids.
- I hope to gain better exposure and technical skill for computer assisted drawings/animations
- I will finish a co-authored book with Seiichi Kamada on diagrammatic algebra.

So too little to say and too much time to say it in.

So too little to say and too much time to say it in. Wait!

So too little to say and too much time to say it in. Wait! Switch that.

Featured work



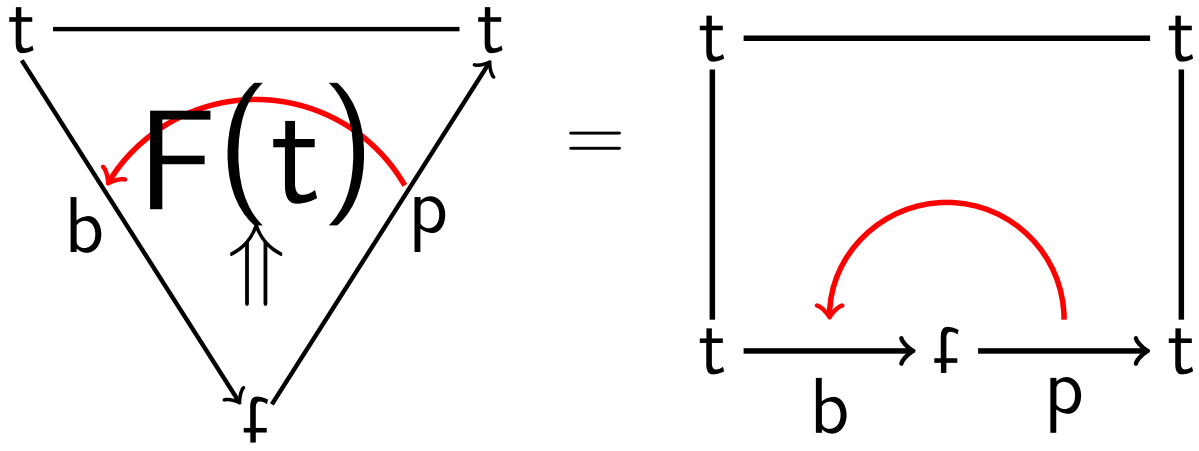
The illustration above is a chart of the 2-twist spun trefoil

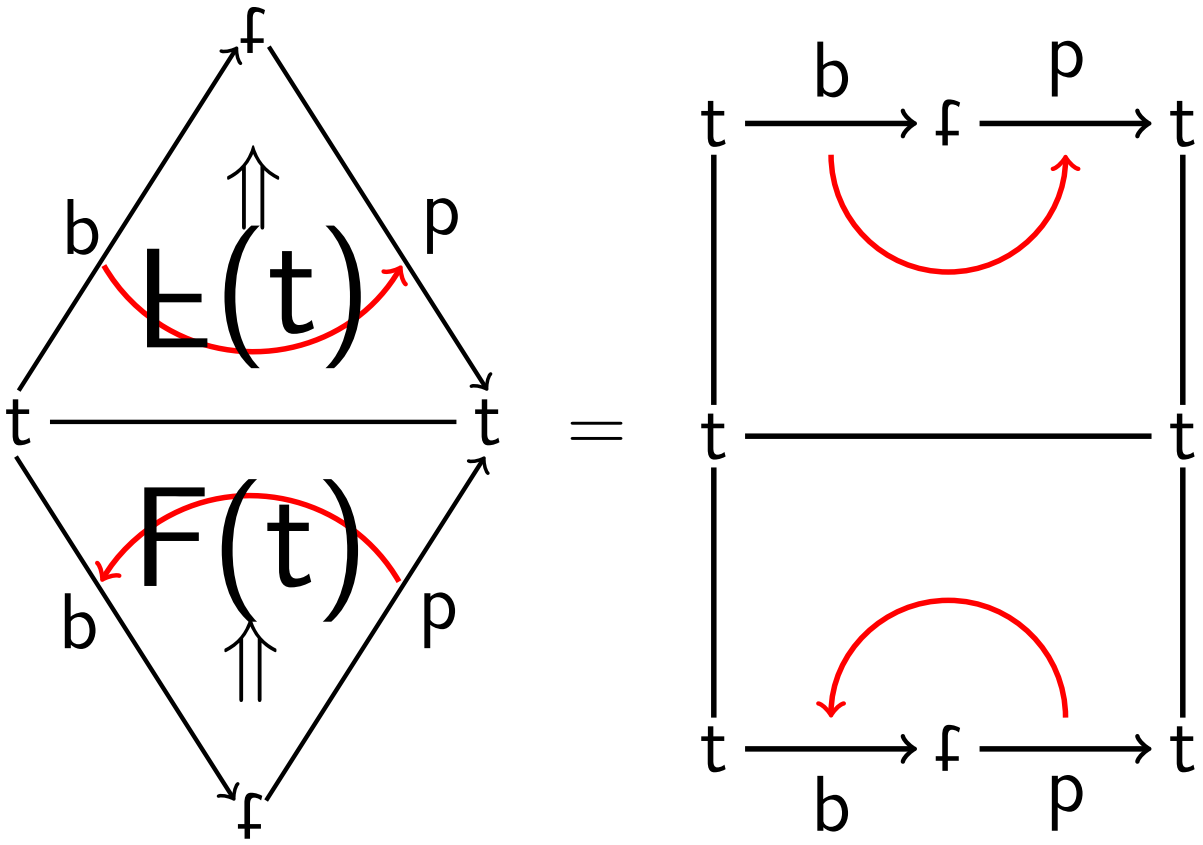
The illustration above is a chart of the 2-twist spun trefoil — a knotted sphere in 4-dimensional space.

The illustration above is a chart of the 2-twist spun trefoil — a knotted sphere in 4-dimensional space. With Masahico Saito and Joachim Rieger, I developed movie move versions of the Roseman moves.

The illustration above is a chart of the 2-twist spun trefoil — a knotted sphere in 4-dimensional space. With Masahico Saito and Joachim Rieger, I developed movie move versions of the Roseman moves. Saito, Jelsovsky, Kamada, Langford, and I defined quandle cocycle invariants.

Samples from DA

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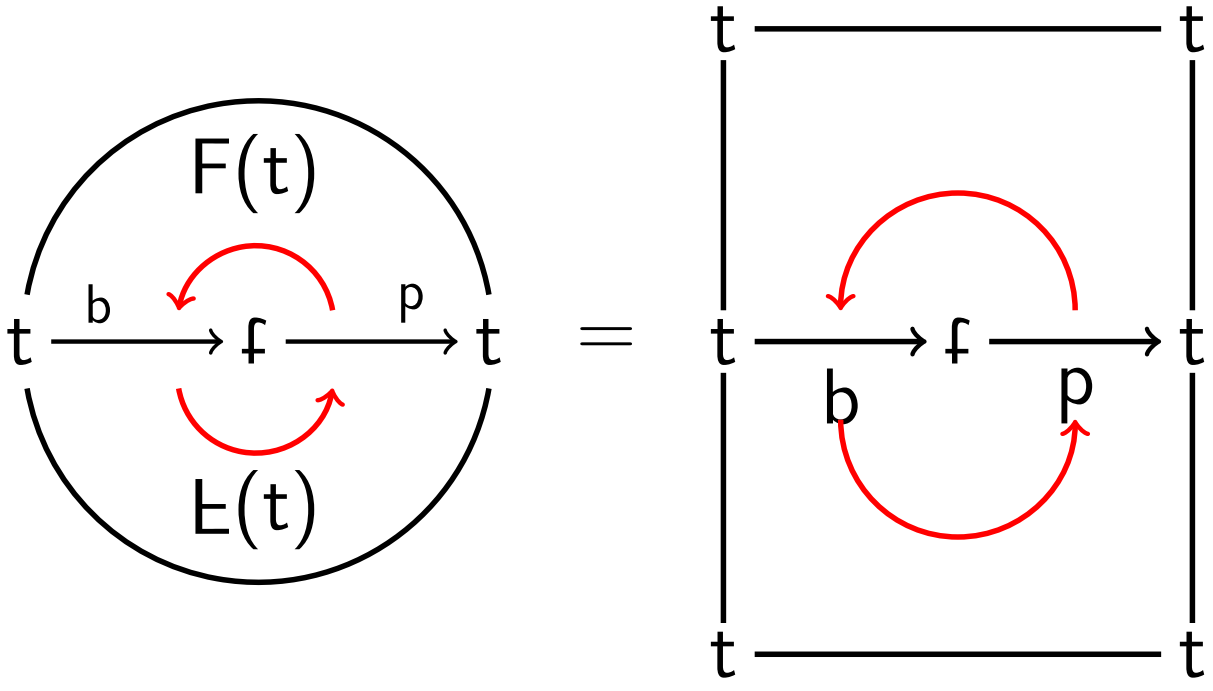
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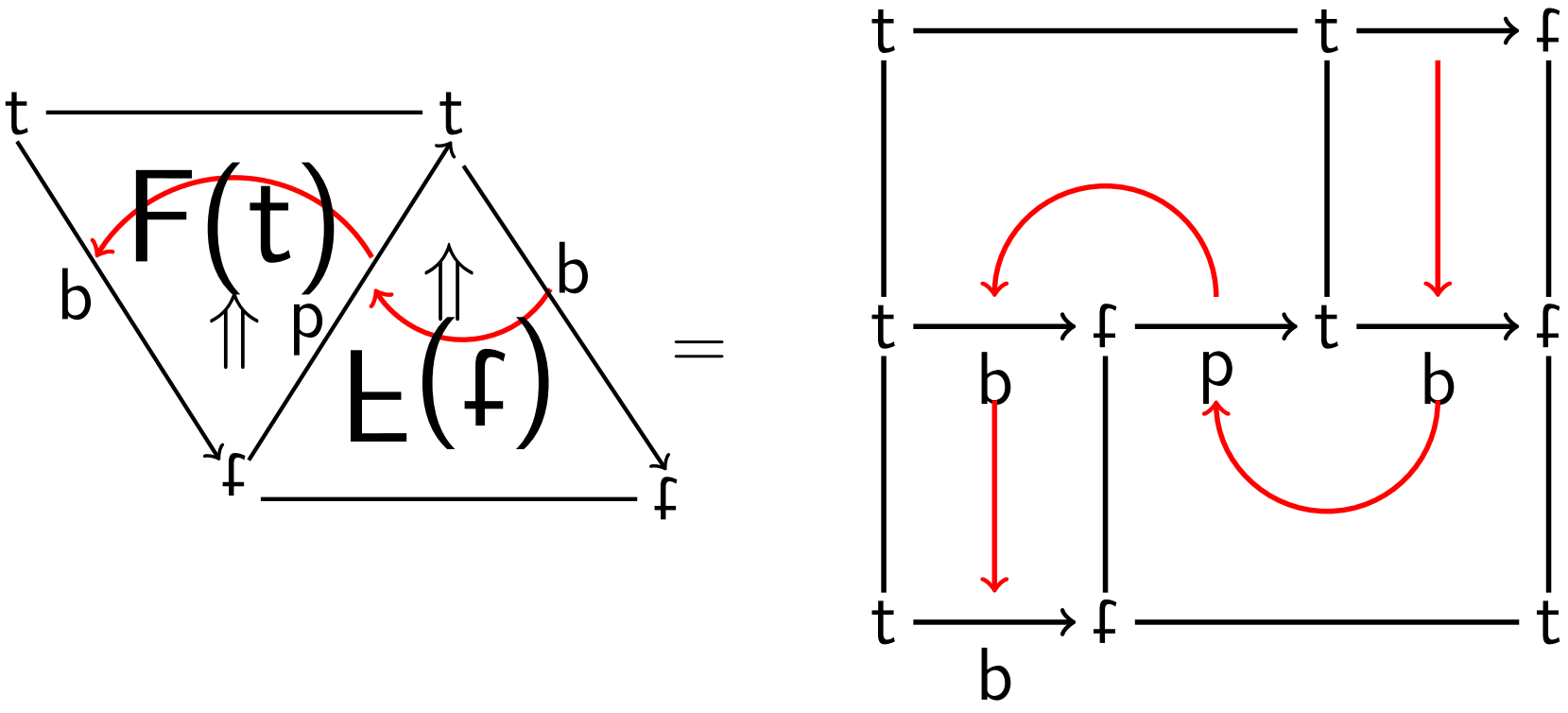
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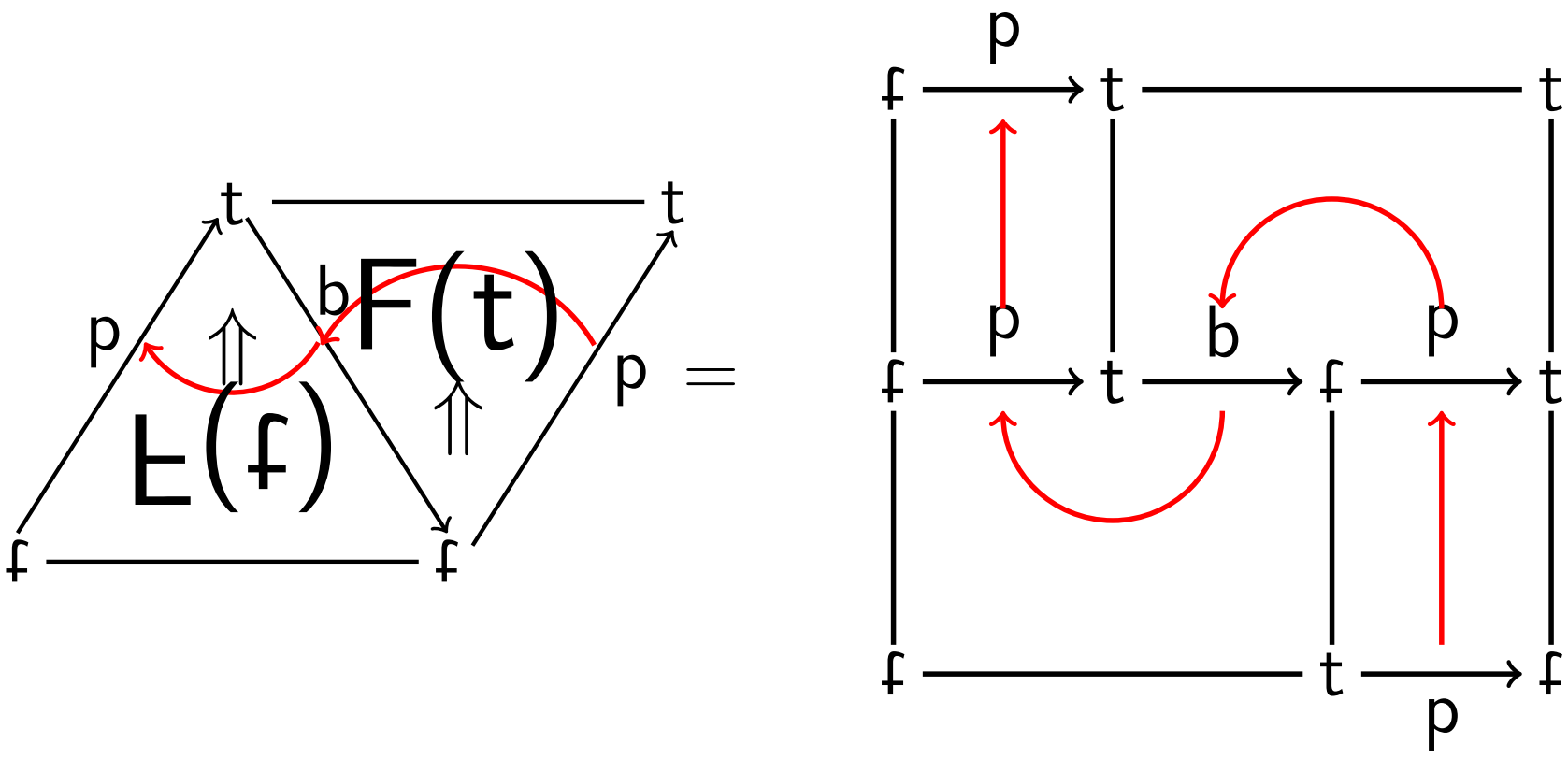
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Rémi Coulon

RESEARCHER

CNRS / Université de Rennes
France

Rémi Coulon

MATERIAL FOR POPULARIZATION EVENTS

- 3D printing
- Laser cut
- Imaging
  (Python, Processing, Blender)
- Handiwork…



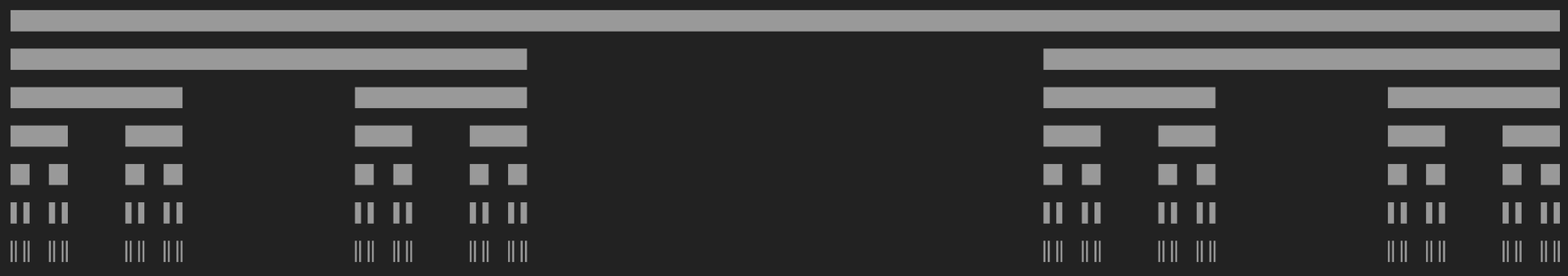
EXAMPLE : ANTOINE'S NECKLACE

EXAMPLE : ANTOINE'S NECKLACE

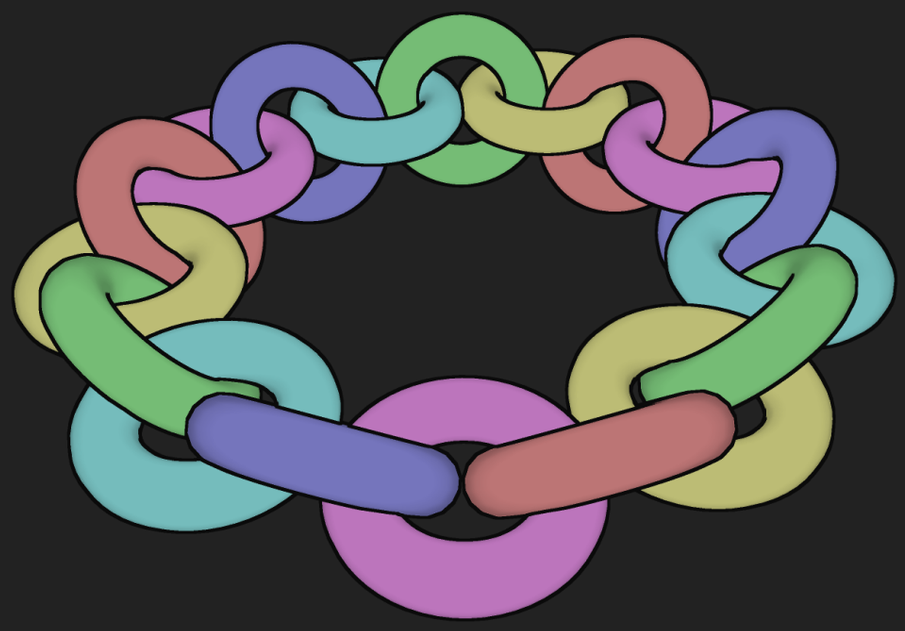
Cantor set

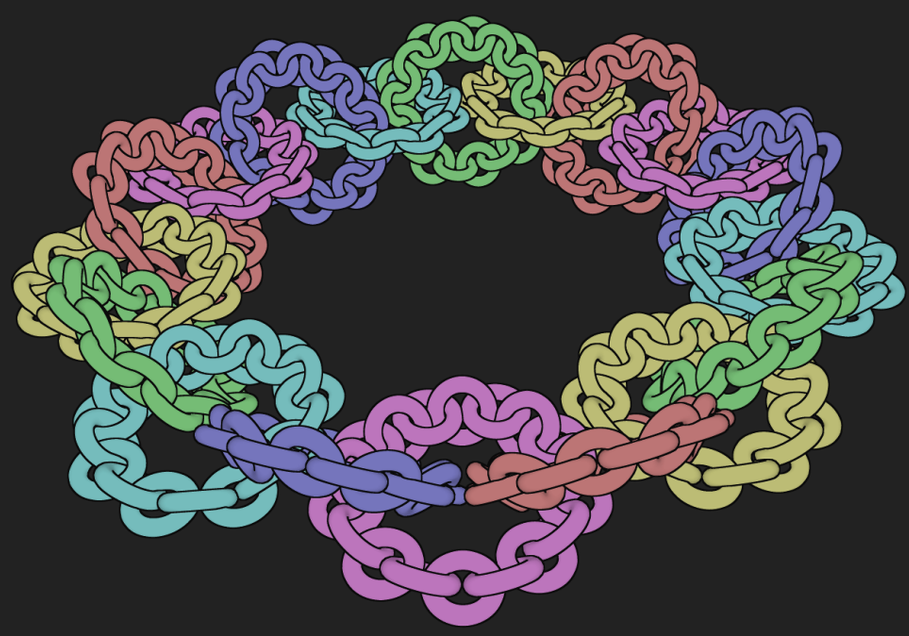
EXAMPLE : ANTOINE'S NECKLACE

Cantor set



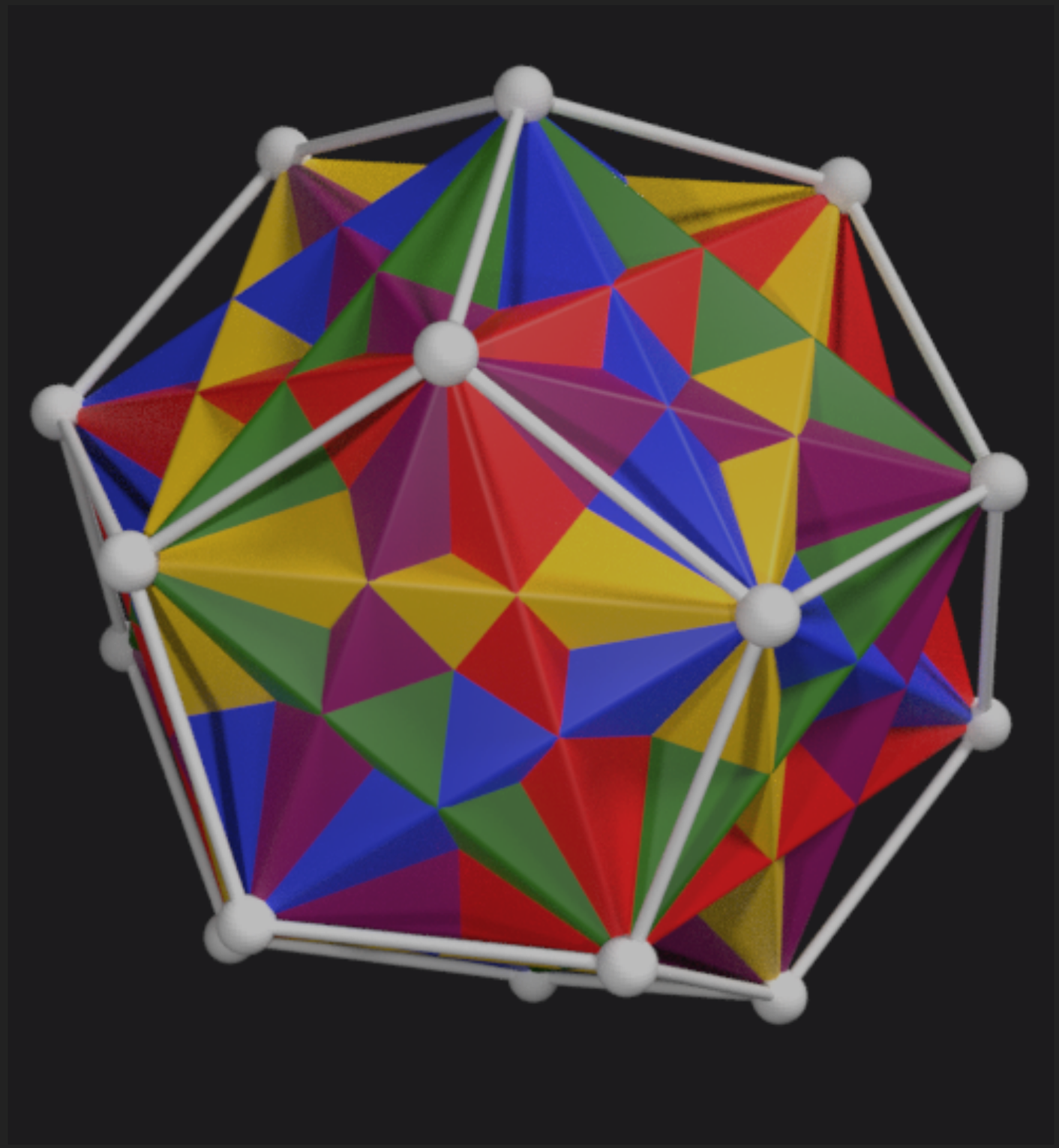
A special embedding of the Cantor set in the 3D space





SOME MOTIVATIONS

- Interface between ***symbolic computation system*** and ***3D imaging software***
- e.g. SageMath and Blender
- Model-View-Controller architecture



EMILY DONOVAN

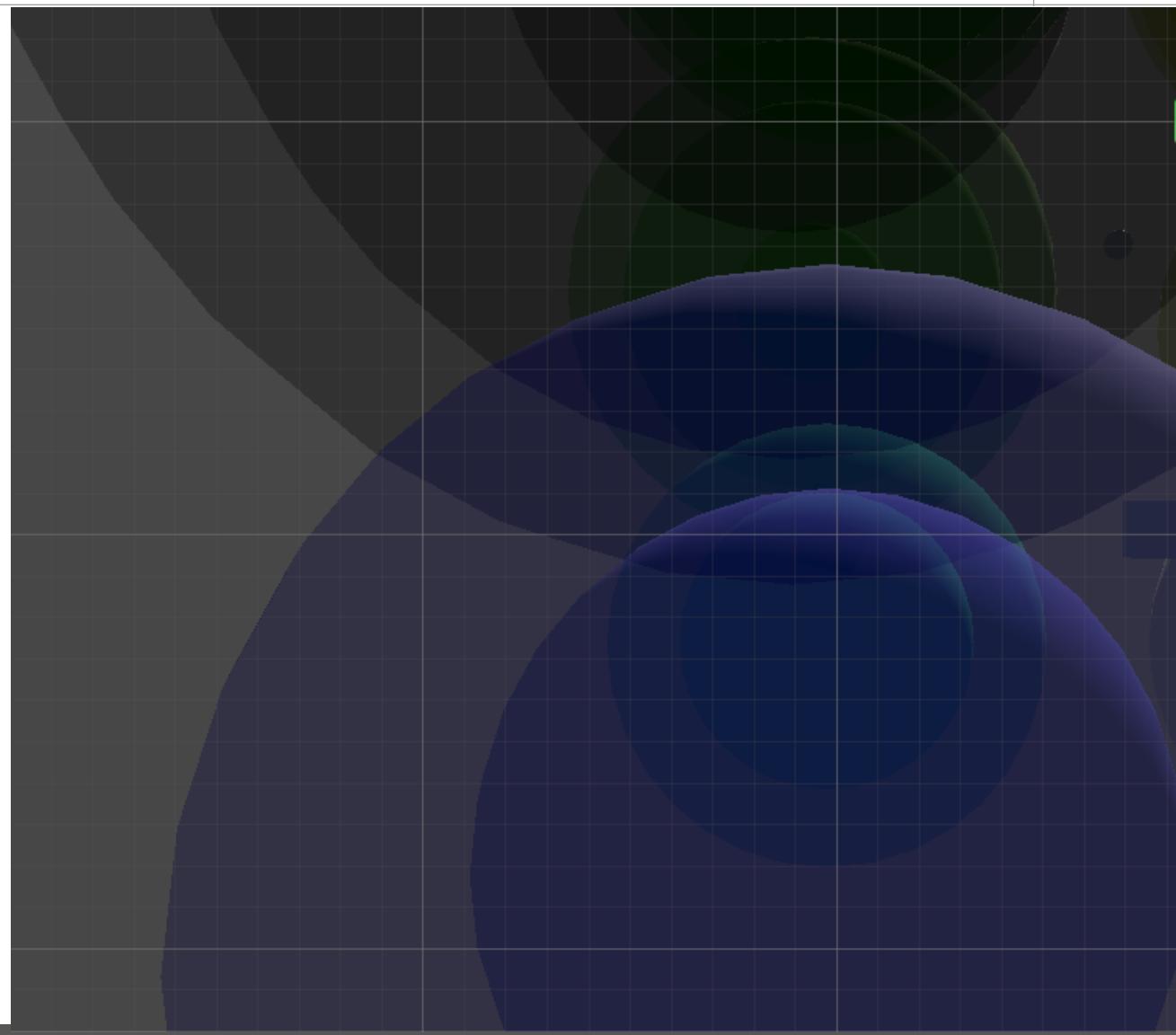
QUEEN MARY
UNIVERSITY OF LONDON



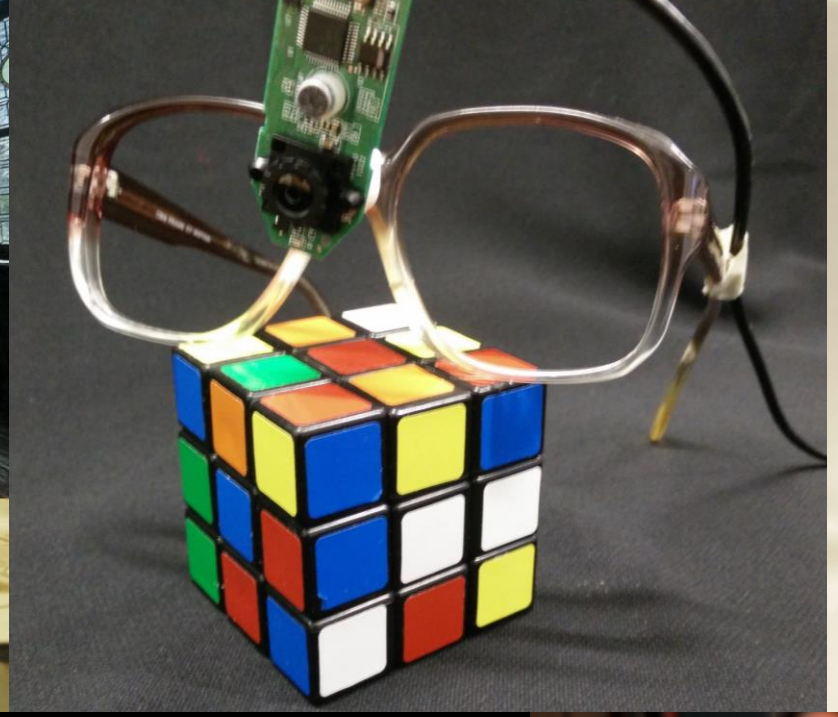
MEDIA & ARTS
TECHNOLOGY

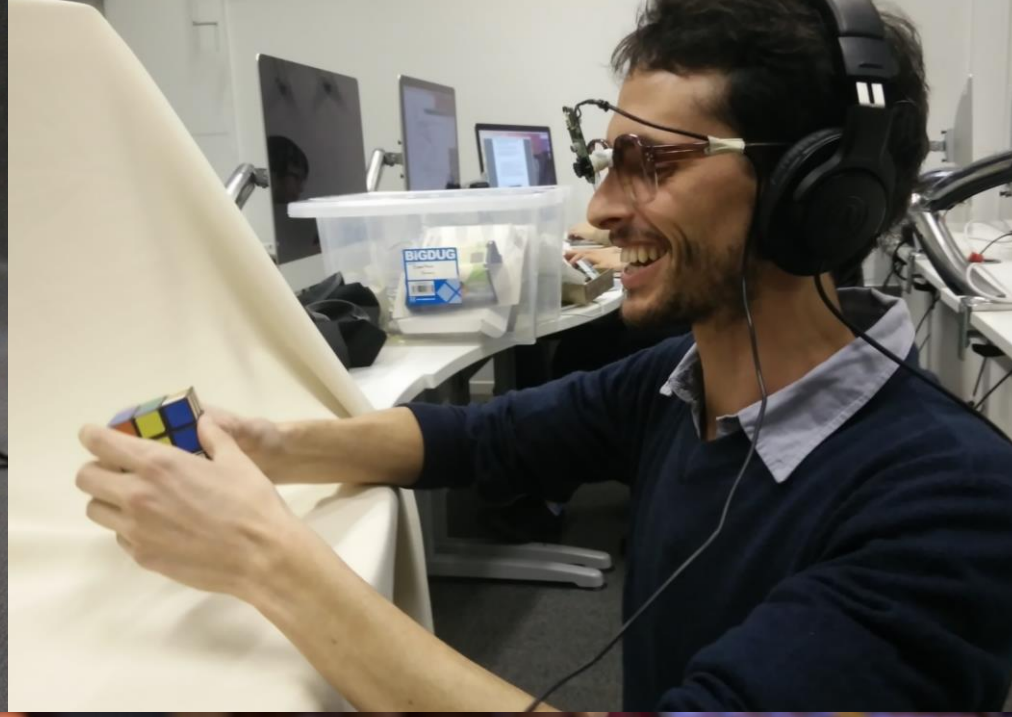
Research Interests

- Doing a PhD in four dimensional visualisation using virtual reality & the extent to which humans can perceive 4D
- Its been shown that people can learn to make some accurate spatial judgements in 4D
- Currently looking at sphere packing - building an interactive application to look at what (if any) packings of 3-spheres people might come up with
- Inspired by the theory of perception as the attunement (through interaction) to invariant patterns of sensory input.
- Want to investigate if we can develop intuitive perceptions by physically interacting with with abstract mathematical structures?
- Wondering whether it's also possible to investigate this through interacting in VR based on different types of metrics or vector spaces, or other type of structures?








BIGDUG





Goals



Explore and prototype:

- Designing skipping patterns using Knot Theory/surfaces
- Designing coloring patterns for multiperson juggling
- Exploring vector fields through the body in VR mapping your position in 3D world space to virtual output space
- Animating the body as a torus turning inside out
- I want to understand better: Symmetry, Spinors, Shaders, Geometric Algebra

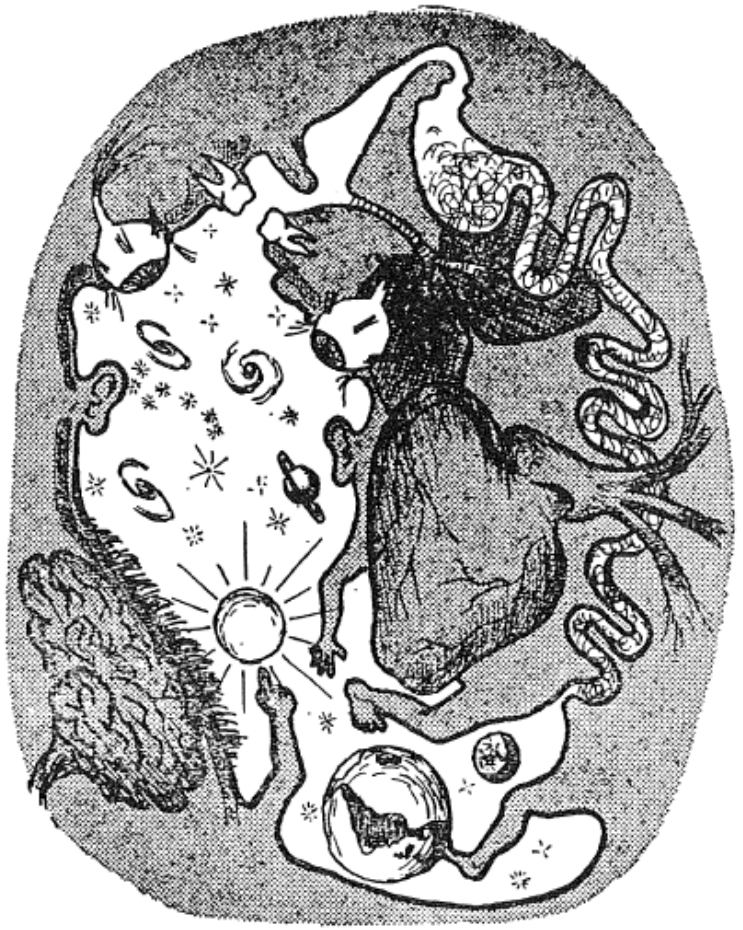


Figure 20 from ‘One Two Three... Infinity’ by George Gamow

https://youtu.be/u-qEDZoxA3I

An Introduction

Gabriel Dorfsman-Hopkins

ICERM/Berkeley

September 5, 2019

Who am I?

Who am I?

Semester Postdoc at ICERM

Who am I?

Semester Postdoc at ICERM

RTG Postdoc at UC Berkeley in Arithmetic Geometry

Deforming the Pythagorean Tree Fractal

The Pythagorean tree fractal is generated recursively, stacking squares on the legs of right triangles. Varying the triangle deforms the fractal. One can animate this, or instead view the time axis as the vertical axis and 3d print the defomration.

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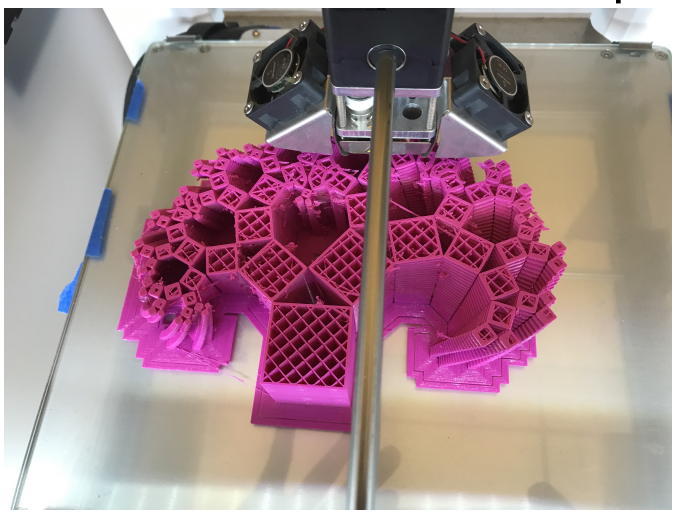

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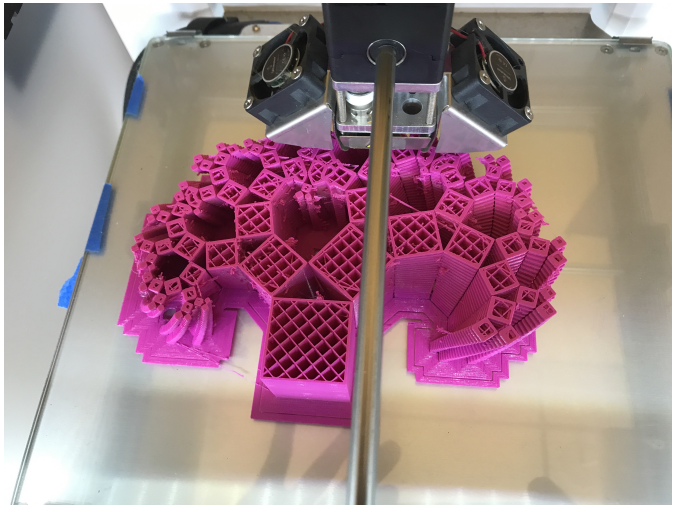

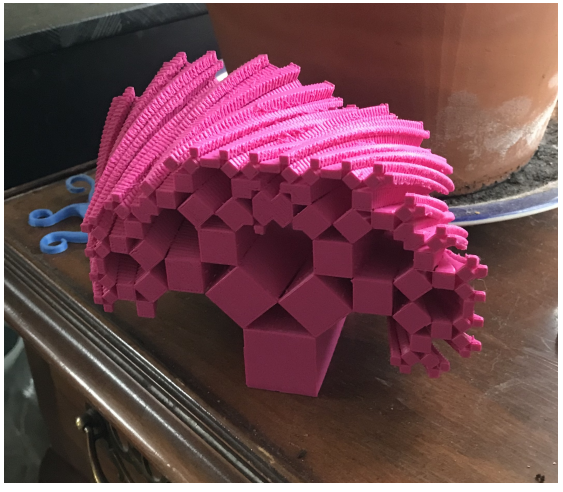

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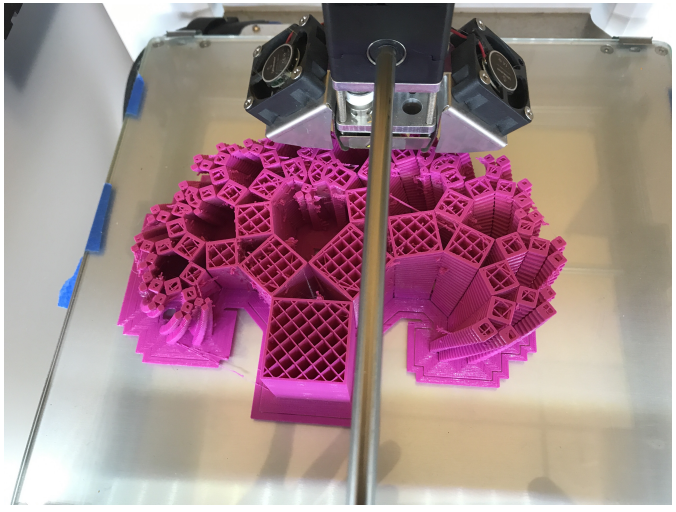

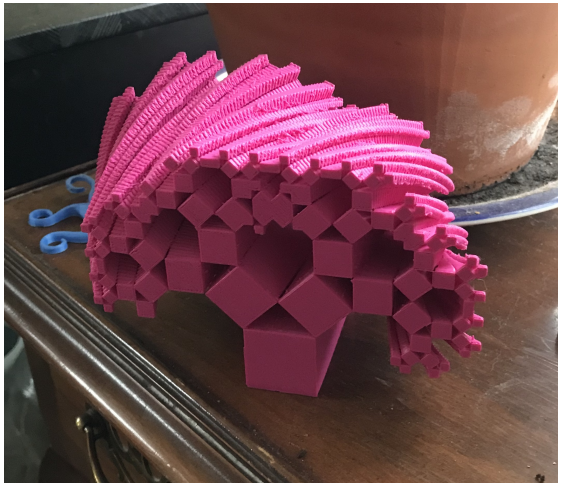

Tools:

- Rhinocerous/rhinopythonscript
- Ultimaker 3d printer

Fabric of Spacetime

I am also interested in mechatronic art, blending electronics, lights, motors and textiles. This is a giant crocheted hyperbolic manifold wired up with electronics.

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Fabric of Spacetime

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Tools:

- Crochet
- LEDs and Servo Motors
- Arduino
- Lots of electrical wire

Deformation of Fractals

I'd like to improve and build on the deformation project.

Deformation of Fractals

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Smoothing the staircase quality of the Pythagorean tree fractal. (i.e., get better at rhino)

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- Deformations of Julia sets

Deformation of Fractals

I'd like to improve and build on the deformation project.

- Smoothing the staircase quality of the Pythagorean tree fractal. (i.e., get better at rhino)
- Deformations of Julia sets
- Script/applet that can turn a path through the Mandelbrot set into a 3d model of the associated Julia set deformation

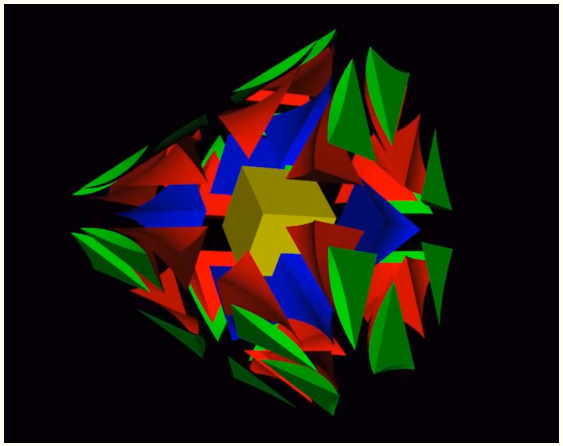
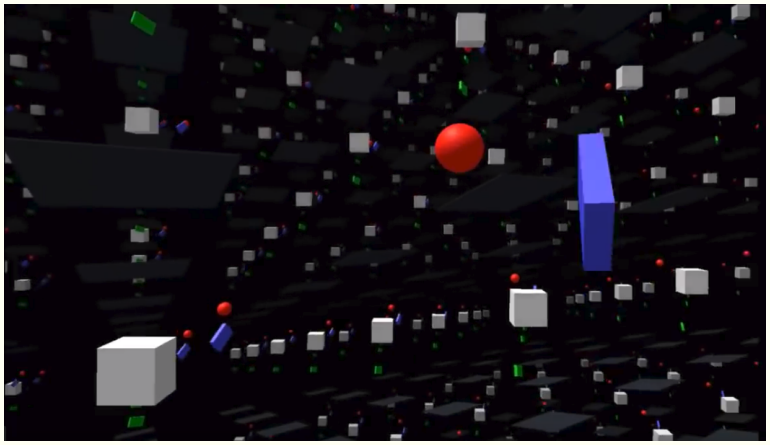
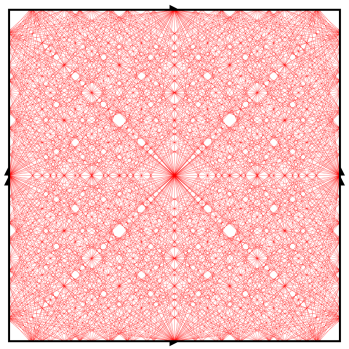
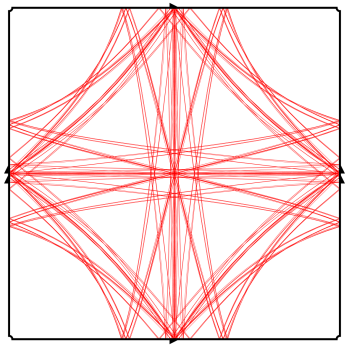
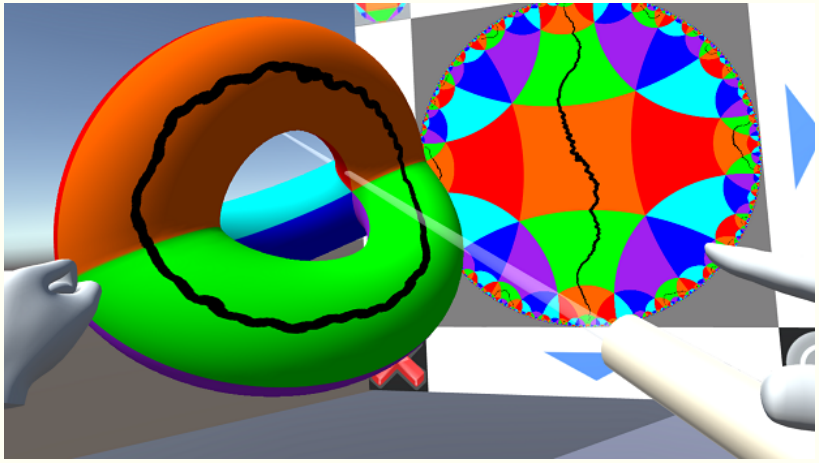
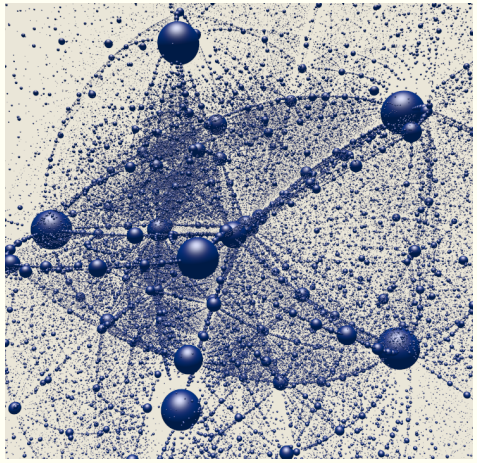
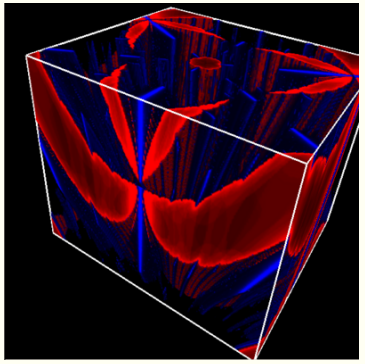
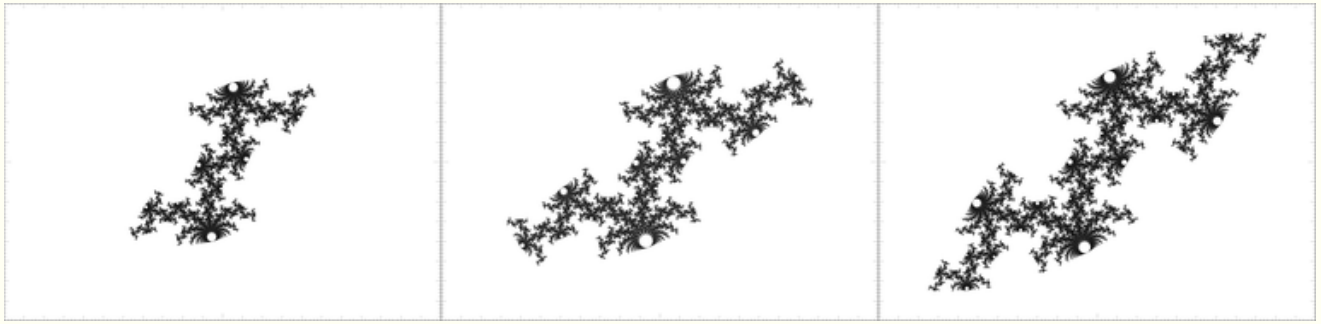
Thank you!

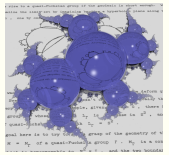
David Dumas

University of Illinois at Chicago

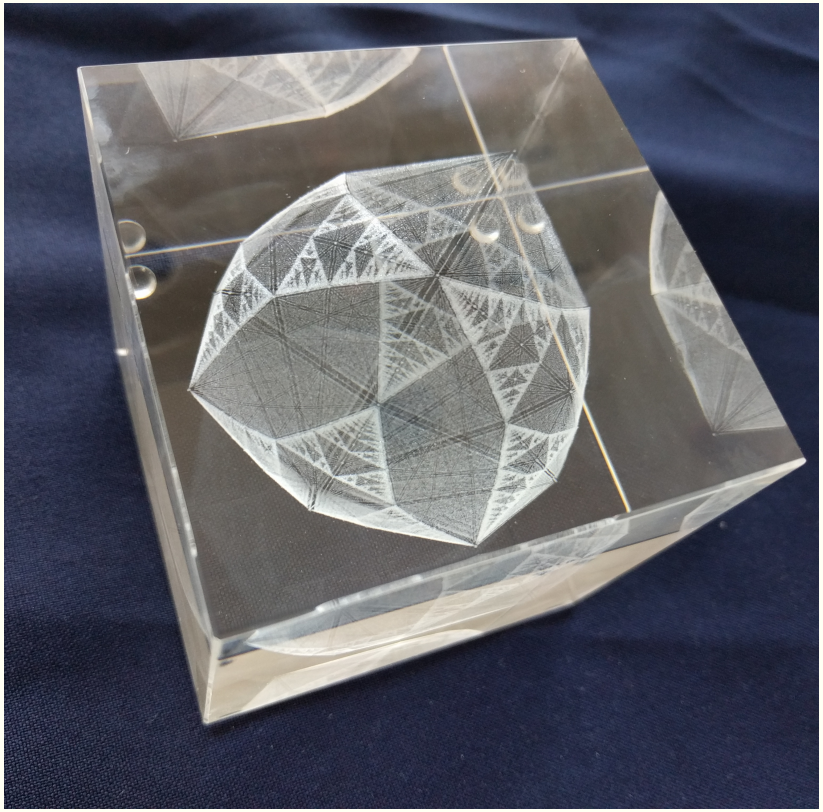
http://dumas.io

david@dumas.io

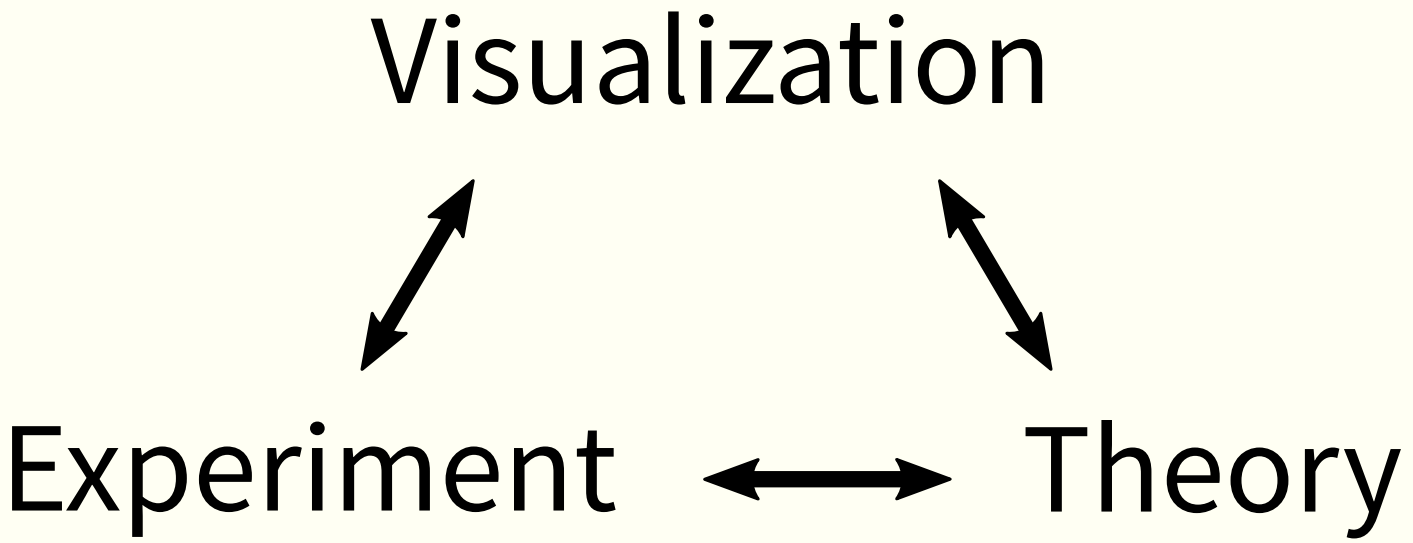


Including collaborations with Adrahtas, Armas, Brock, Guo, Guéritaud, Huang, Reichman, Schamberger, Tran.





(with Grossman and Guéritaud)


Visualization
Experiment
Theory

Specific goals:

- Refine 3D printing skills & apply to the study of moduli spaces
- Develop VR environments for research and exposition
- Learn from the amazing people attending the program!



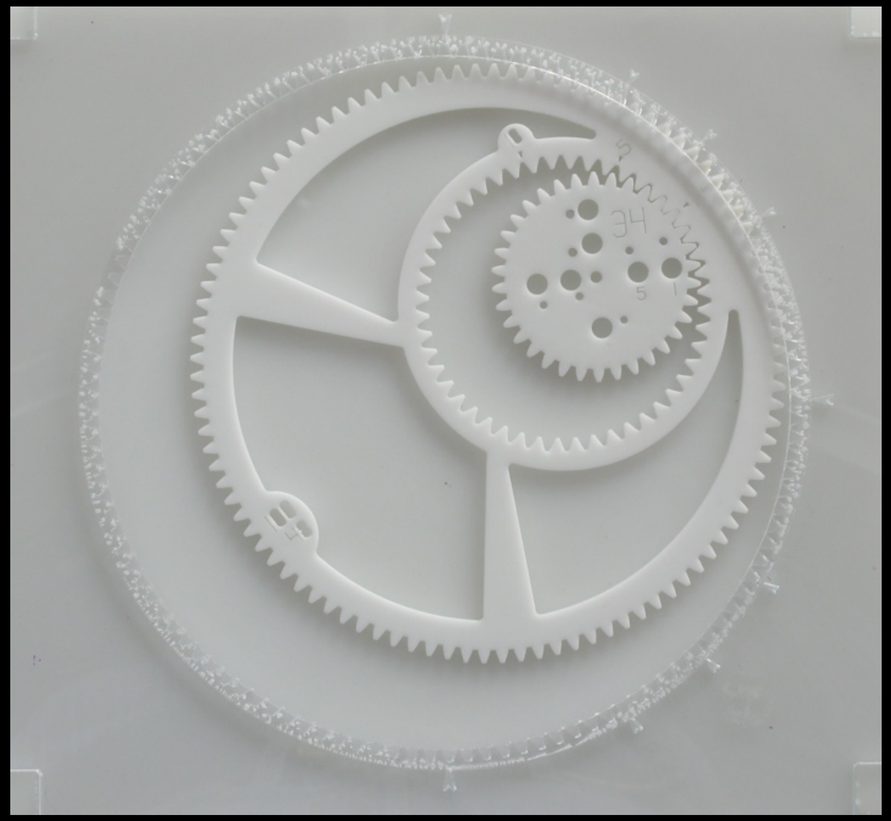
John Edmark

Stanford University

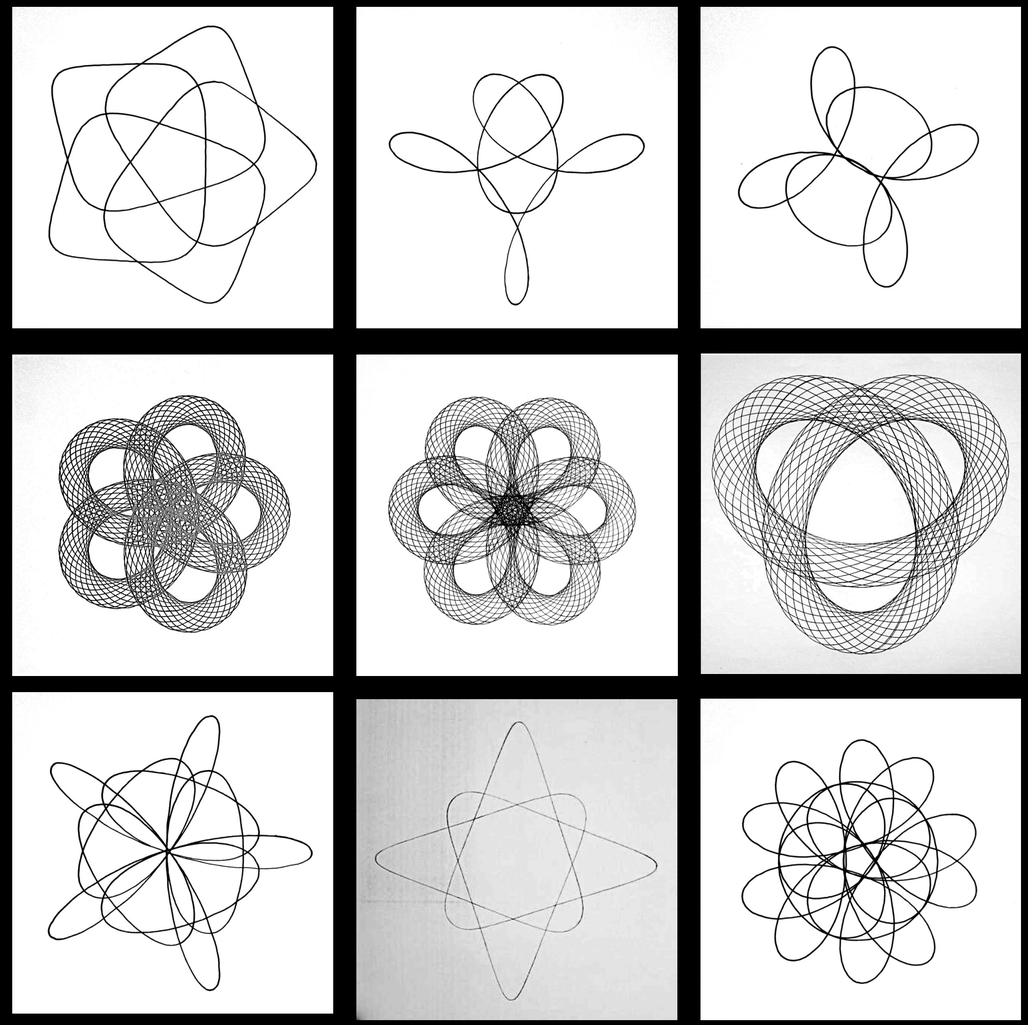
ICERM

Sept 2019

Gear-Based Pattern Generation

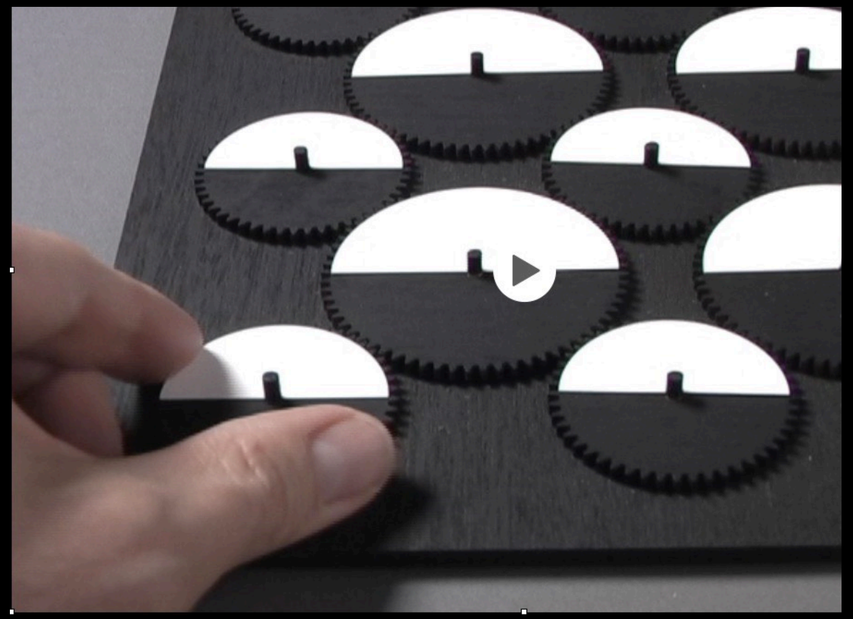


Recursive-Spirograph

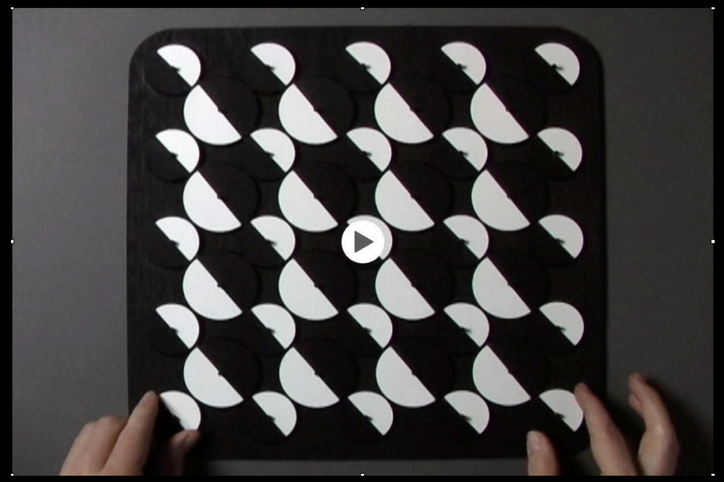


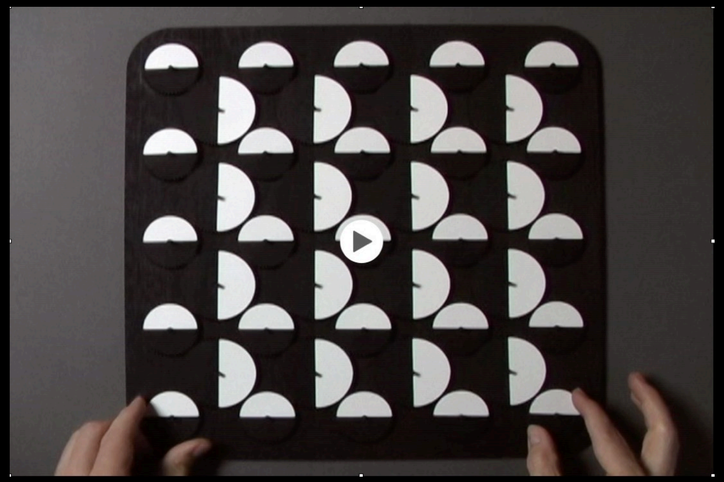
Single Closed Paths

Gear-Based Pattern Generation

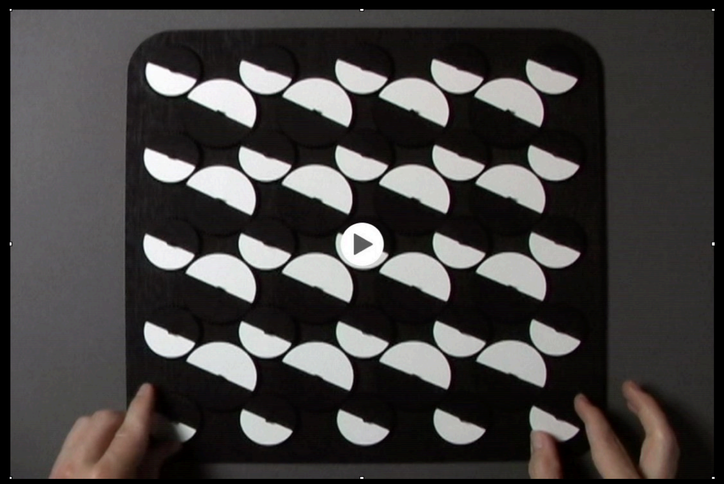


PatTurn (3:4)



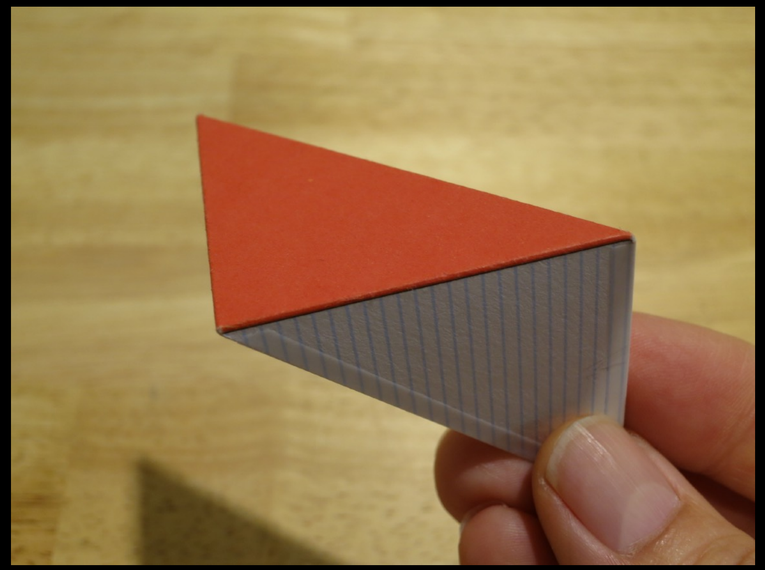




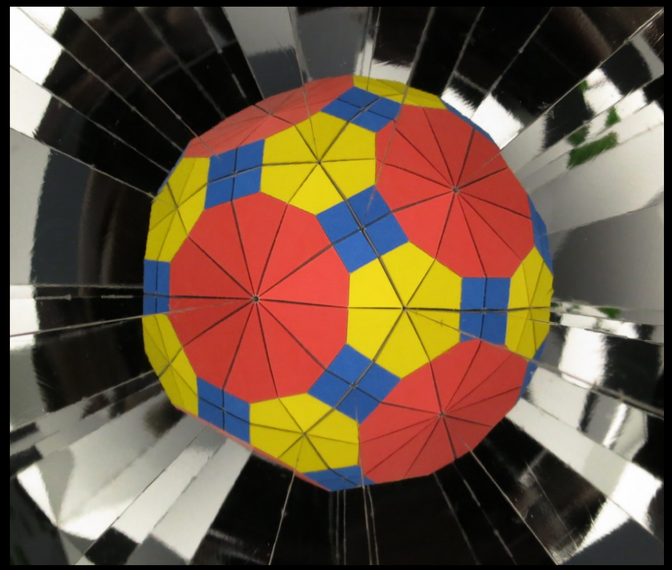


Polyhedral Kaleidoscopes









Phylotactic Spirals base on Golden Angle



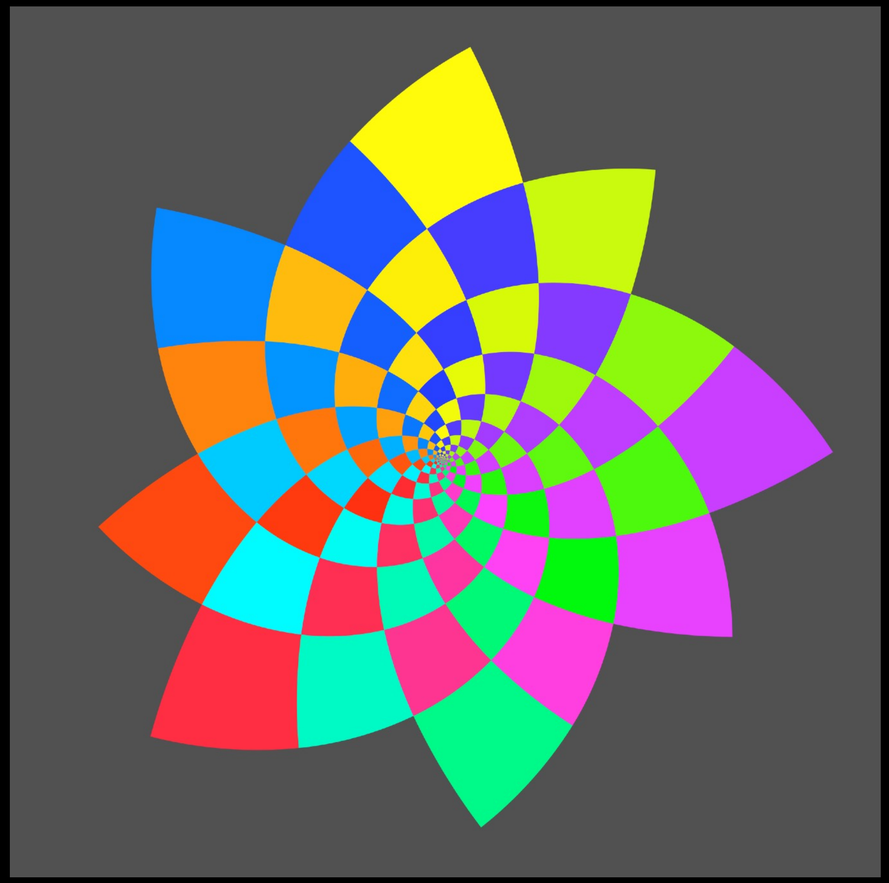




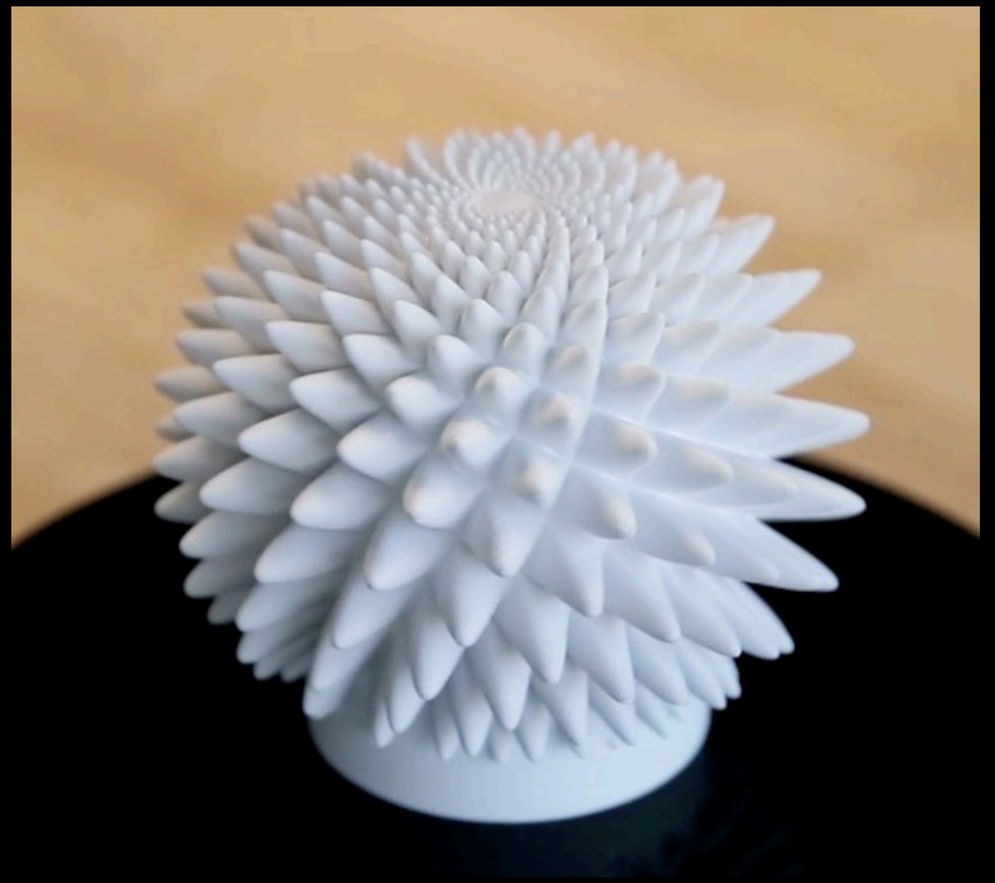




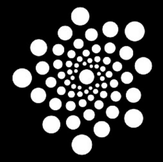
Phylotactic Spirals base on Golden Angle



Chromataxis 8-13 H89
Logarithmic Spiral Tilings



BLOOMS
Strobe Animated Sculptures



Demo

Aaron Fenyes

University of Toronto

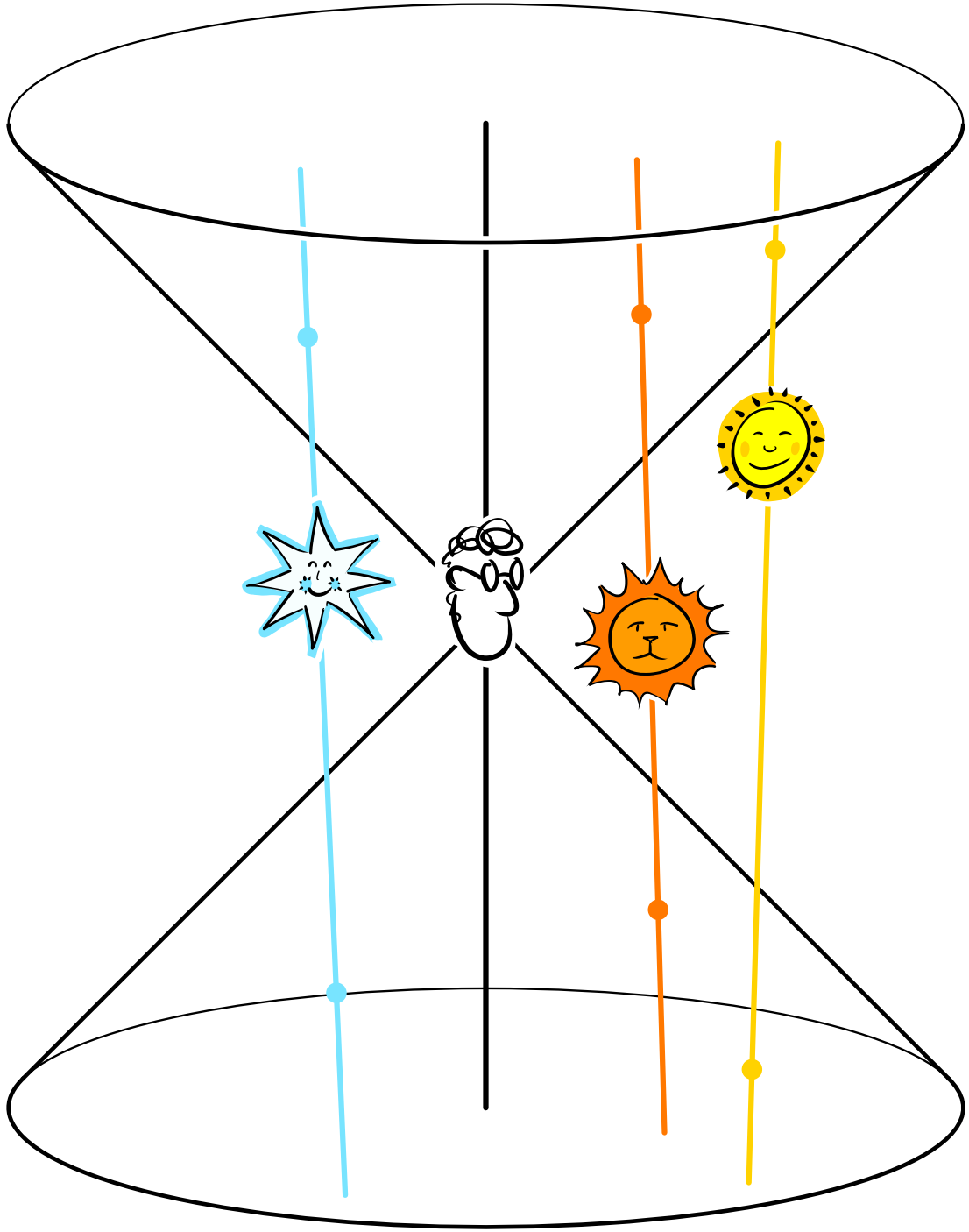
visiting ICERM
Sep. 4–20

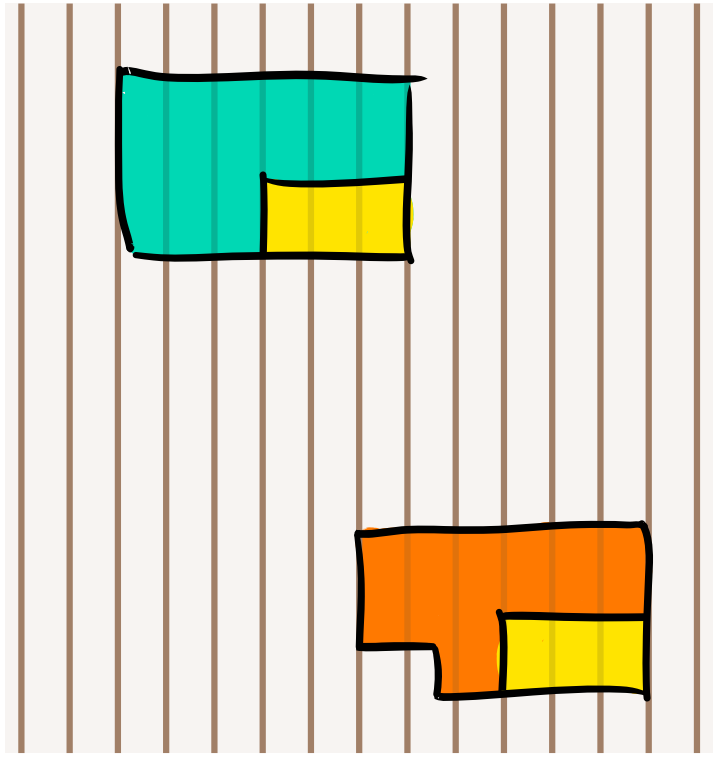
Institut des Hautes Études Scientifiques



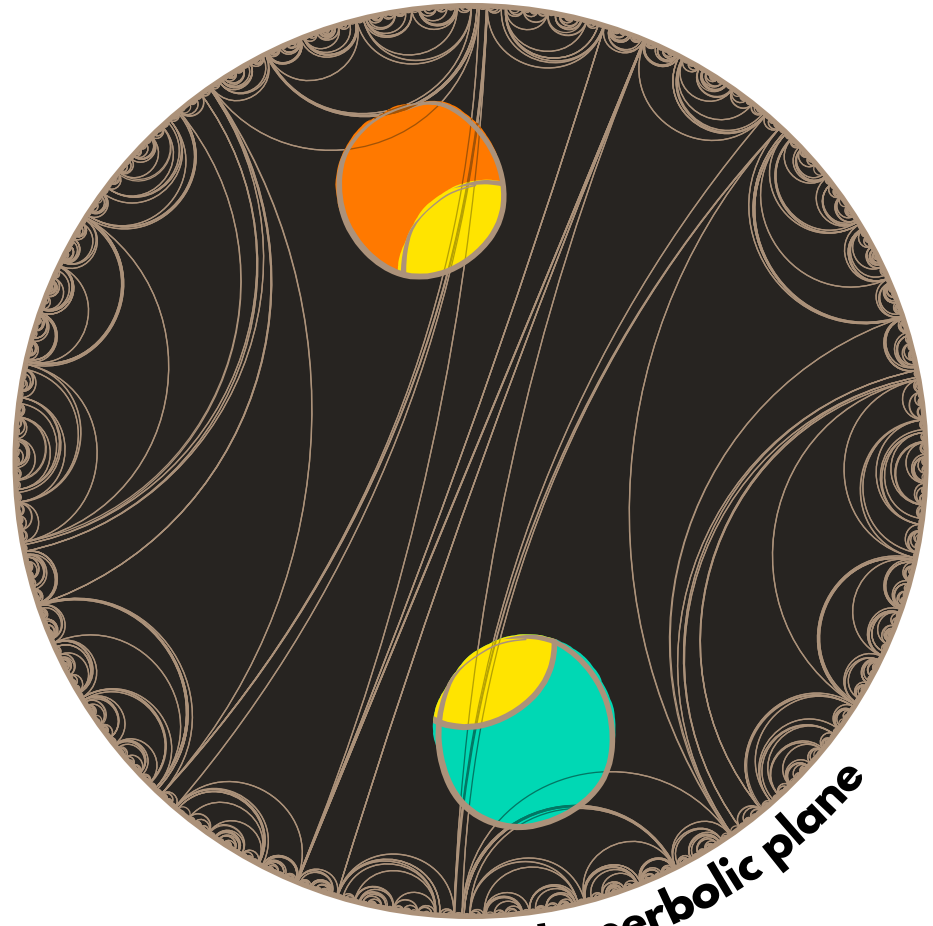






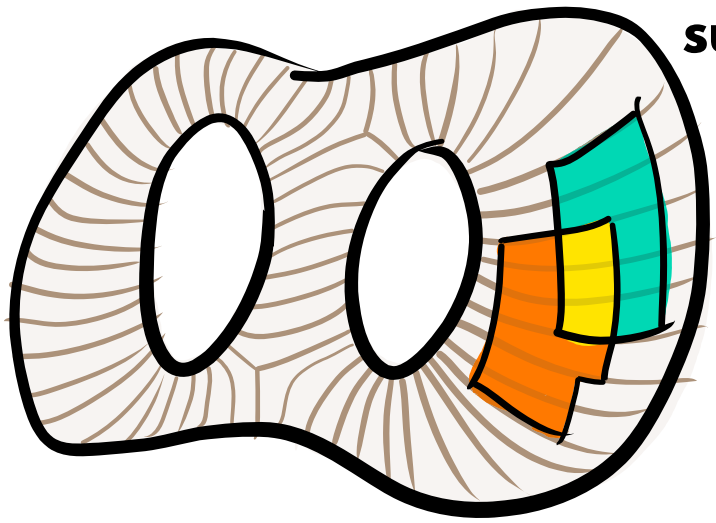


flat plane

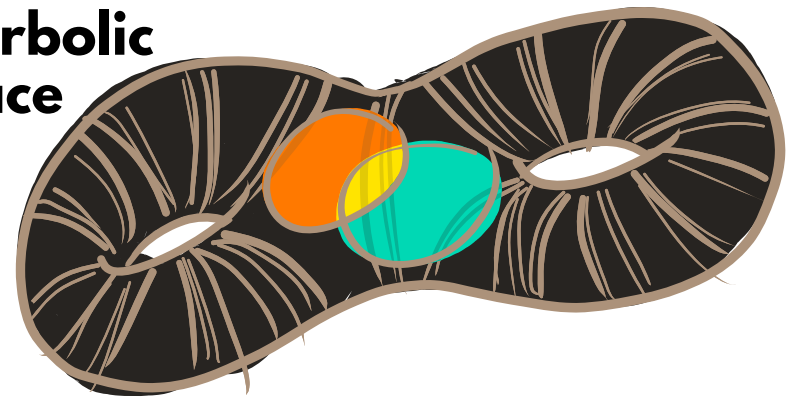


hyperbolic plane

half-translation surface

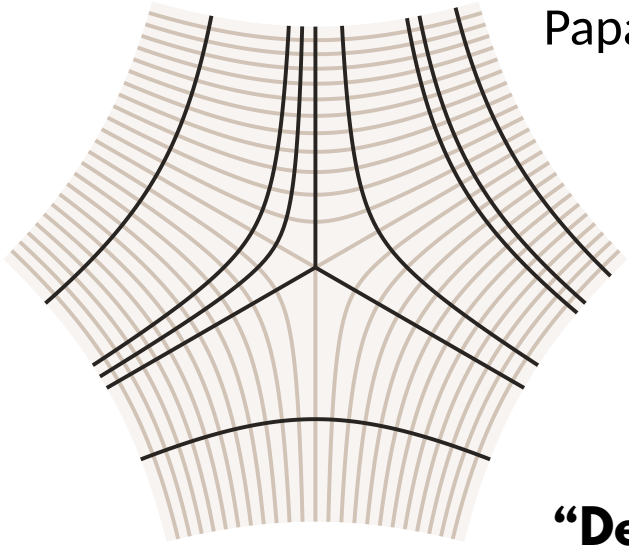


hyperbolic surface



The shear parameterization

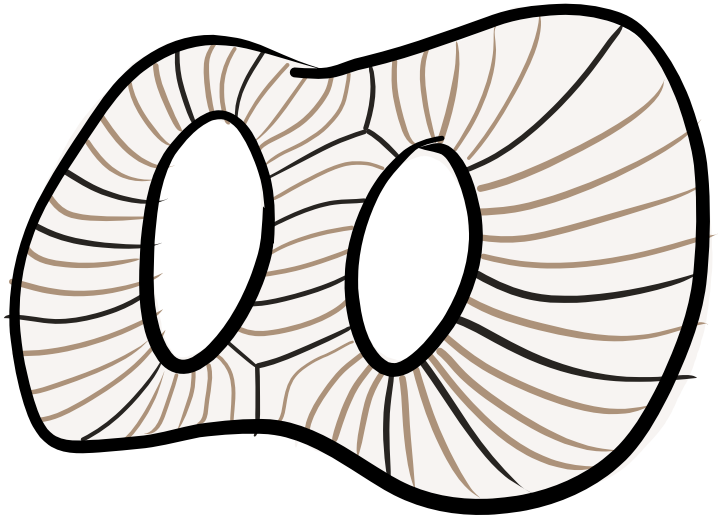
Thurston (1986), Bonahon (1987),
Papadopoulos – Théret (2007),
and many others





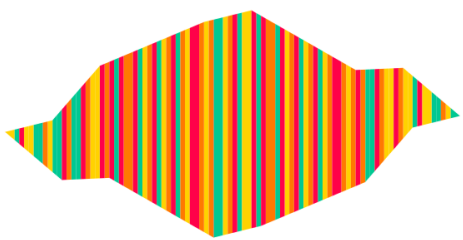
“Deflating” ideal triangles turns a hyperbolic surface into a half-translation surface

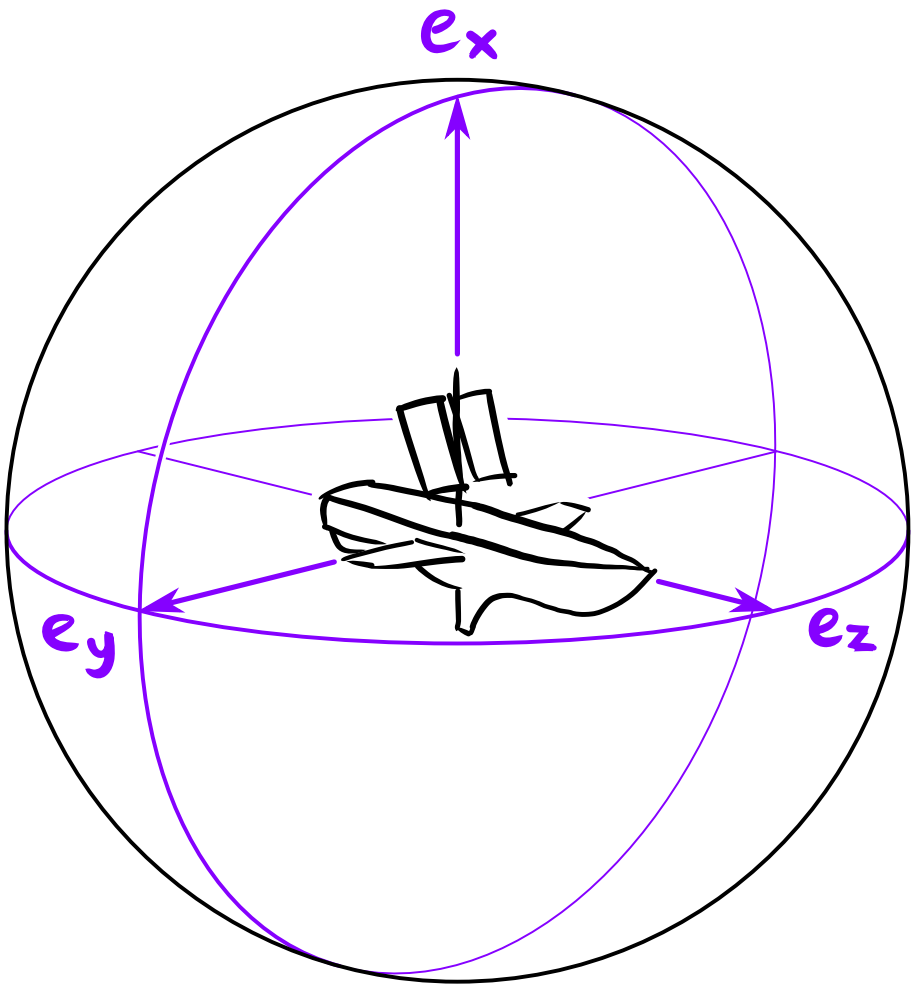
Gupta (2014)

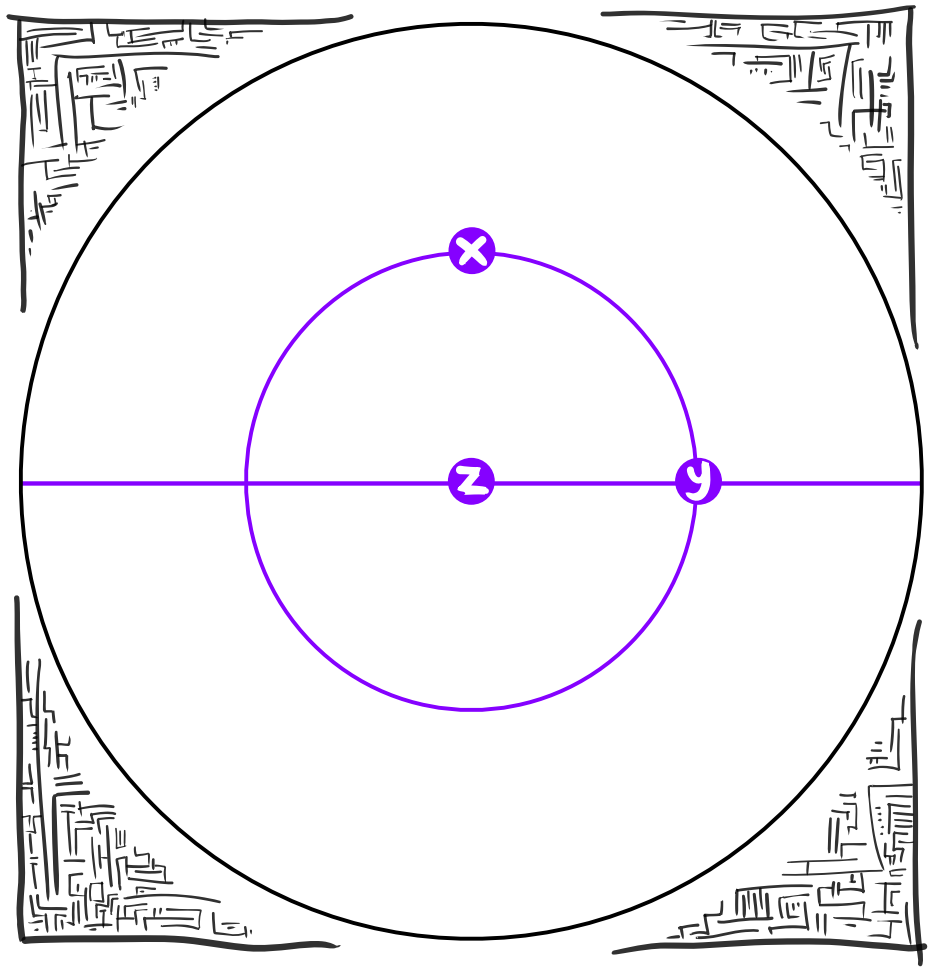


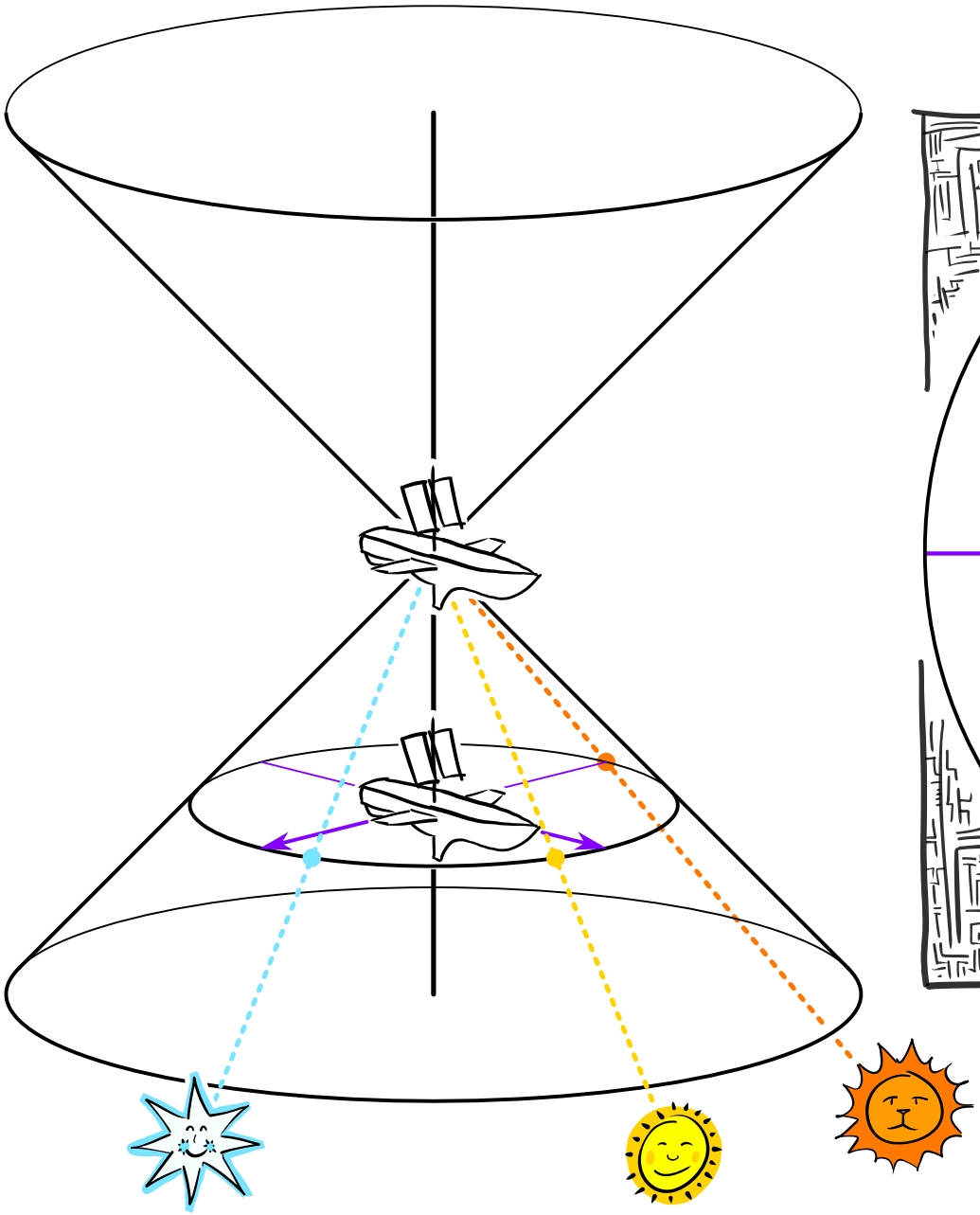


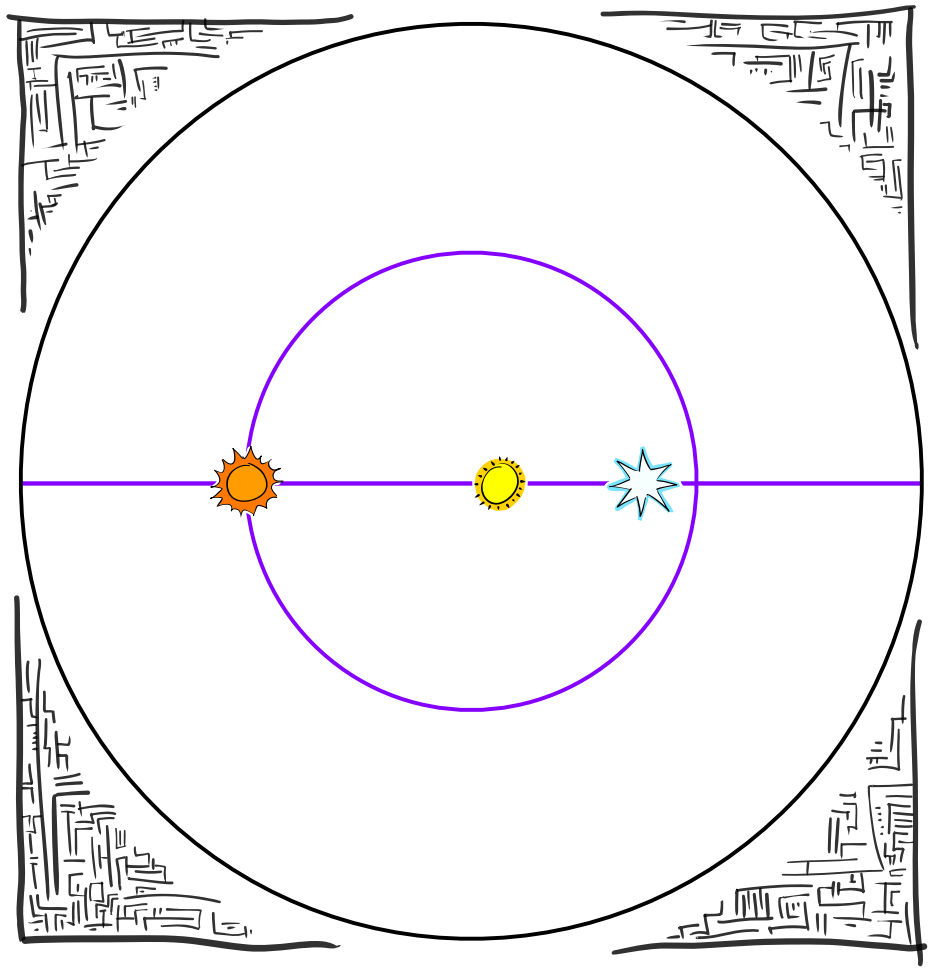


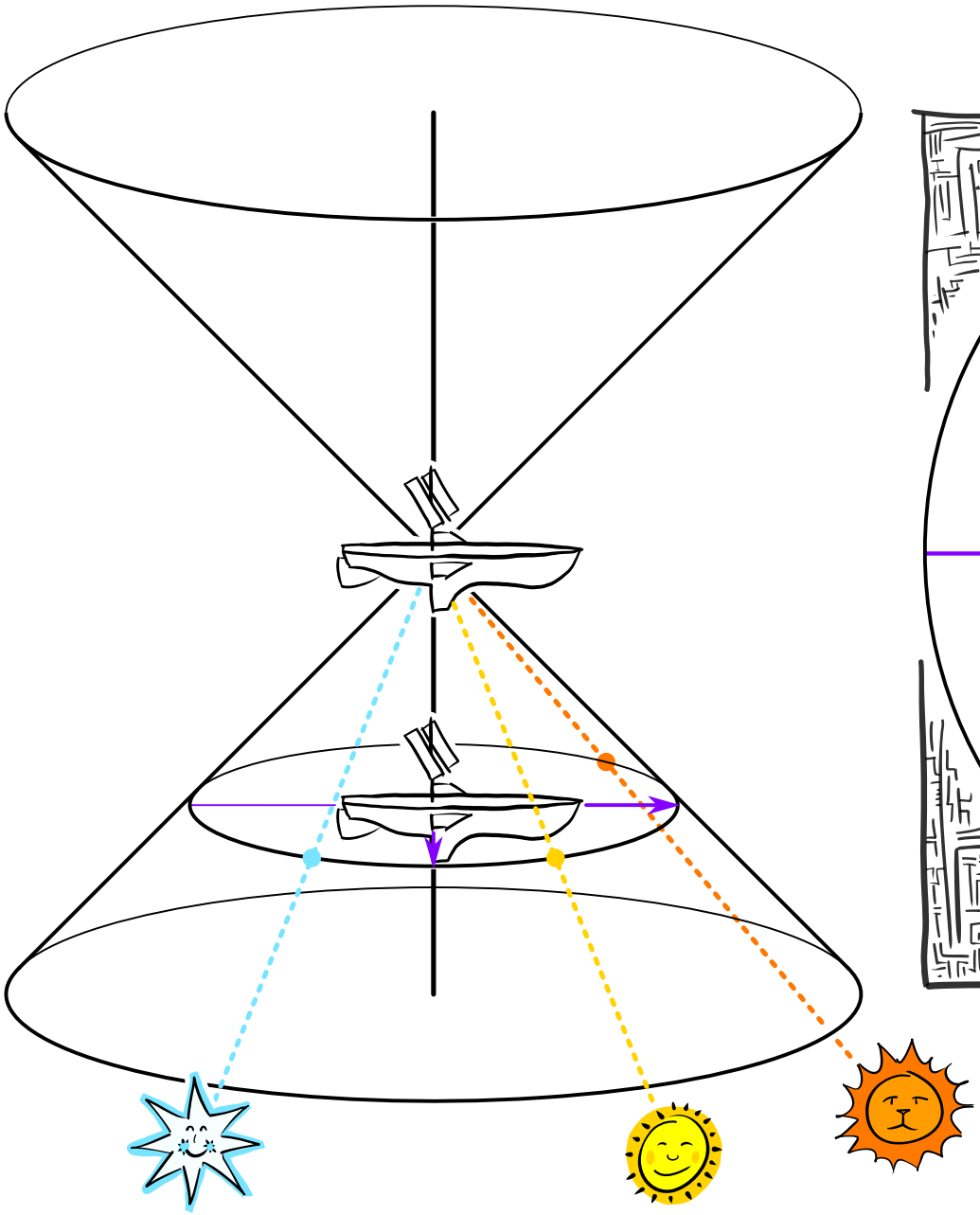


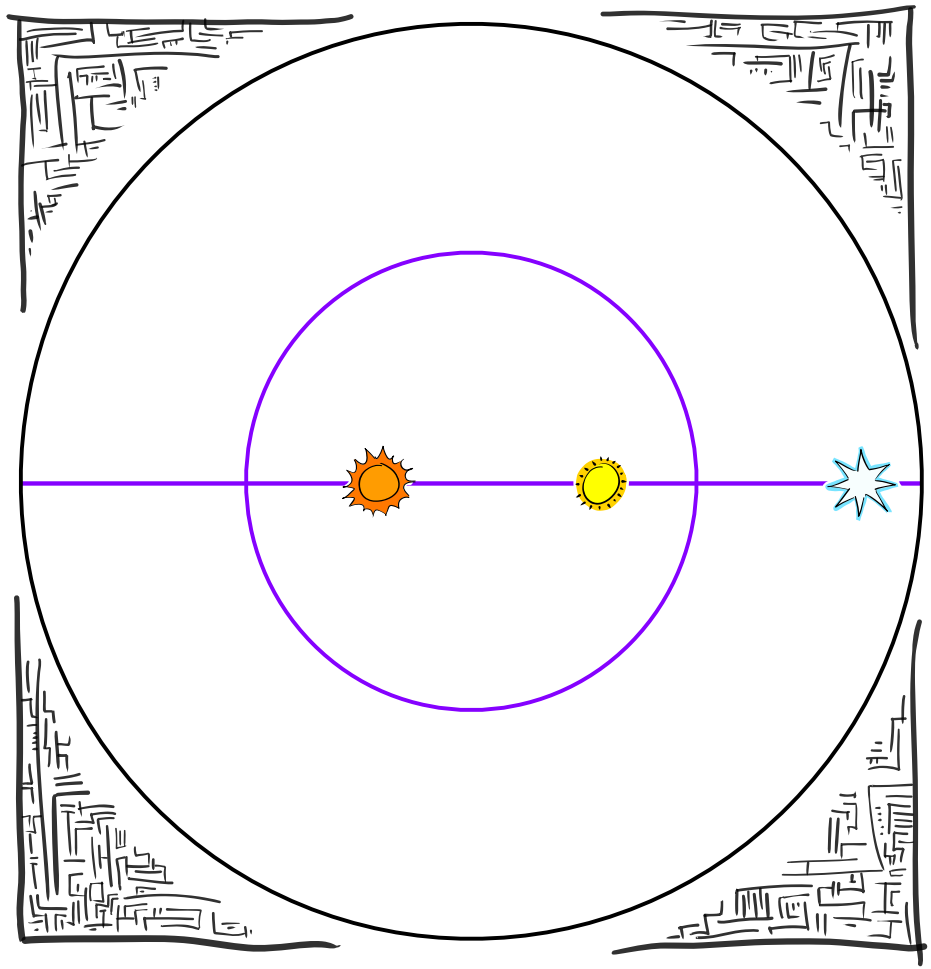

e_x
e_y
e_z

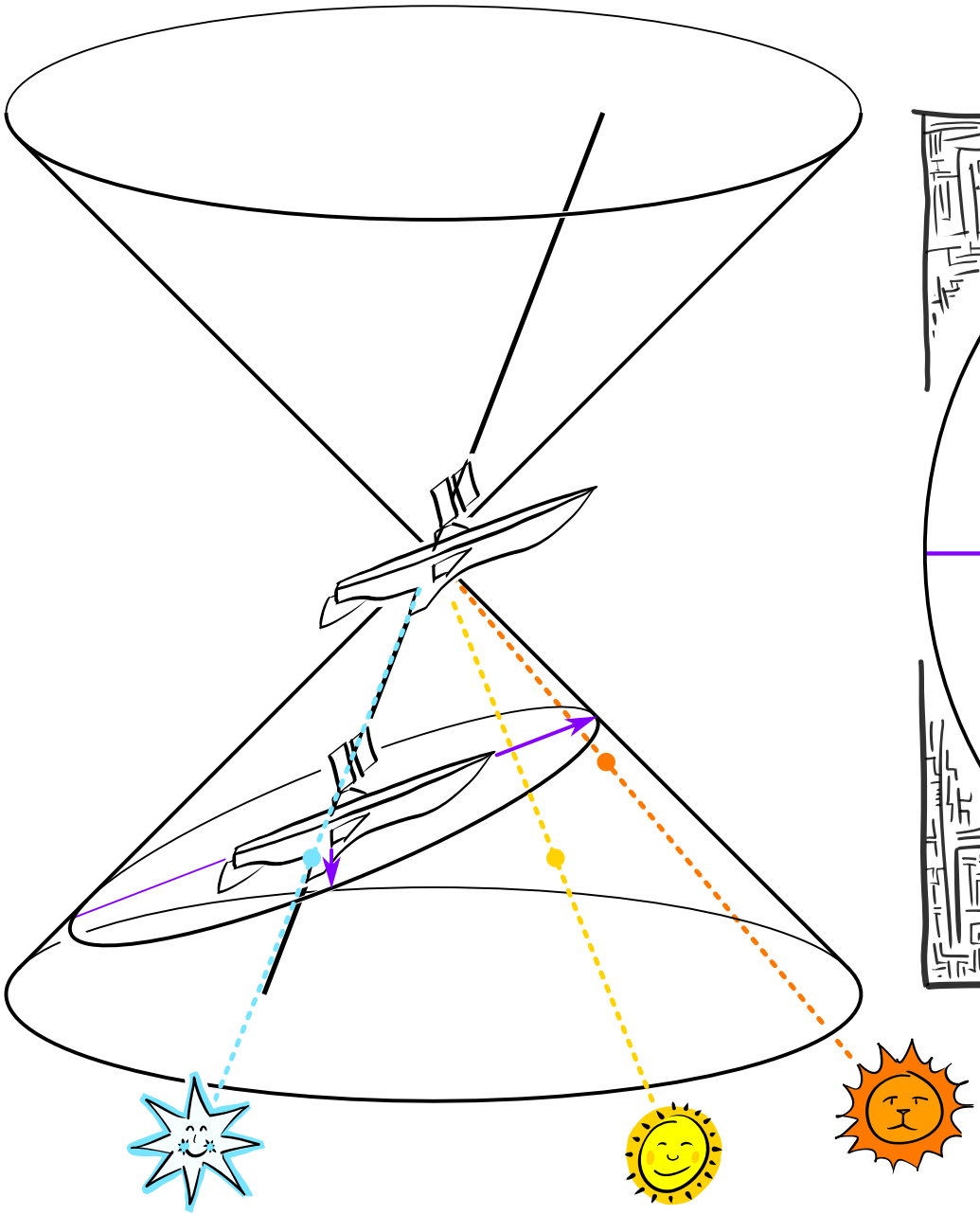

x
z
y

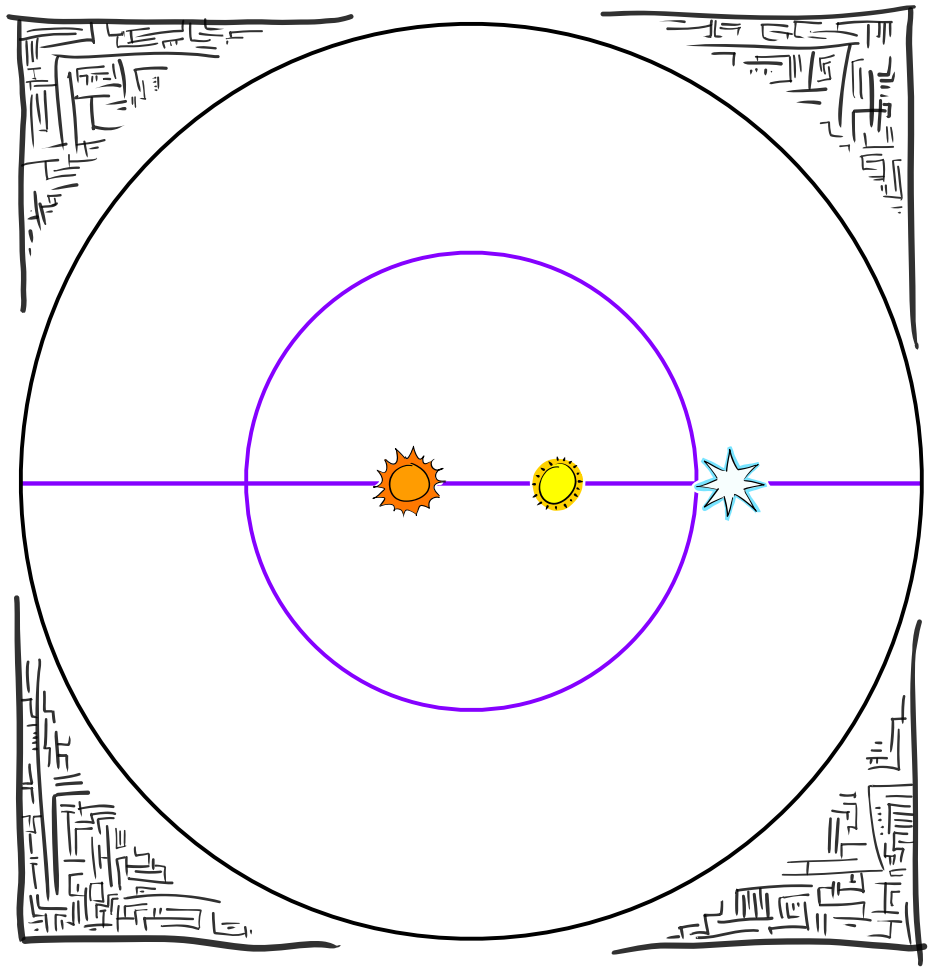


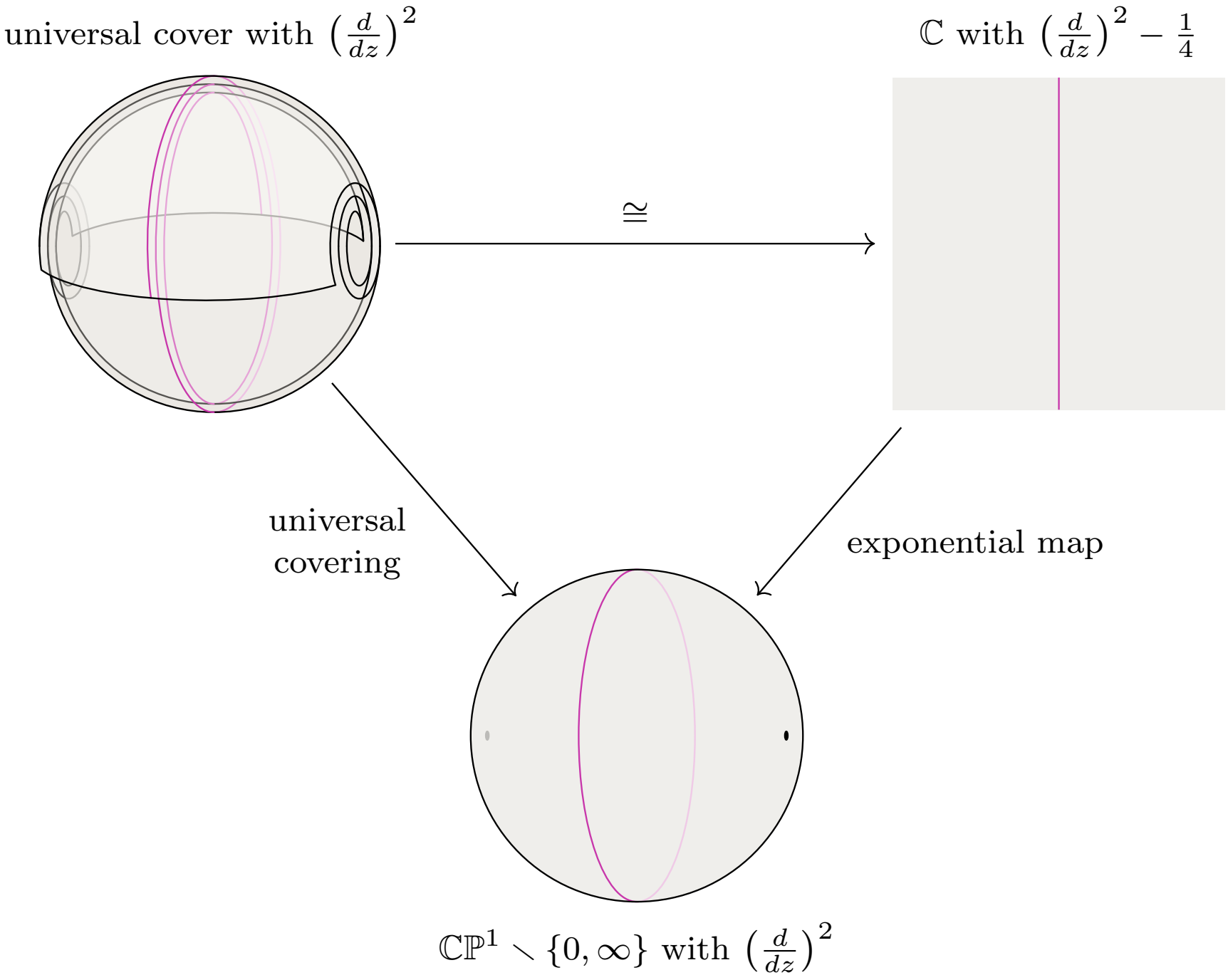











universal cover with $\left(\frac{d}{dz}\right)^2$
$\mathbb{C}$ with $\left(\frac{d}{dz}\right)^2 - \frac{1}{4}$
$\cong$
universal
covering
exponential map
$\mathbb{CP}^1 \setminus \{0, \infty\}$ with $\left(\frac{d}{dz}\right)^2$

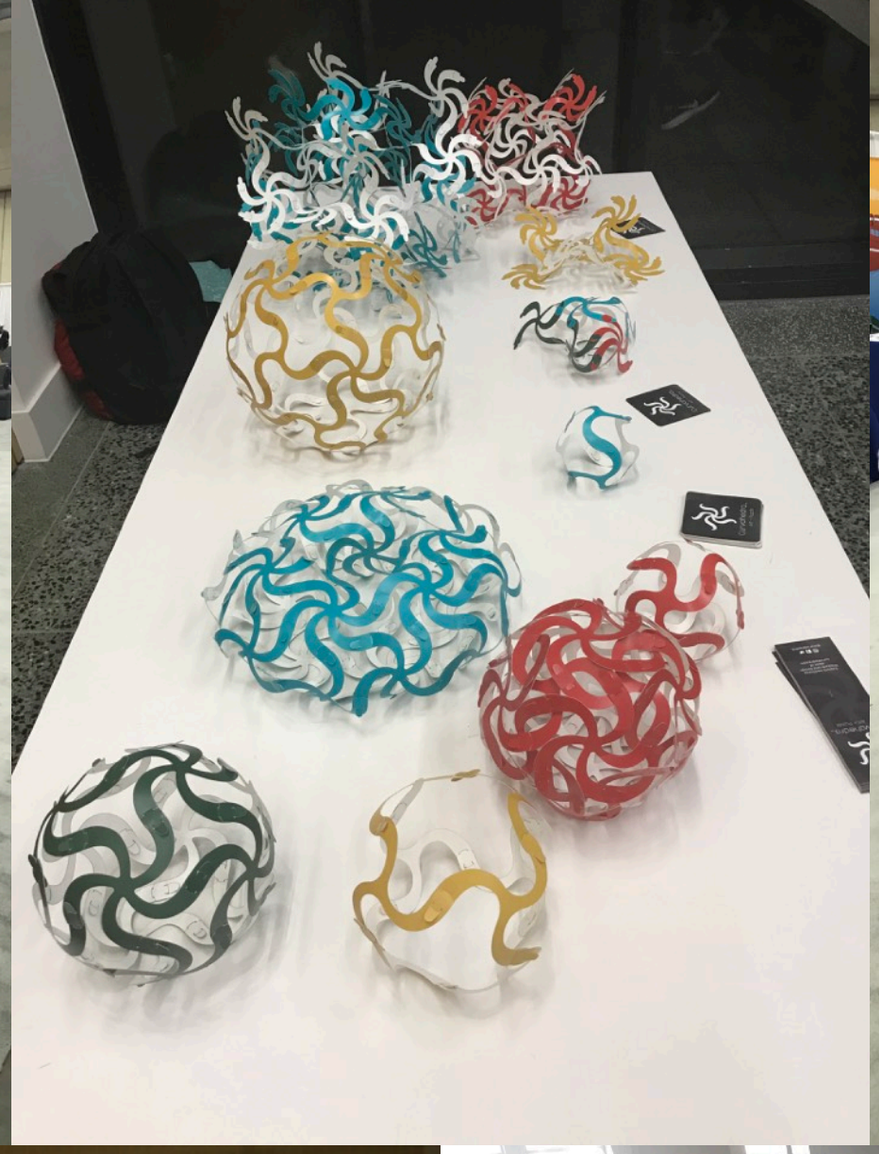


Edmund Harriss

(@Gelada)

University of Arkansas


American Institute of Mathematics
focused collaborative research
Math Teachers' Circle



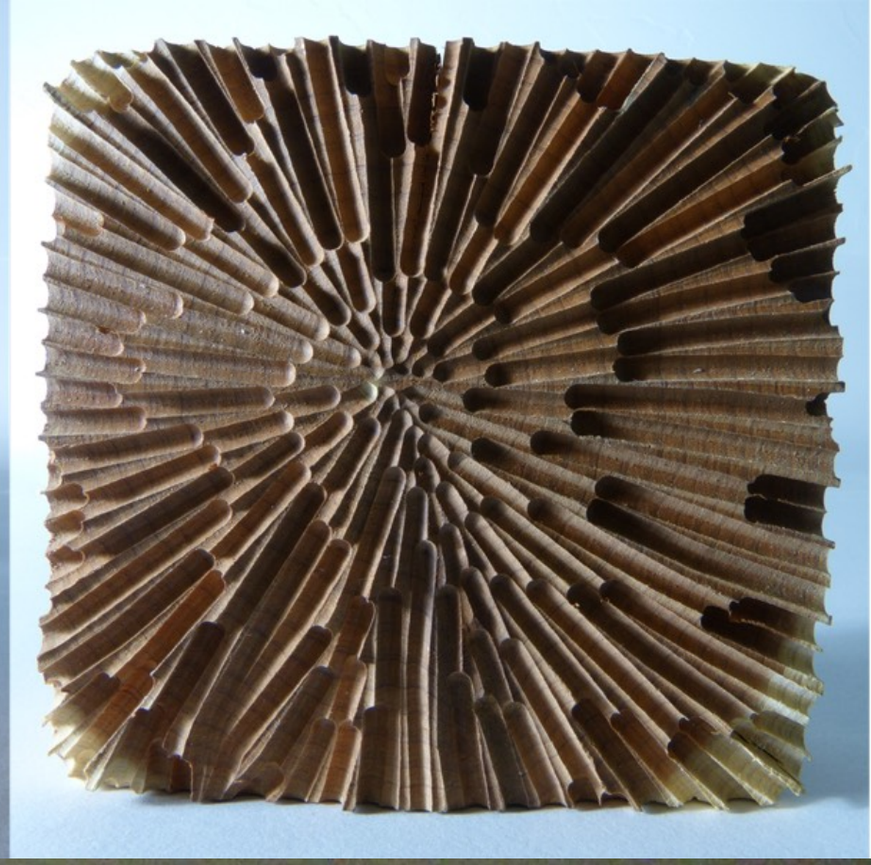



WOMEN
MEN









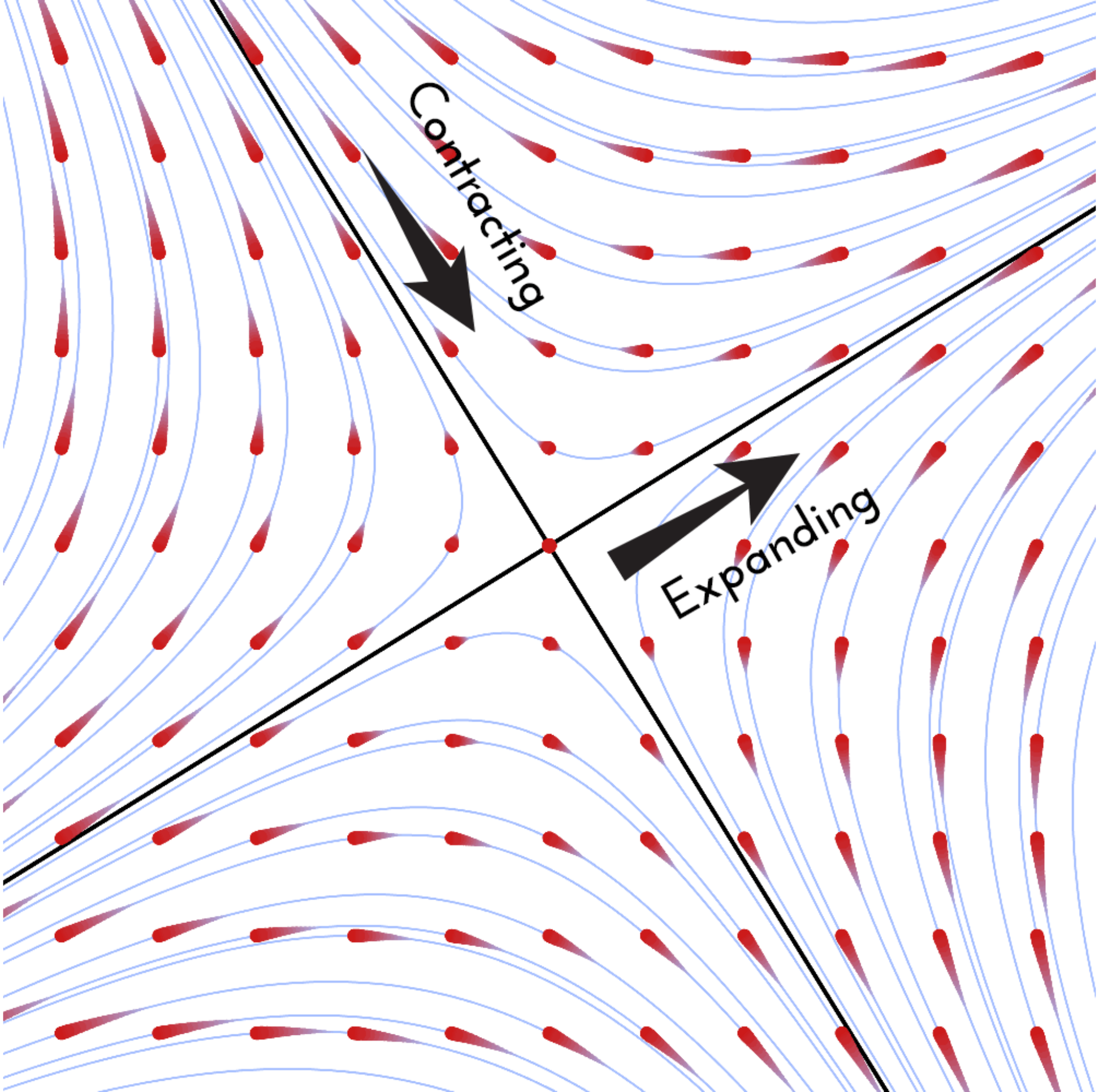


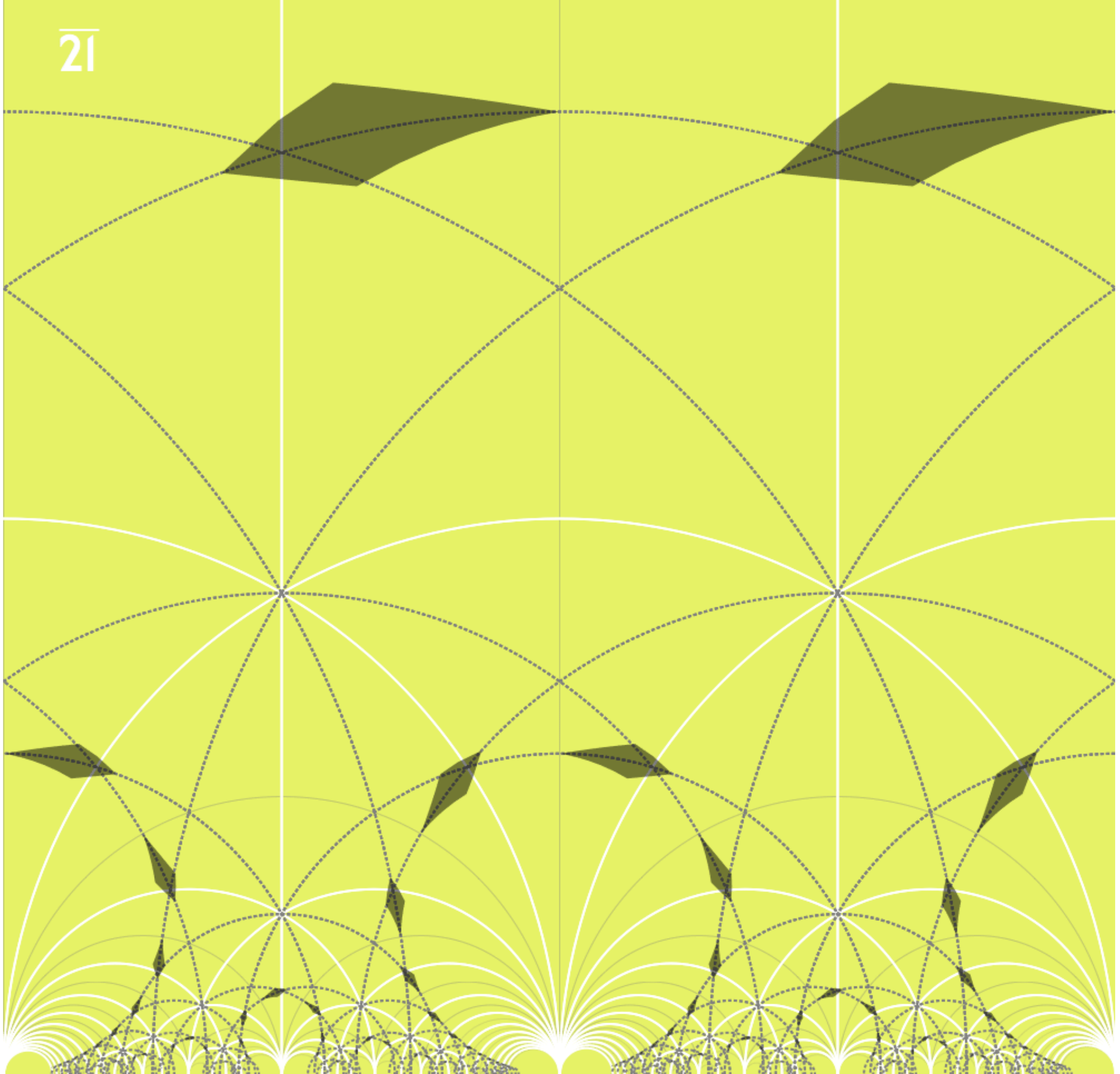









Contracting
Expanding



Ellen Eischen

http://www.elleneischen.com



UNIVERSITY OF
OREGON

Primary Research Area

- I work in (mostly algebraic) number theory and especially like topics that draw on a variety of tools, including:
  - L-functions (generalization of Riemann zeta function)
  - Modular forms
  - p-adic methods
  - Arithmetic geometry
  - Iwasawa theory, an approach to studying p-adic families of arithmetic data, tied to Galois theory

The Gaussian periods in the 255,255-th cyclotomic extension fixed by the action of the automorphism $\zeta \mapsto \zeta^{254}$ for each 255,555-th root of unity ζ.

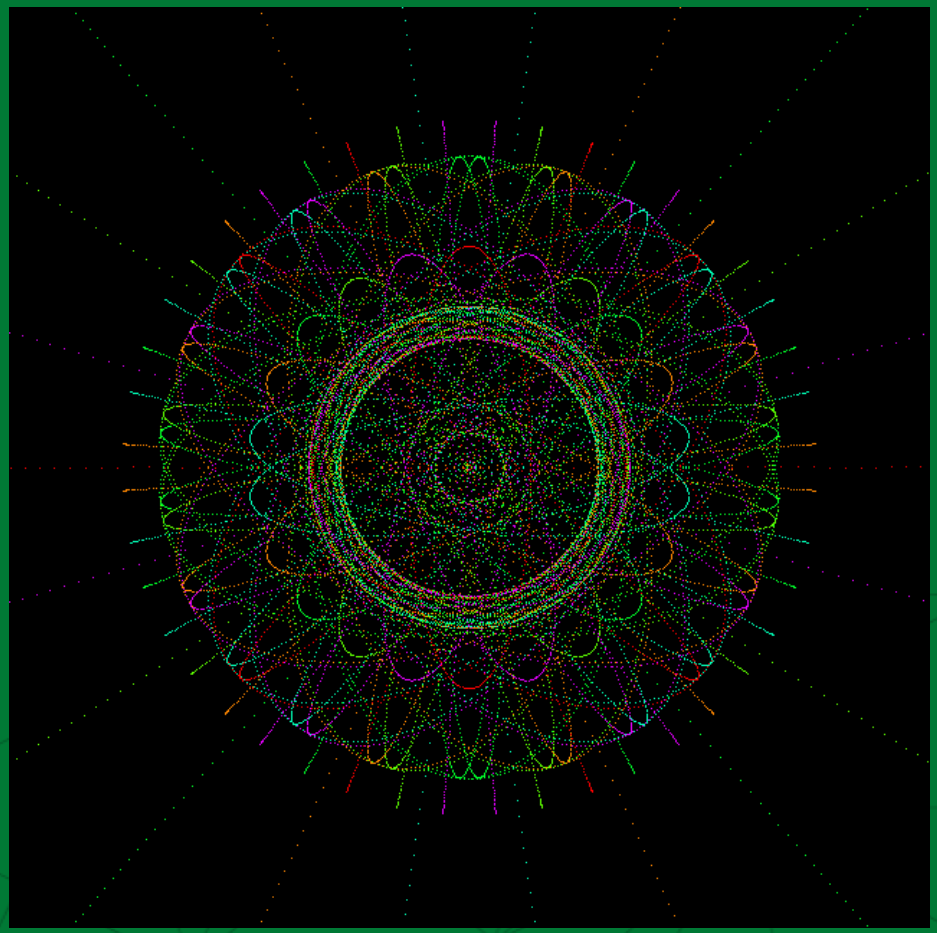


Image credit: E. Eischen, based on earlier work by W. Duke, S. R. Garcia, T. Hyde, and R. Lutz.

Goals for semester:

- Begin collaboration illustrating number theory

- Finish preparing new undergraduate course
  Math and the Creative Process:
  A participatory exploration of number theory

Visualization and programming

- My experience is through applied and interdisciplinary projects.
- Want to bring illustration into my research field, viewed as among the most inaccessible areas.
- Especially interested in visualization as a tool for exploration and communication.

Bernat Espigulé

UNIVERSITAT DE BARCELONA



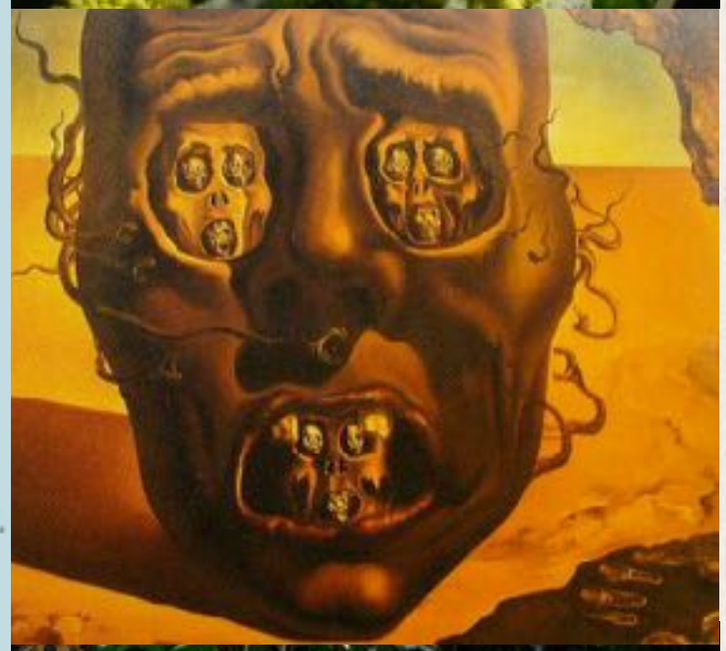
(Left to right: Antonio Garijo, Núria Fagella, Dan A. Paraschiv, Anna M. Benini, Jordi Canela (on leave), Xavier Jarque, Bernat Espigulé and Robert Florido). Course 2017-18

1989 Figueres





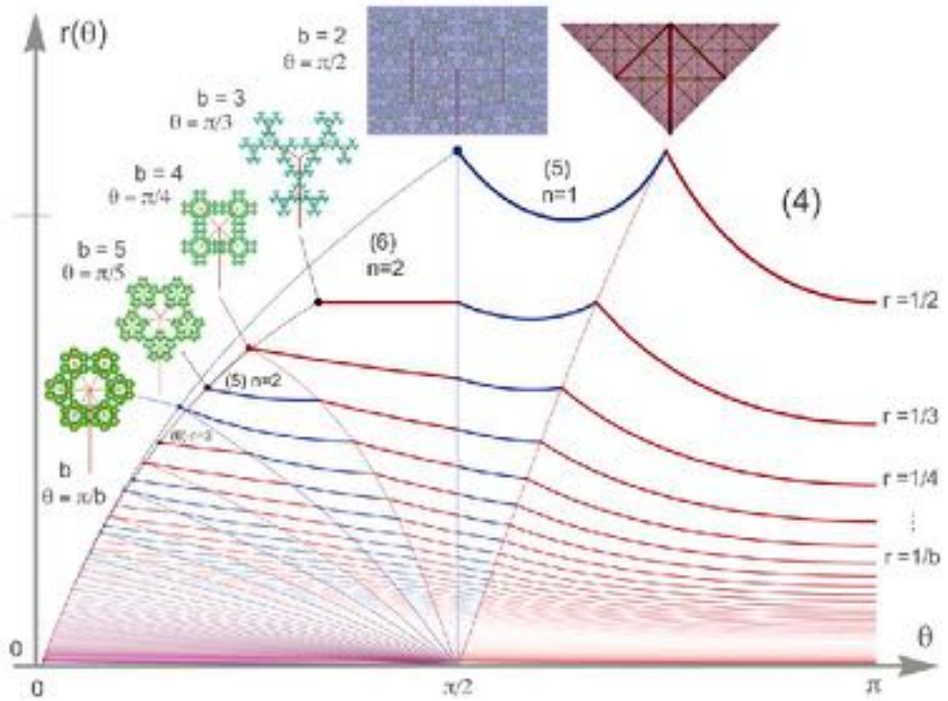




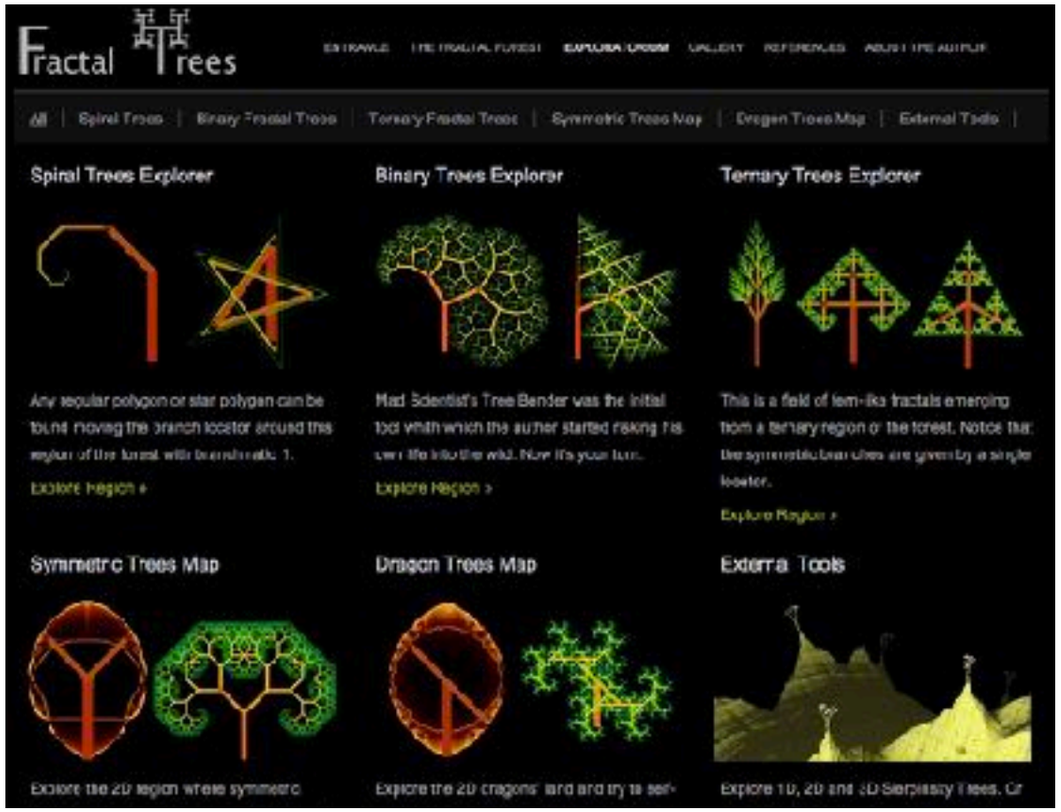




Universitat Autònoma de Barcelona
University of California Santa Barbara



Heidelberg Universität 2011 - 2013

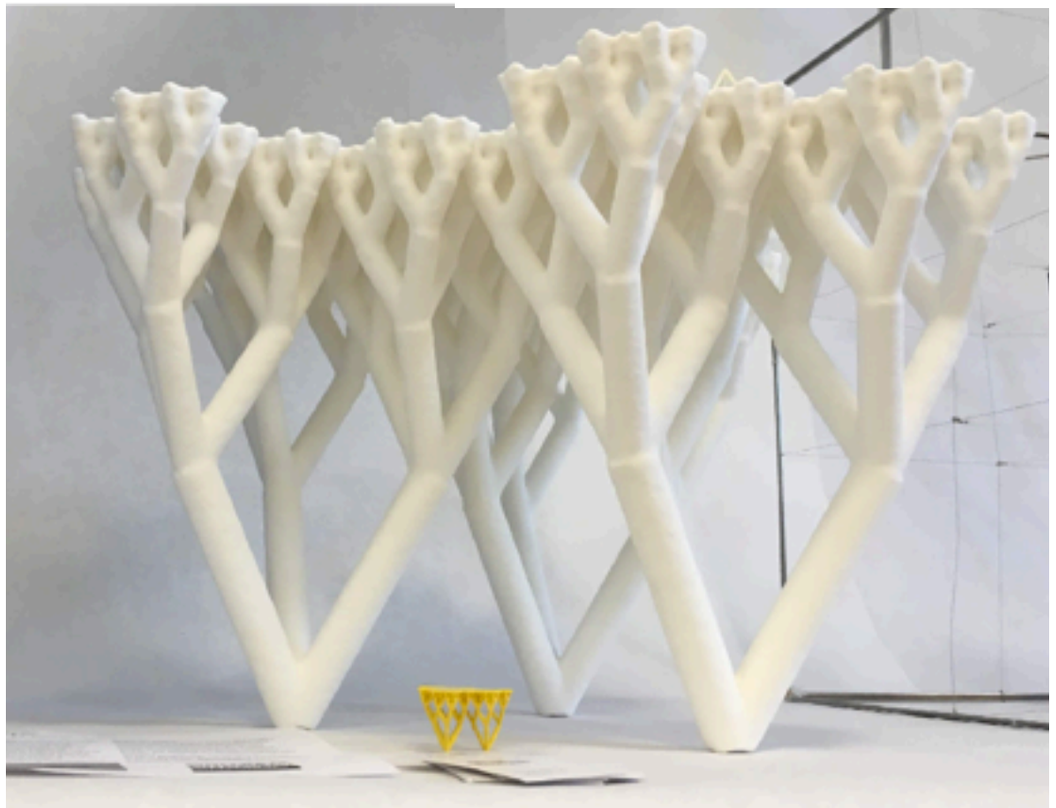


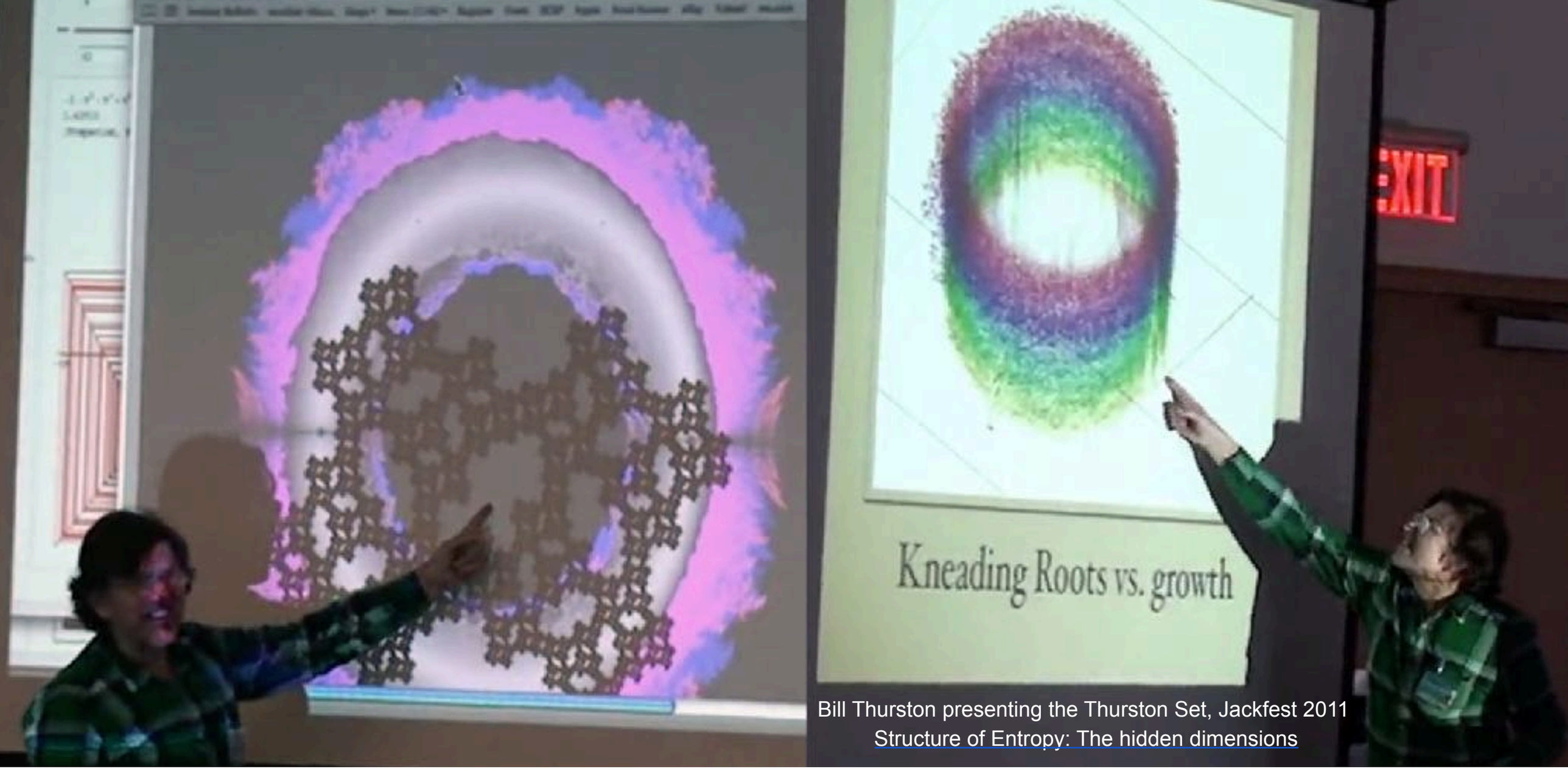


2013 - 2017

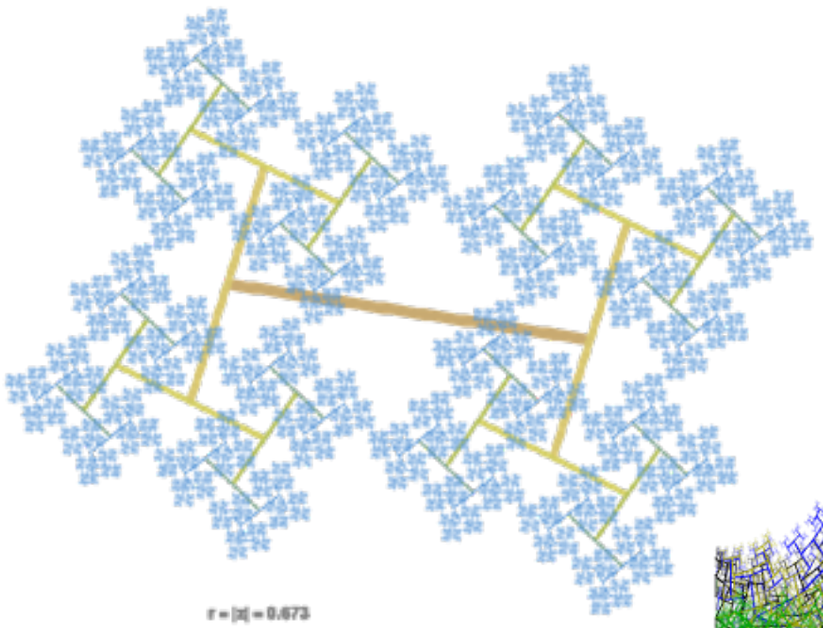
ComplexTrees.com

UNIVERSITAT DE BARCELONA



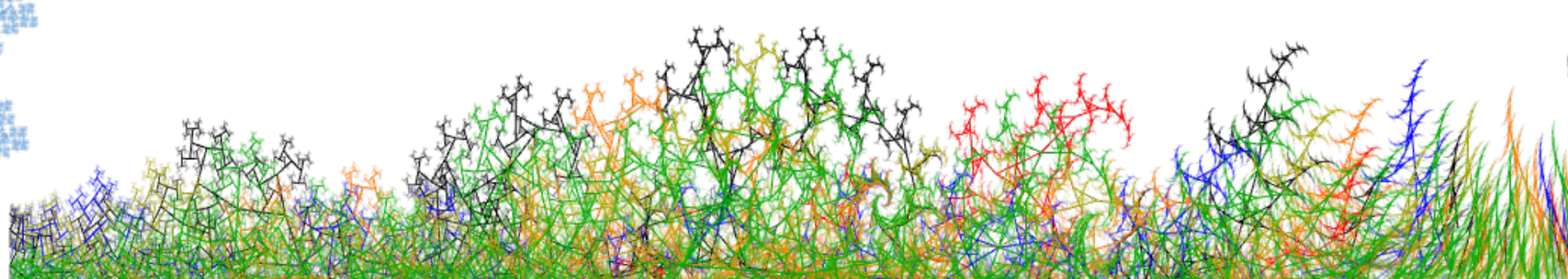


Bill Thurston presenting the Thurston Set, Jackfest 2011
Structure of Entropy: The hidden dimensions



Math Cartography: Mapping Polynomial Roots of Complex Trees

Collaborate, Contribute… join TREES.TEAM



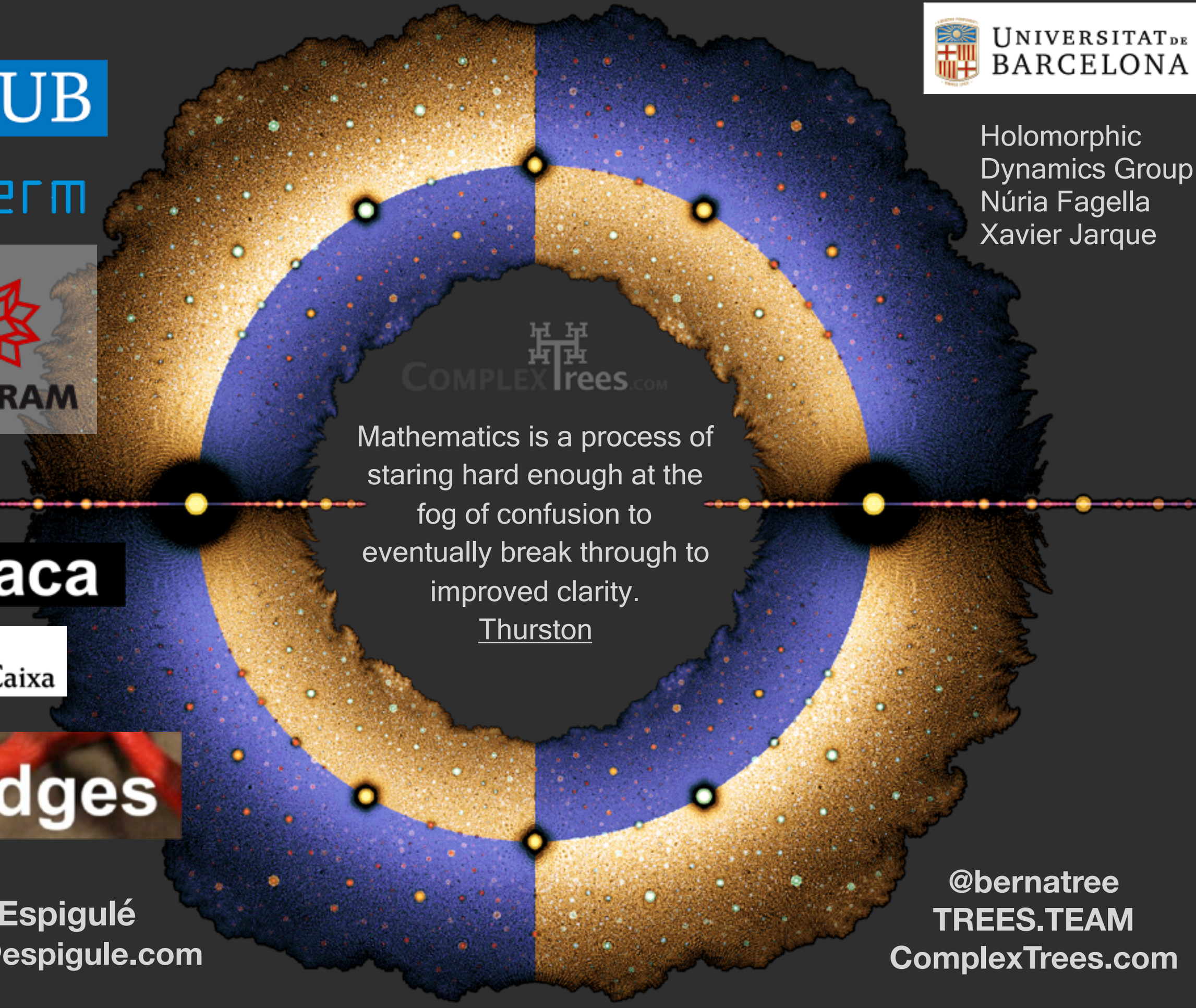
IMUB

ICERM

WOLFRAM

UNIVERSITAT DE BARCELONA

Holomorphic Dynamics Group
Núria Fagella
Xavier Jarque



Mathematics is a process of staring hard enough at the fog of confusion to eventually break through to improved clarity.
Thurston

mmaca

"la Caixa" CosmoCaixa

Bridges

Bernat Espigulé
bernat@espigule.com

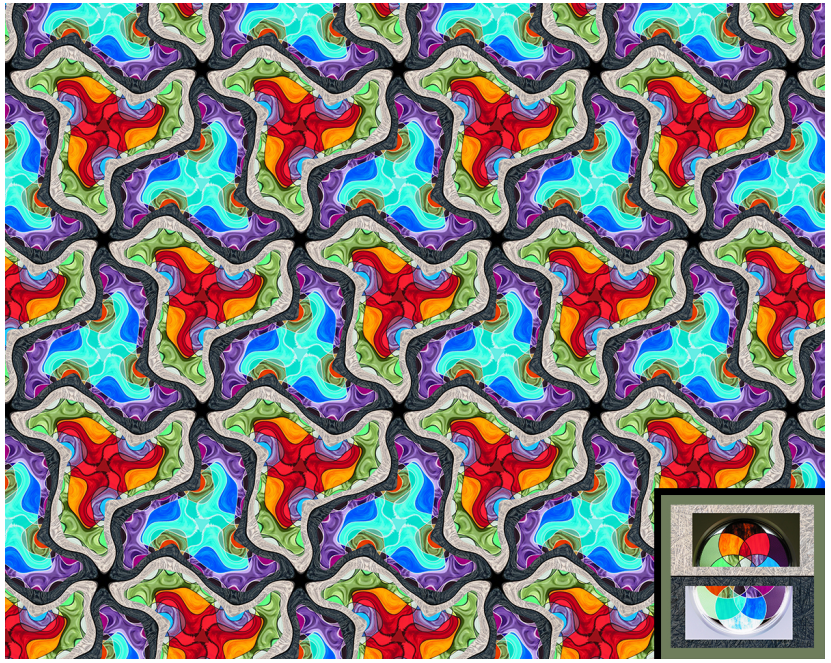
@bernatree
TREES.TEAM
ComplexTrees.com

Frank Farris

Santa Clara University

Past projects: *Creating Symmetry (wallpaper)*



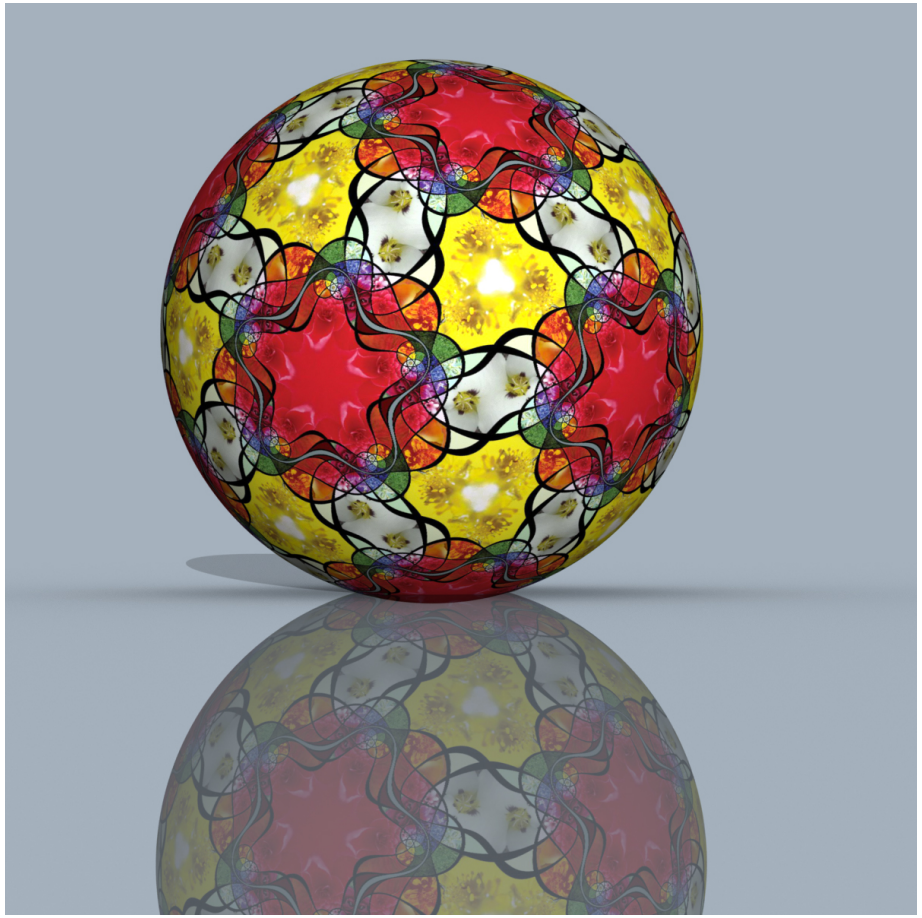


Theme: Continuous mathematics provides design spaces for patterns

Now with fewer bugs!

Open-source *SymmetryWorks* software has GUI for easy experimenting.

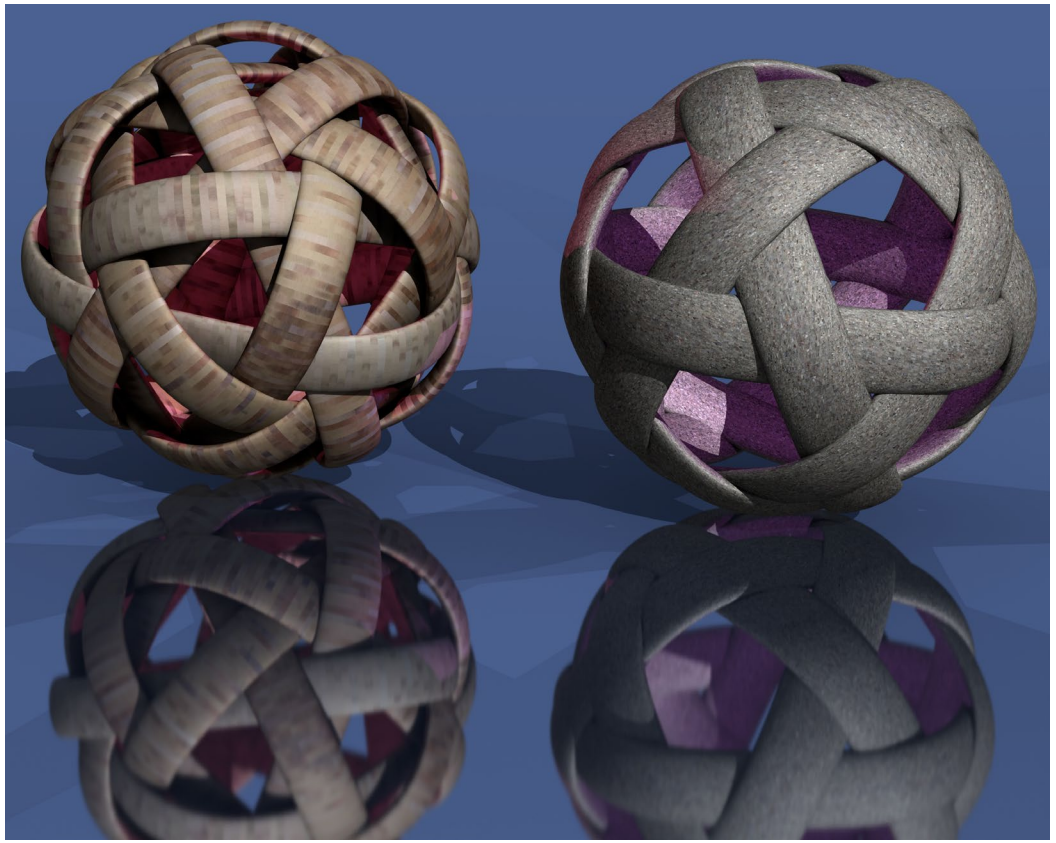
Past: Patterns and VR

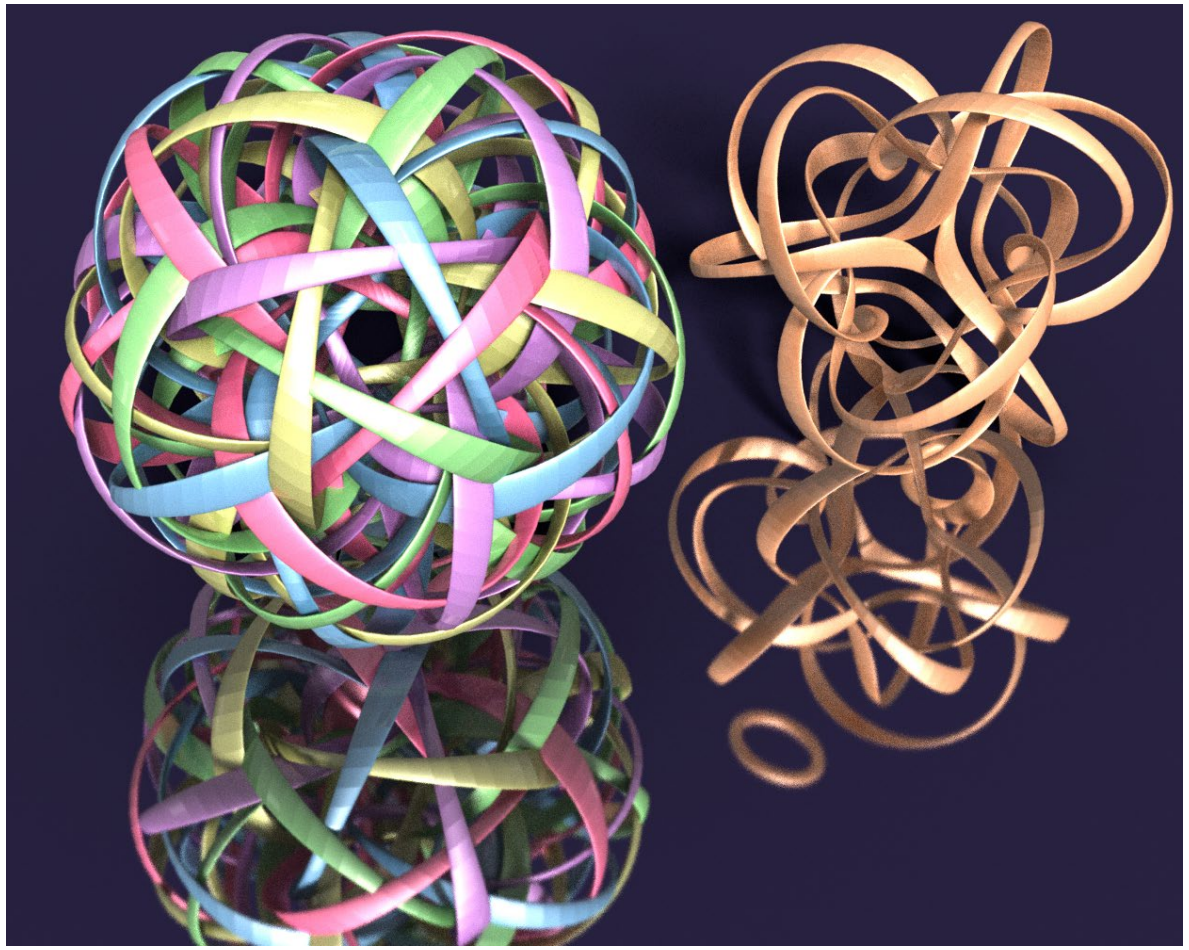




Surreal “Imaginary Landscapes”

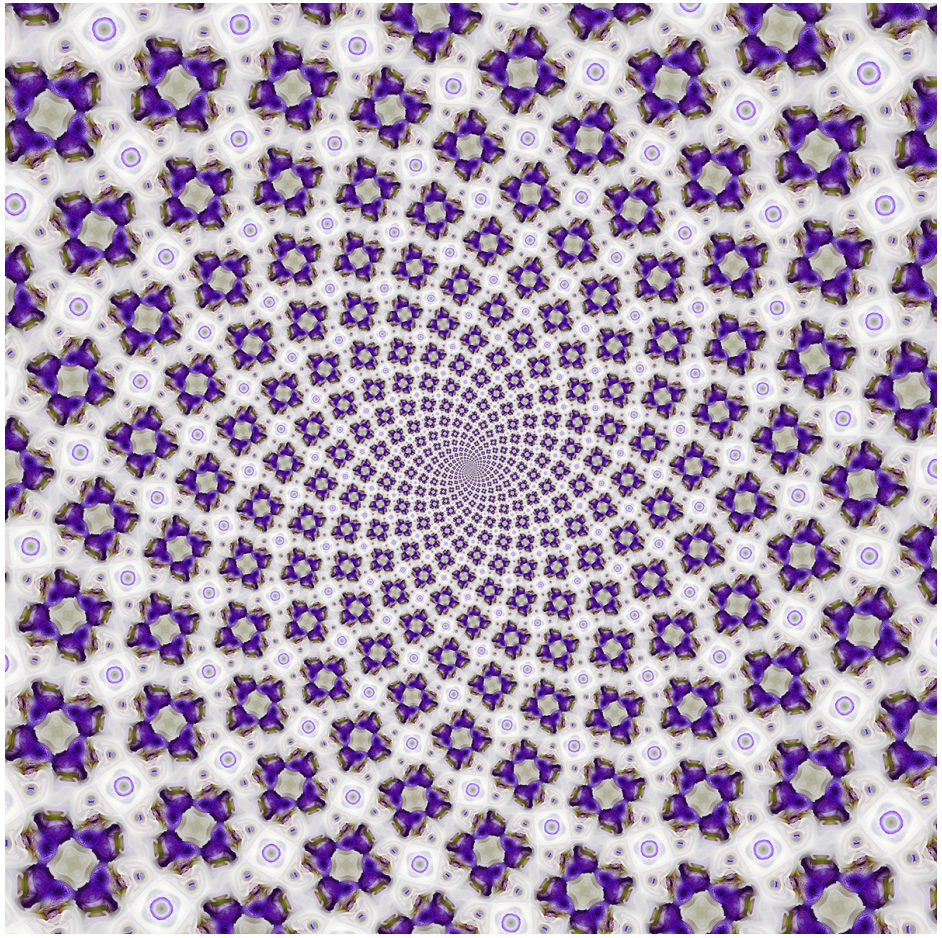
Now/Future: Weaving (plaiting) bands

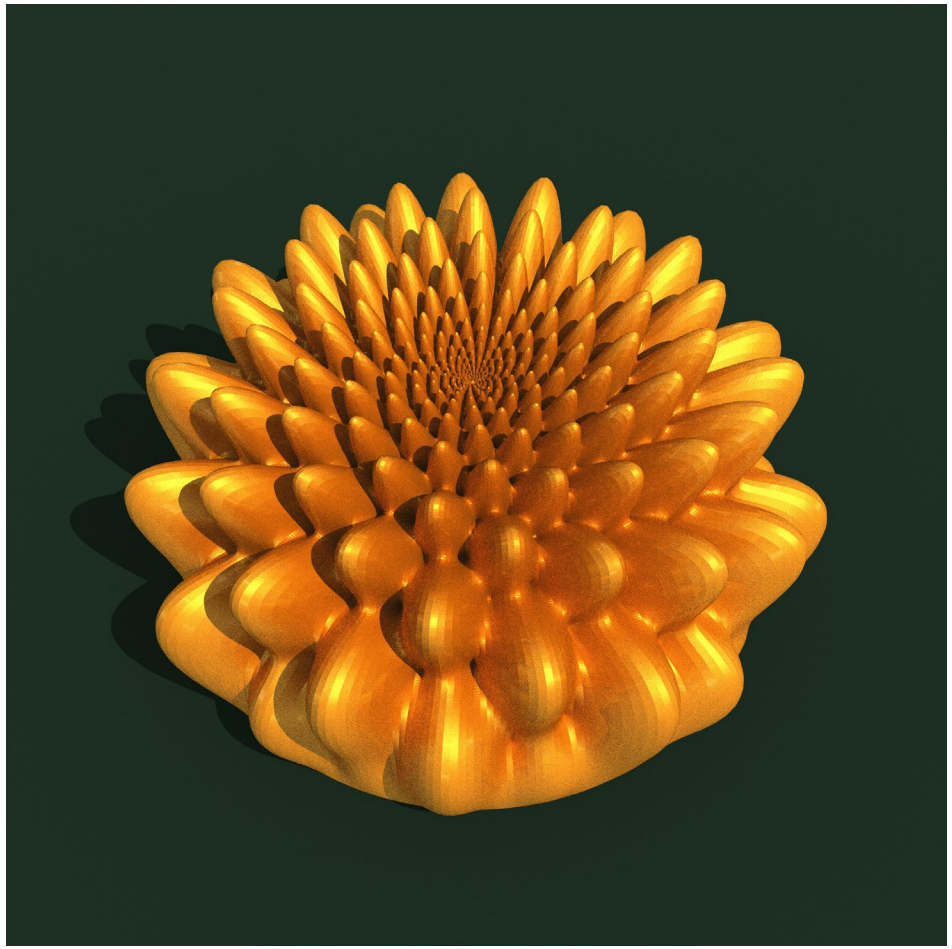




MS about polyhedral nearly ready for JMA submission; expand to frieze and wallpaper patterns?

Now/Future: Fibonacci Spirals (w. John Edmark)

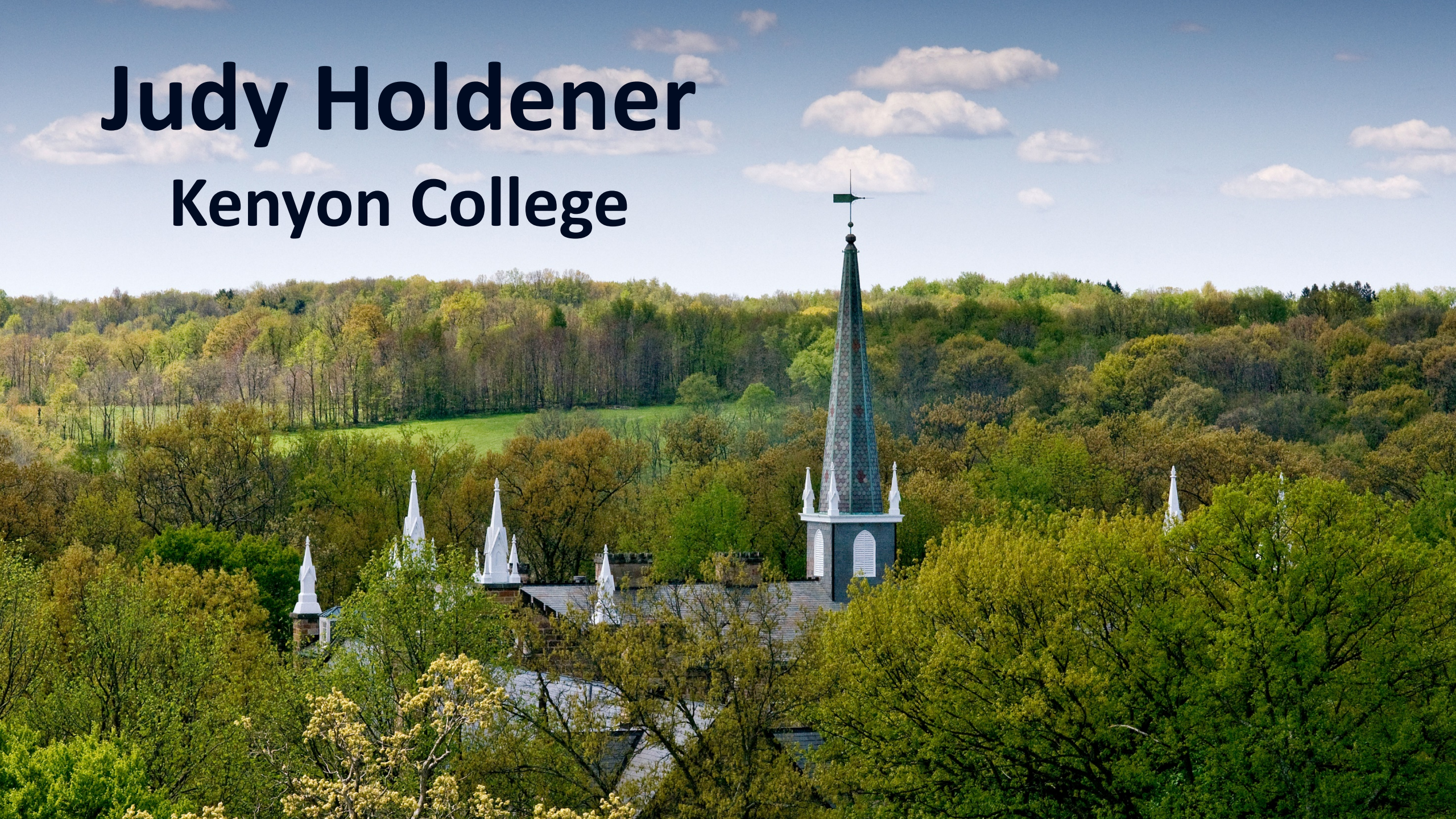


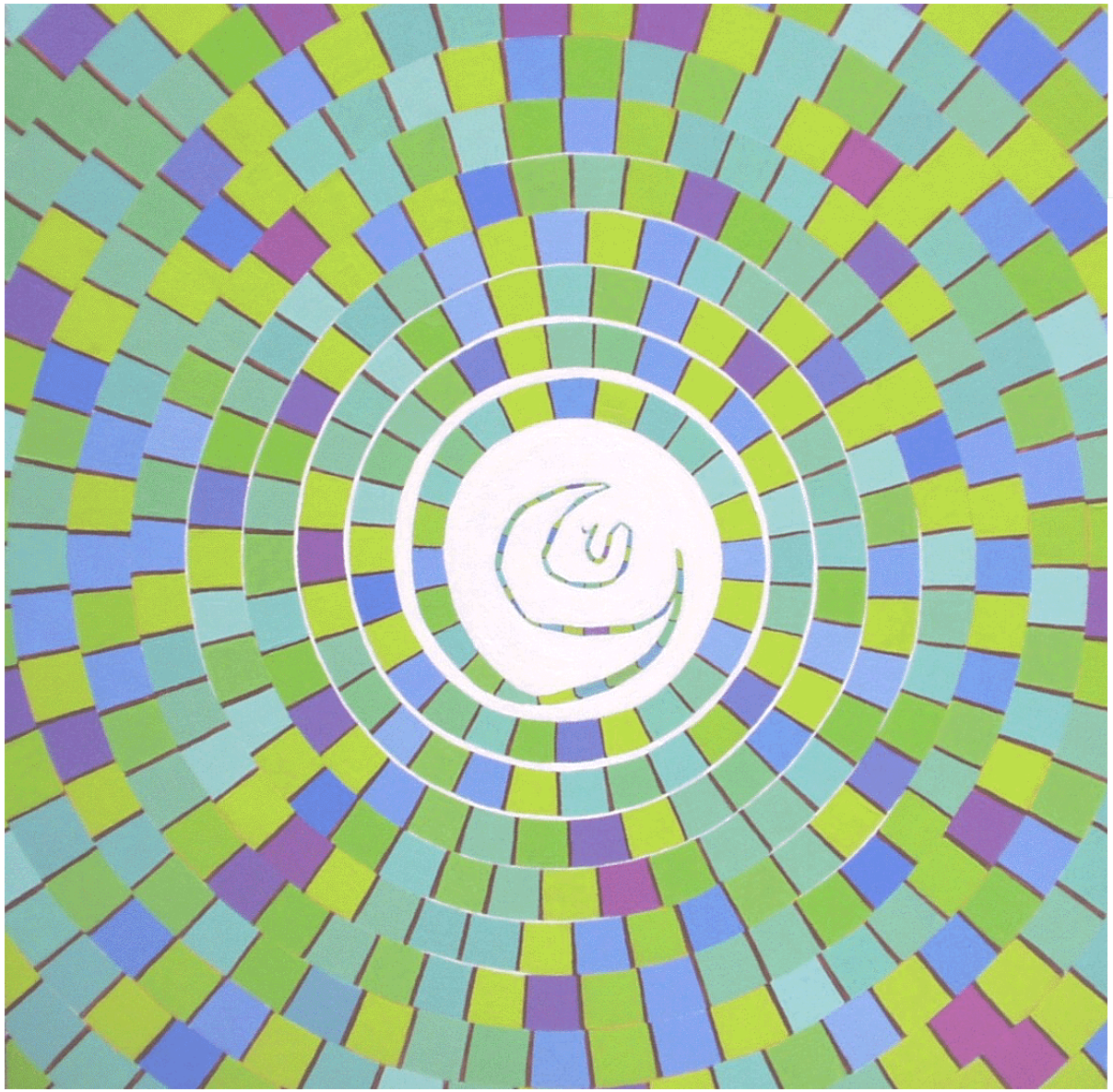


Project page submitted

Judy Holdener

Kenyon College





"*Abundancy*" *acrylics on canvas, 36'' x 36''*

THE AMERICAN MATHEMATICAL MONTHLY MAA

Perfect and Deficient Perfect Numbers

Judy Holdener and Emily Rachfal

Abstract. If n is a positive integer, then $\sigma(n)$ denotes the sum of the divisors of n. The number n is said to be *deficient perfect* if $\sigma(n)/n = (2x-1)/x$ for some $x \in \mathbb{N}$. We show that every perfect number has a deficient perfect divisor, generalizing a consequence of Euclid and Euler's characterization of even perfect numbers, namely that every even perfect number has an almost perfect divisor.

1. INTRODUCTION. The study of perfect numbers has spawned the definition and investigation of several related numbers: almost perfect numbers, deficient perfect numbers, and spoof perfect numbers. At first glance, these perfect spin-offs might appear to be curious alternatives to perfect numbers, arising out of the intractability of problems related to perfect numbers. However, a closer look reveals that these perfect variants are inextricably linked to perfect numbers. Indeed, the Euclid–Euler characterization of even perfect numbers reveals that every even perfect number is a multiple of an almost perfect number. In this note we show that the situation is similar with odd perfect numbers in that every odd perfect number is a multiple of a deficient perfect number. Since every almost perfect number is also deficient perfect, this means every perfect number has a deficient perfect divisor. Additionally, we examine the possibility of constructing odd perfect numbers and Descartes numbers from odd deficient perfect numbers.

June, 2019

WHEN THUE-MORSE MEETS KOCH

JUN MA AND JUDY HOLDENER

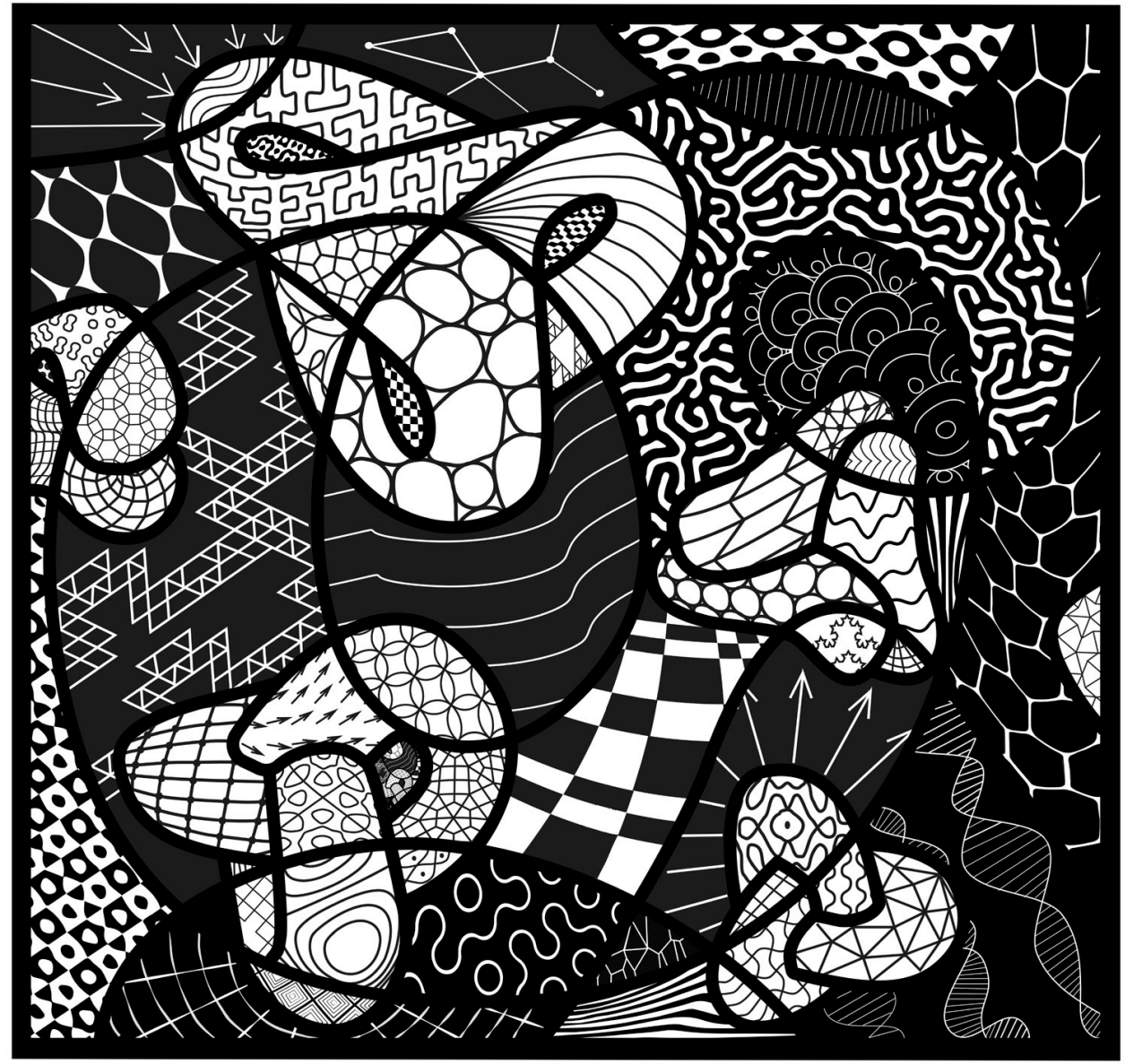
ABSTRACT. In this paper, we reveal a remarkable connection between the Thue-Morse sequence and the Koch snowflake. Using turtle geometry and polygon maps, we realize the Thue-Morse sequence as the limit of polygonal curves in the plane. We then prove that a sequence of such curves converges to the Koch snowflake in the Hausdorff metric. In the final section we consider generalized Thue-Morse sequences and provide a characterization of those that encode curves converging to the Koch snowflake.

1. INTRODUCTION

The Thue-Morse sequence and the Koch snowflake have much in common. Both are defined iteratively. Both exhibit properties of self-similarity. Both first appeared in the early 1900's (the Koch snowflake in 1906 and the Thue-Morse sequence in 1912). And both continue to appear frequently - yet independently - in popular mathematical writing today. In this paper, we will show that the commonality between these two famous objects is deeper yet. Indeed, by realizing the Thue-Morse sequence geometrically as the limit of polygonal curves in the plane, we will show that the connection between the Thue-Morse sequence and the Koch snowflake is much stronger than one might expect.

The Thue-Morse sequence is a two symbol sequence typically defined by iterating a substitution map σ. Given the alphabet $A = \{a, b\}$, define the morphism $\sigma : \mathcal{A}^* \to \mathcal{A}^*$ by setting $\sigma(a) = ab$ and $\sigma(b) = ba$. If $\sigma^0 = a$, we see that σ generates the sequence of words:

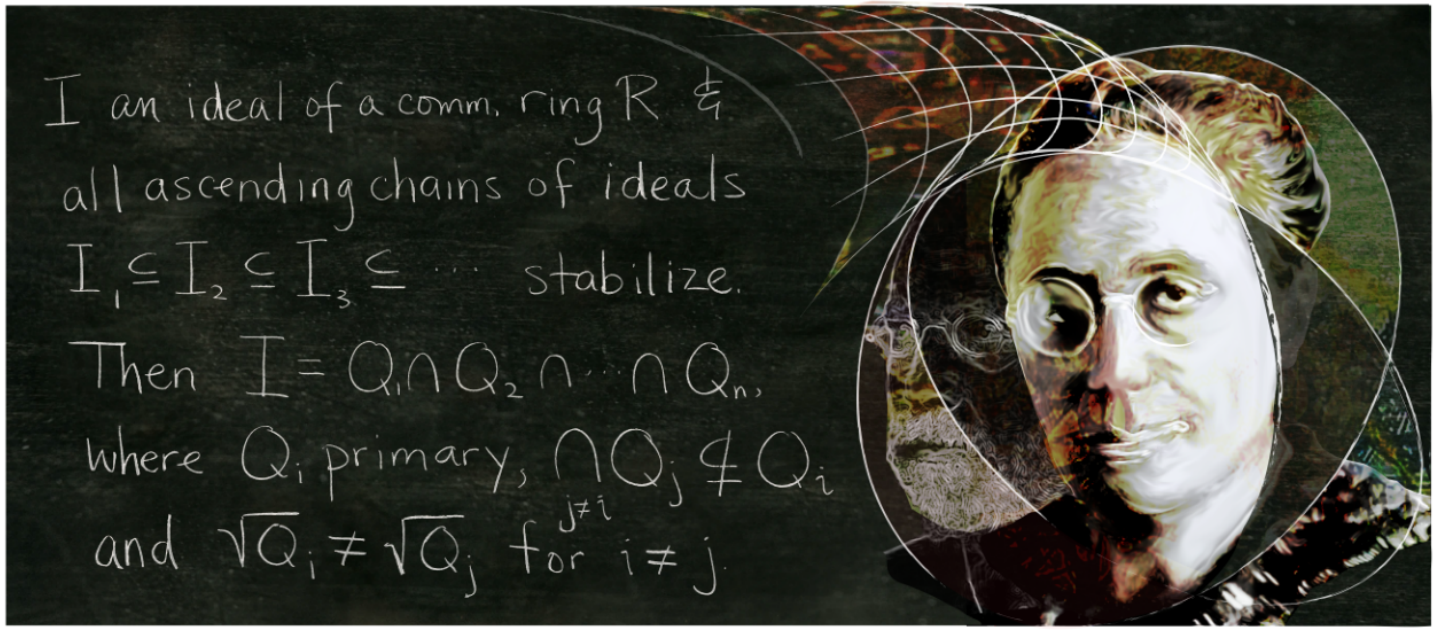
Appeared in the journal *Fractals: Complex Geometry, Patterns, and Scaling in Nature and Society* in 2005



"Immersion"

digital, 36'' x 36''

Work in Progress…



My digital work will commemorate Emmy Neother's 1921 paper *Idealtheorie in Ringbereichen* (*Theory of Ideals in Ring Domains*), in which Neother extends Lasker's Theorem on the primary decomposition of ideals of polynomial rings to all Noetherian rings.



It was inspired by Jackson Pollock's diptych "Portrait and a Dream," which Pollock painted in 1953 -- just three years before his death.

Goals for the semester…

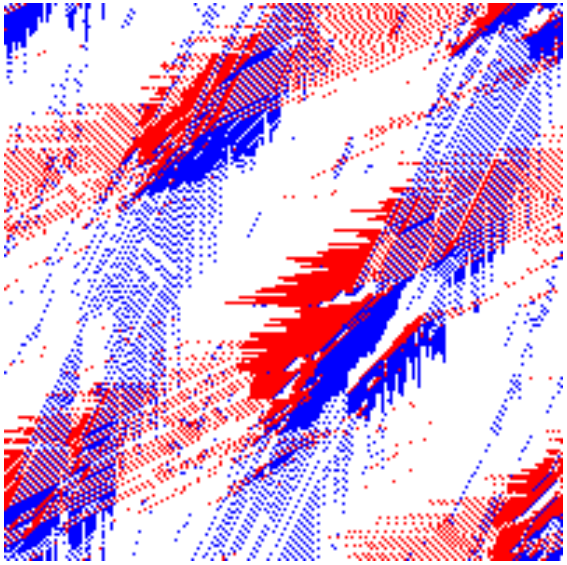
- Identify new projects that can involve undergraduates (ideally at varying levels - not just juniors and seniors)
- Learn new visualization tools in algebra and number theory (I'm looking forward to the Oct 21-25 workshop!)
- Learn how to use a 3D printer
- Become a more proficient Python programmer
- Form new collaborations

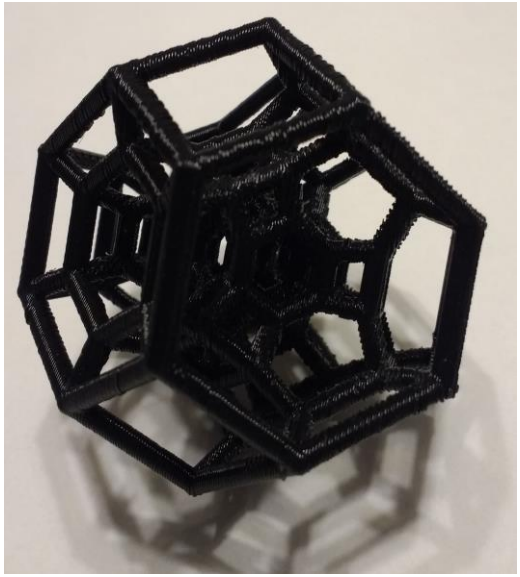
Alexander E Holroyd

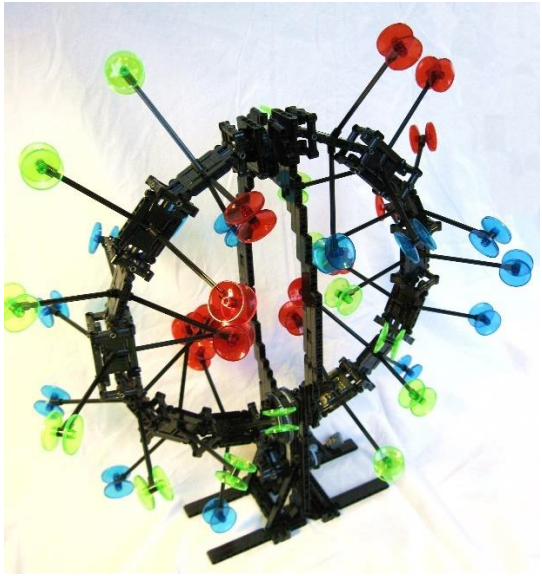
aeholroyd.org

Research: Probability and combinatorics, including percolation, algorithms, statistical physics, cellular automata, permutations, matching, coupling, graph drawing.

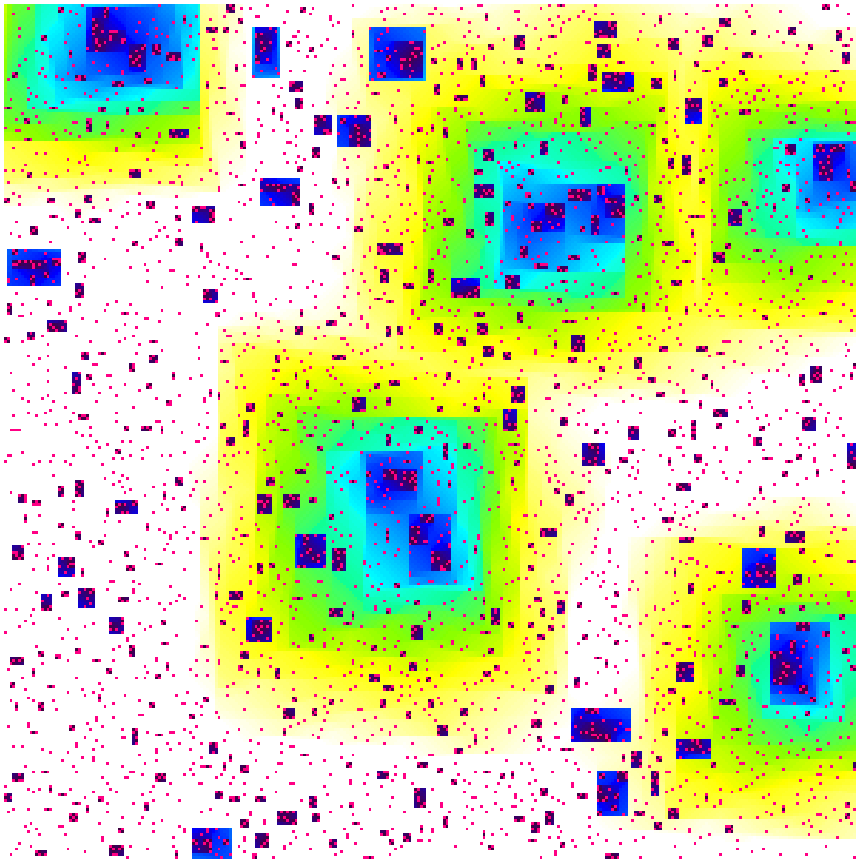
Illustration: Simulations to guide rigorous discovery, 3D visualizations, mechanical computation, puzzles, LEGO.

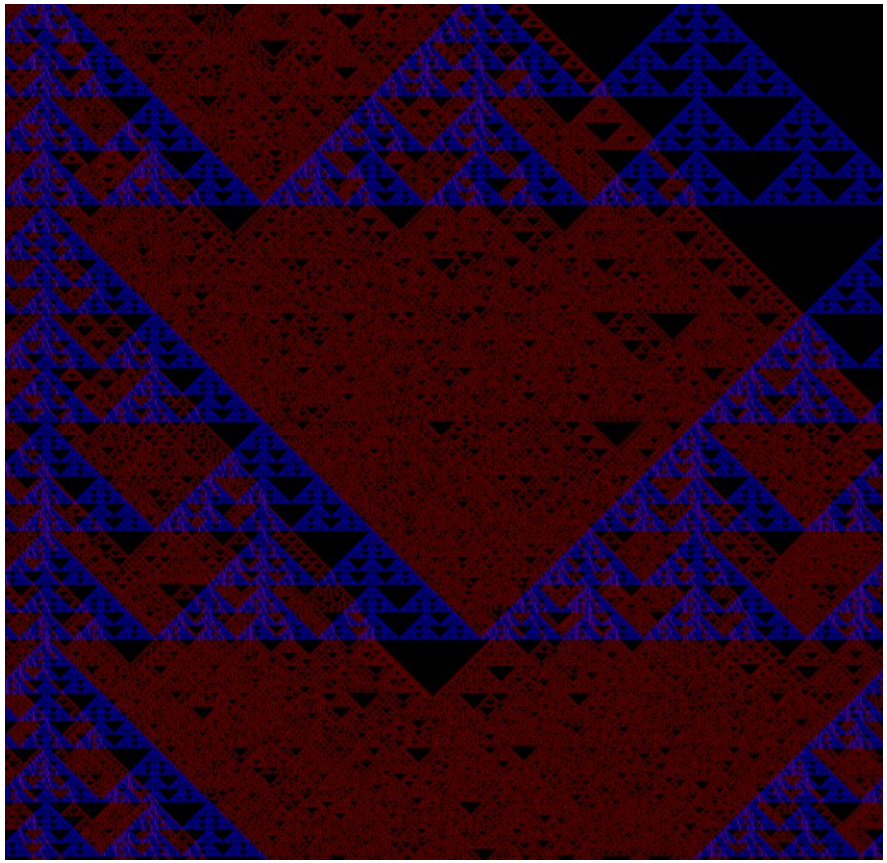




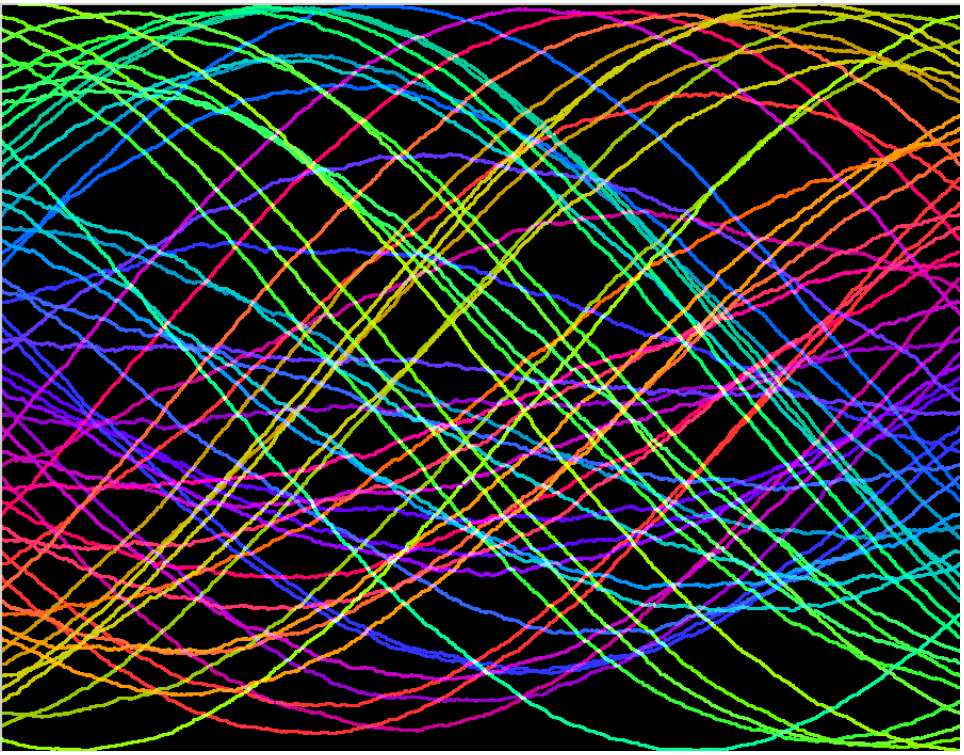


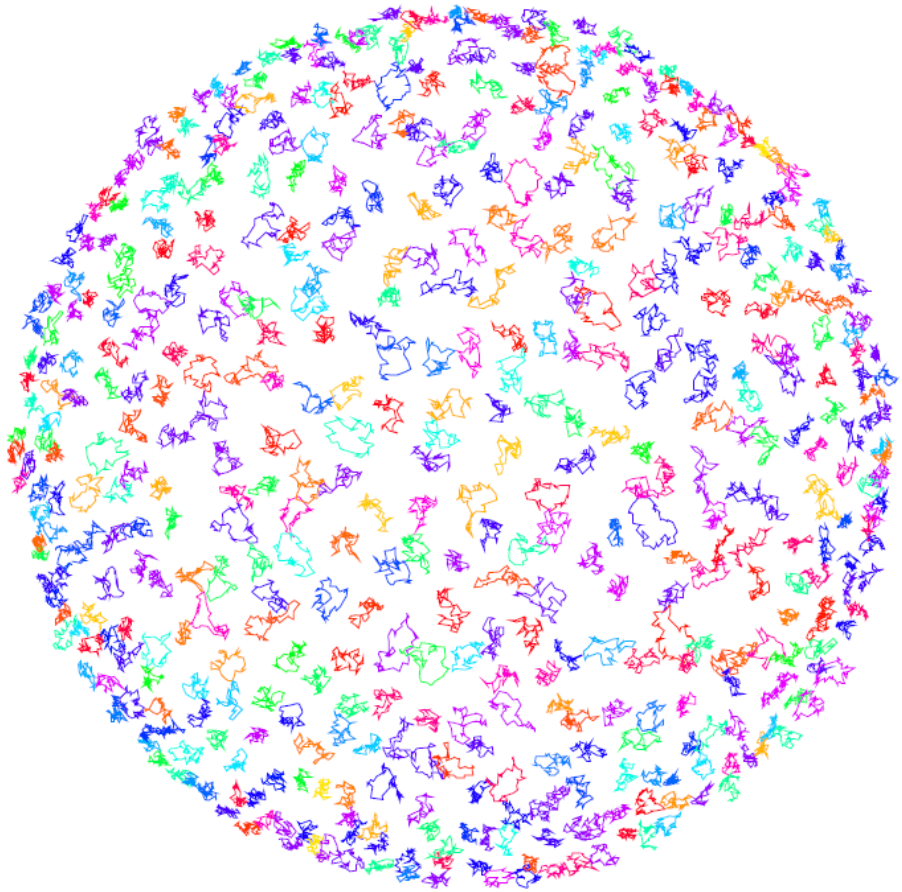
Cellular automata



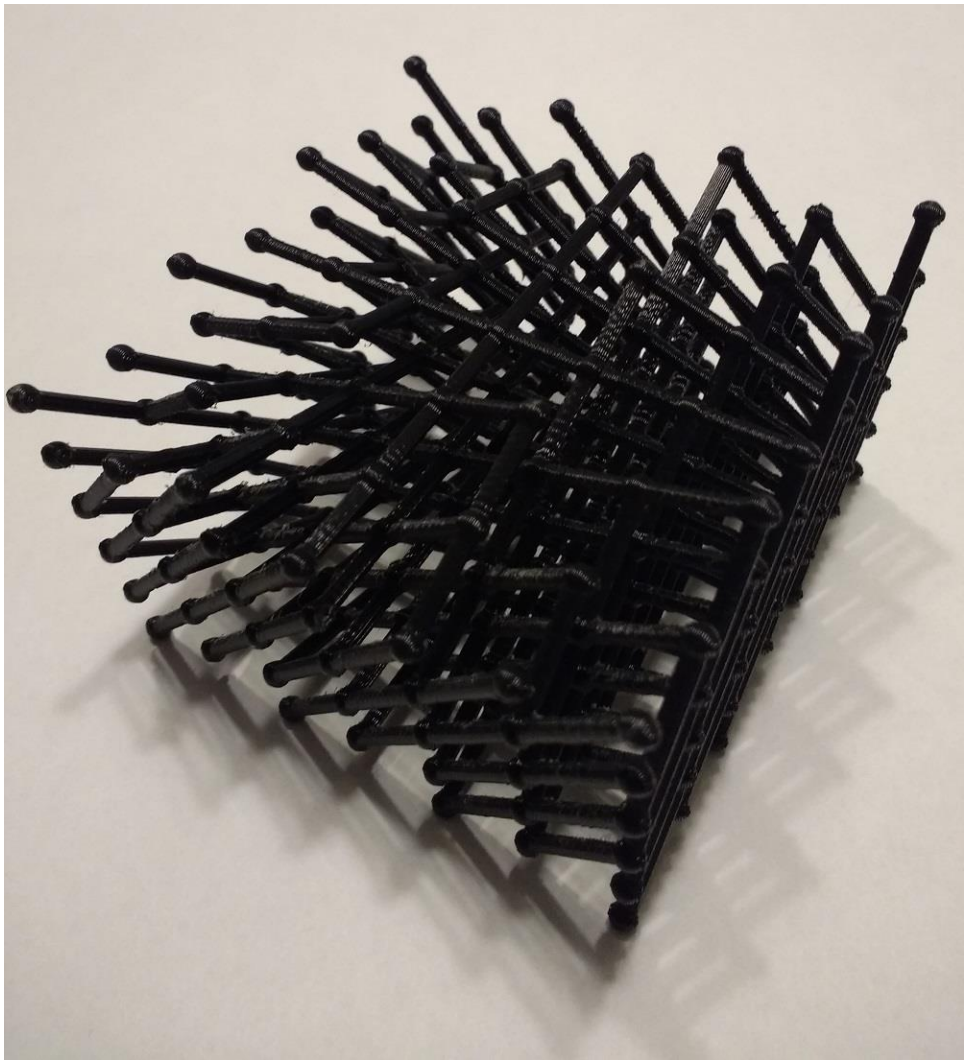


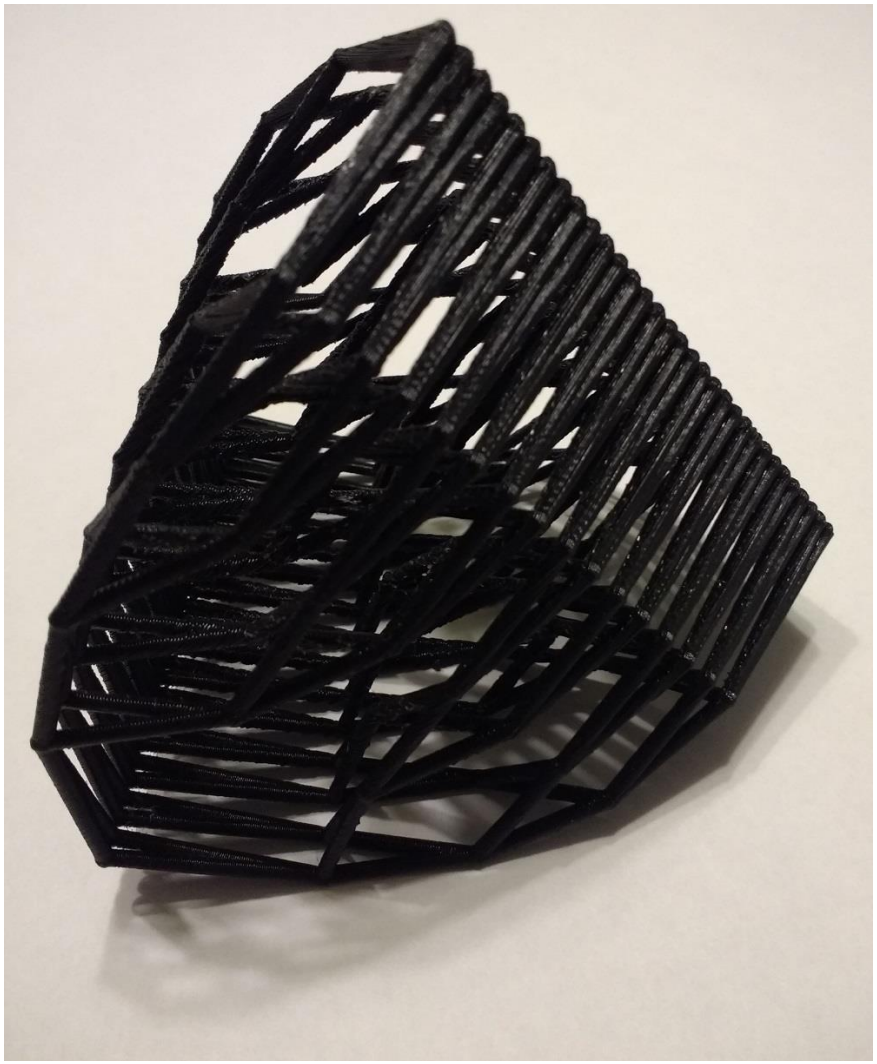
Random sorting networks



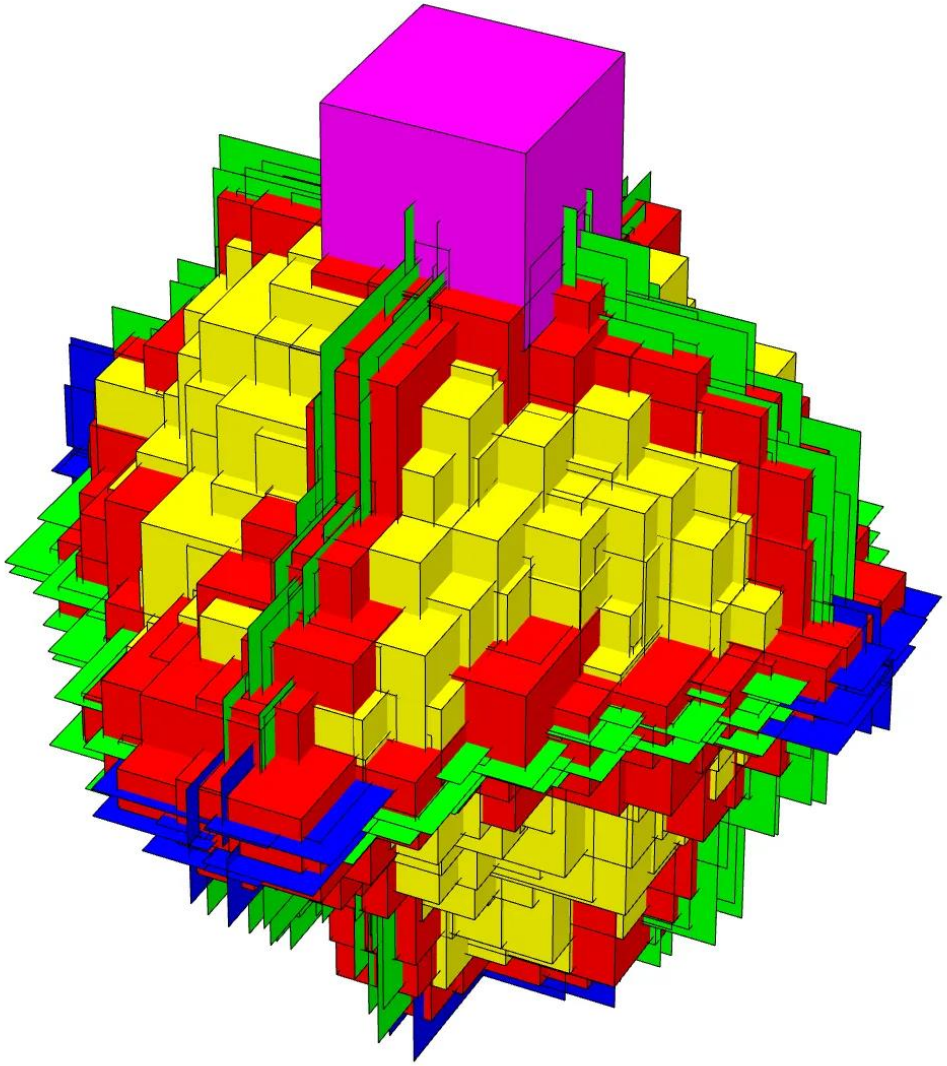


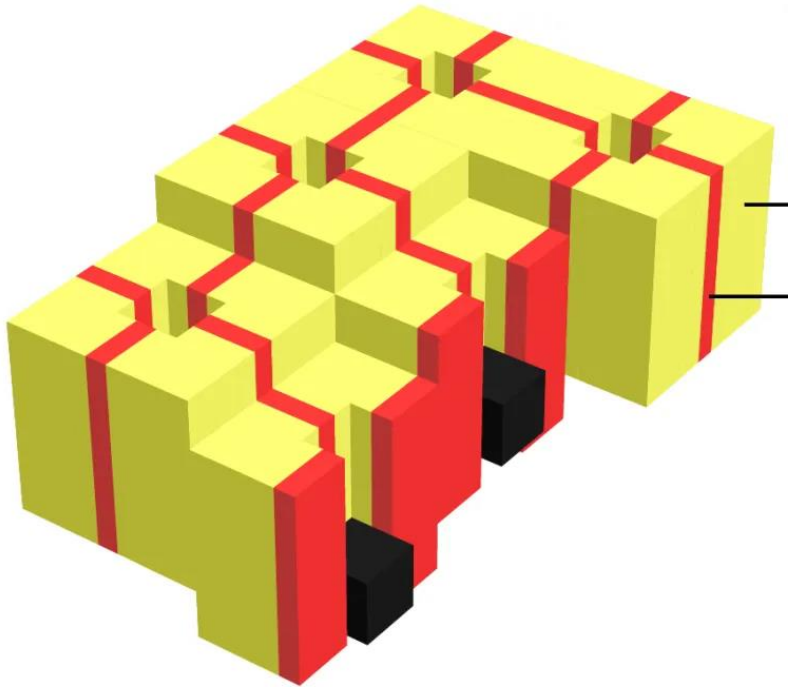
3D graphs



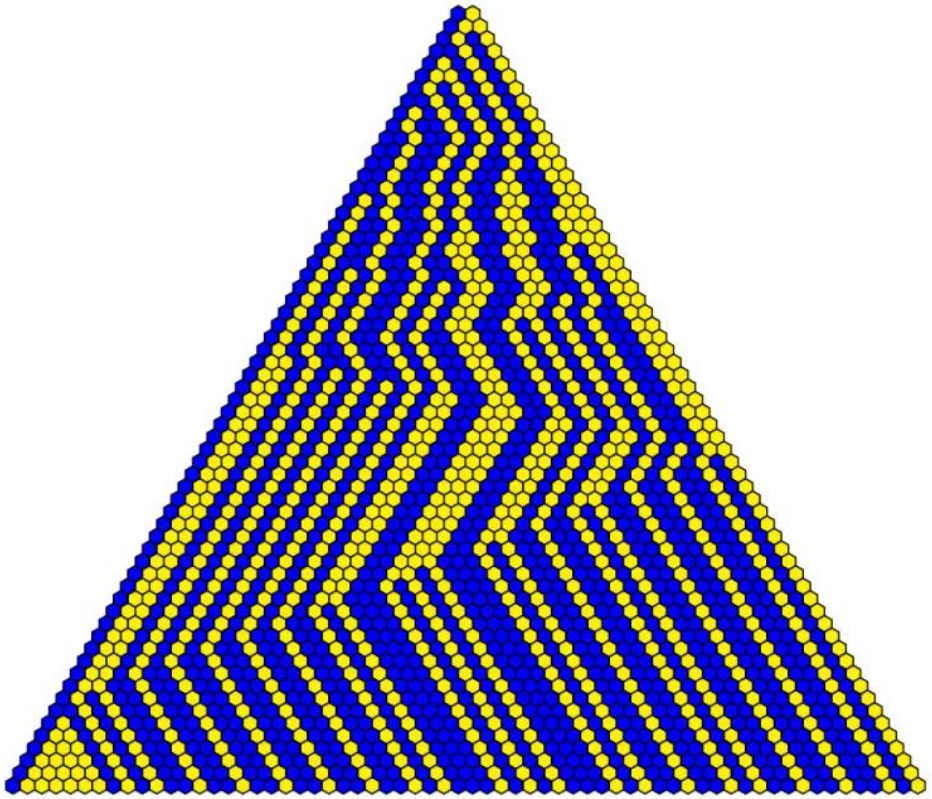


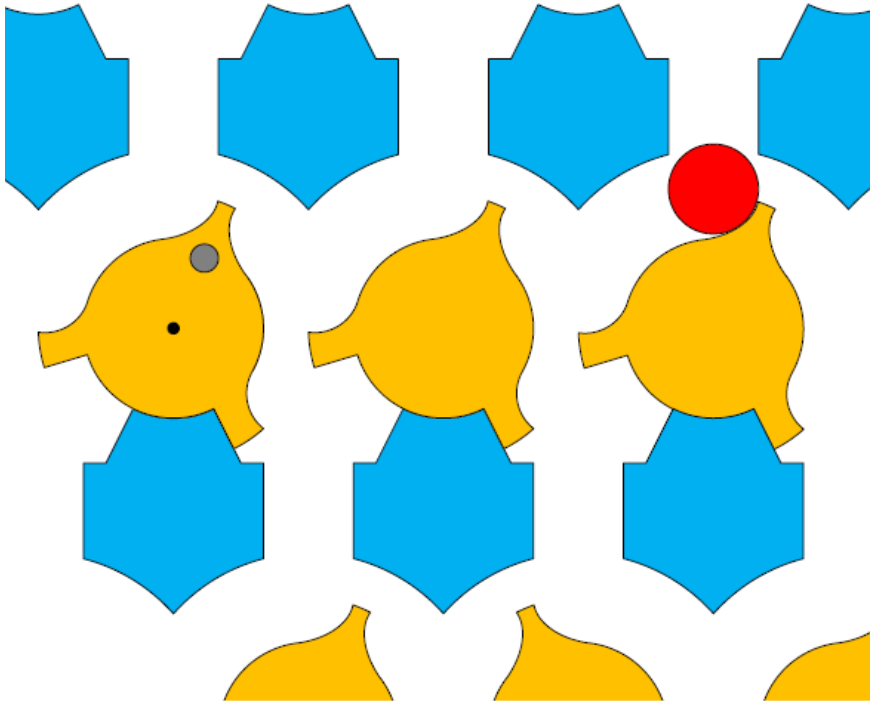
3D figures





Derandomized machines



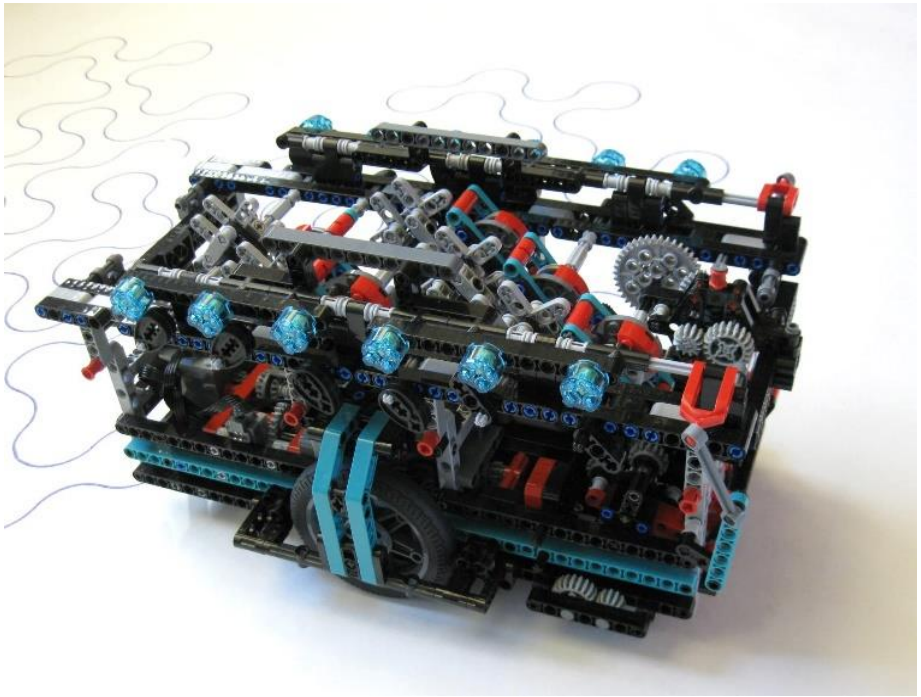


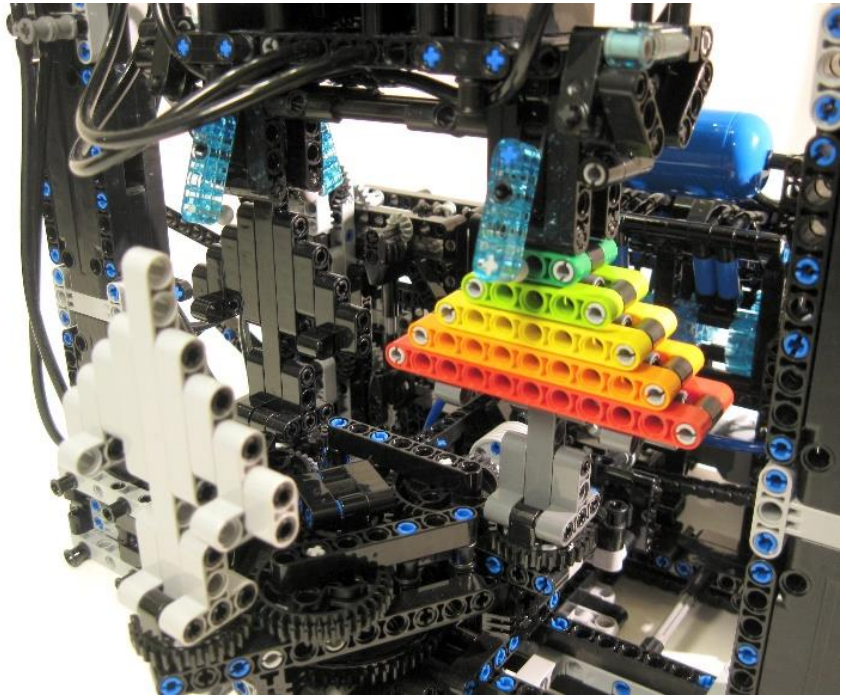
Puzzles and permutations





LEGO mechanical computation

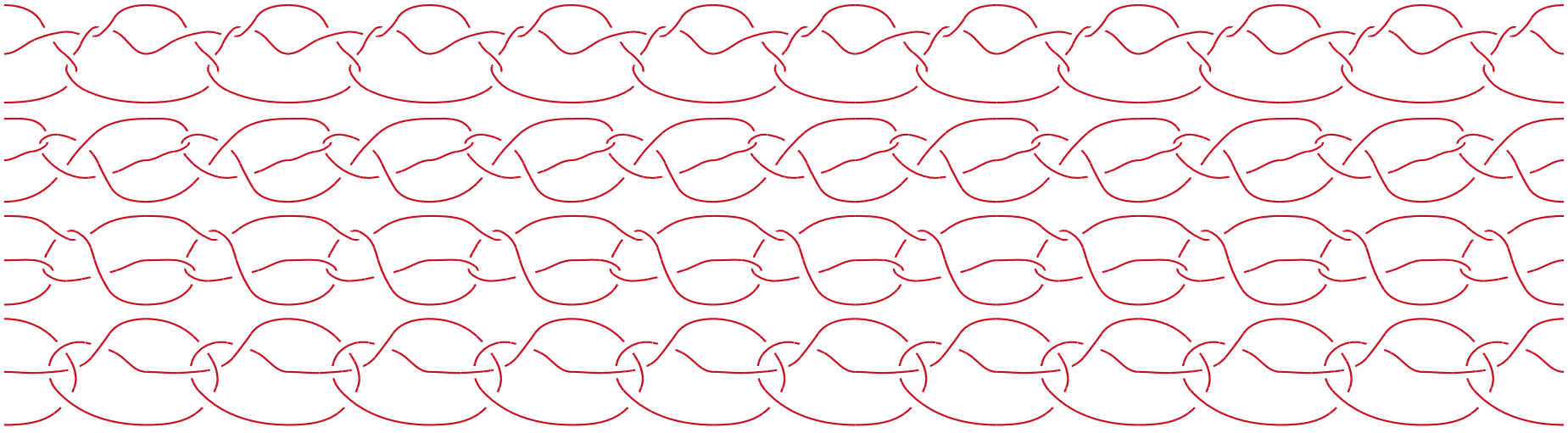




LEGO kinetic art

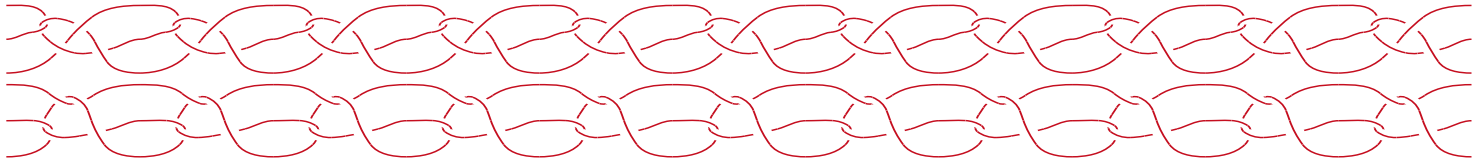






Max Krause

Pronouns: he/him | Technische Universität Berlin | Berlin Mathematical School



Technische Universität Berlin

Past and current research

Ongoing research

- periodic linked structures in $\mathbb{R}^3$
- knots and links in general 3-manifolds
- geometric knot theory

Other mathematical interests

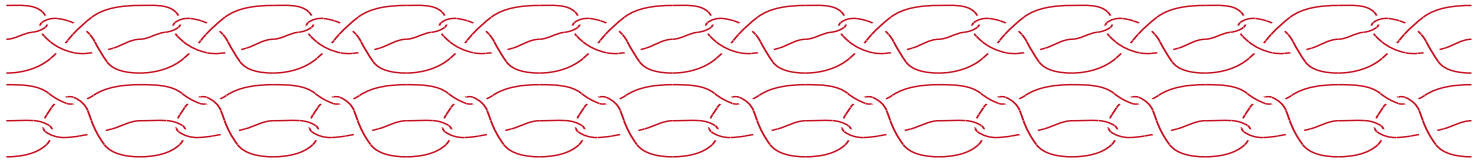
- outer space theory
- homotopy theory
- set theory

Projects

- generating links tables for periodic links (in Python)
- recreating the Rolfsen Knot table in RollerCoaster Tycoon® 2

Goals for the program

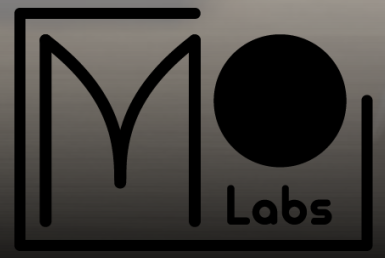
- learn about visualization techniques for knot theory
- exchange ideas on the topology of periodic structures
- make contacts & friends for future cooperation
- enjoy mathematical art



Math Objects since 1999

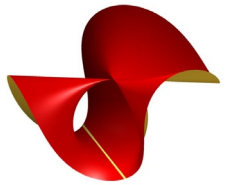
short presentation at ICERM, Sept. 2019
by Oliver Labs (MO-Labs)

- Math sculptures
- Math art
- Math jewelry
- Interactive math
- Math history
- Math explained

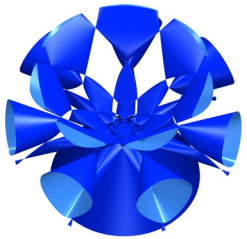


Background: Math Research

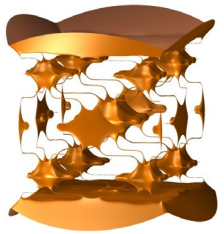
since 1999



Since 1999: Nice equations for **cubic surfaces** (diploma thesis etc.) and related computer algebra and **software development**

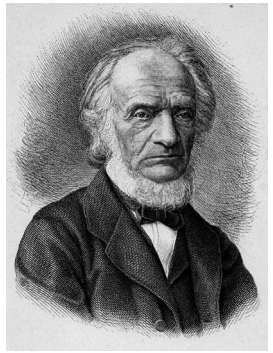


Since 2003: World record surface construction, e.g. a septic with 99 singularities (ph.d. thesis etc.). Using geometry and computer algebra.



Since 2008: Challenges for **algebraic geometry visualization software**

Since 2002: Math history with a focus on 19th century (algebraic) geometry



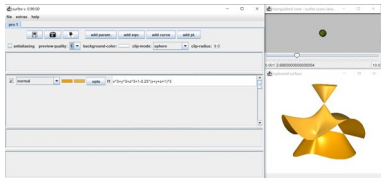
Since 2007: Math didactics, with a focus on dynamic geometry software (including **software development**), **hands on** math, algebra and geometry and their interactions



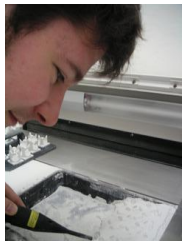
MO-Labs – Dr. Oliver Labs
Math Objects

Types of Math Illustrations

since 1999



Since 2001: An interactive visualization **tool for algebraic geometry in 3d** („surfex“ (α version), 2007 (with MFO) „surfer“)

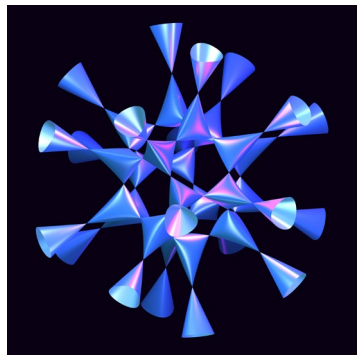


Since 2003: 3d-printed algebraic surfaces and other math objects. Exhibited at many places, e.g. IHP (Paris), Red Dot Design Award Museum (Singapore, 2019), …

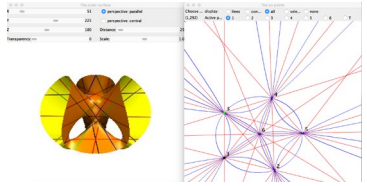


Since 2009: Math in glass, e.g. at the exhibit forms and formulas at Lisbon, (Portugal, 2012-), Deutsches Museum Munich (Germany), …

Since 1999: Algebraic geometry images, e.g. cubic surfaces, for SuSE Linux, for book covers, for the Imaginary exhibition, etc.



Since 2001: A dynamic geometry software („spicy“, α version) with interactive alg. geom. in 2d and 3d and computer algebra back-end, and applications, e.g. cubic surfaces



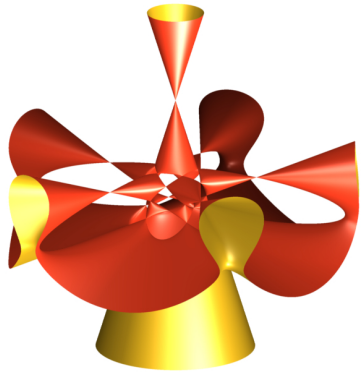
Since 2010: Math jewelry, in particular using algebraic geometry



MO-Labs – Dr. Oliver Labs
Math Objects

Plans for ICERM

Sept. 4 – Sept. 25, 2019

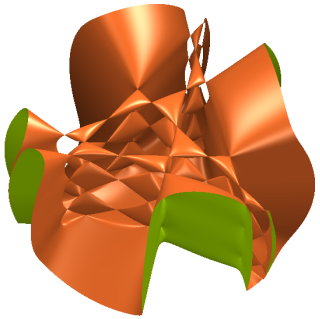


An **online tool** for interactive **visualization of algebraic geometry in 3d**, hopefully easy to use and with high quality output



Some interesting new **hands on math illustrations** and **math art**: Hopefully **with collaborators** from other areas to create **exciting totally new objects**. Also some unique and/or small series pieces for display at art galleries.

Several **algebraic geometry blog articles** explaining some math, using my existing tool in 2d and the new one for 3d



Algebraic geometry objects with parameters; connected to an online 3d printing service, so that people without any math and computer science knowledge may **create their own math objects**



MO-Labs – Dr. Oliver Labs
Math Objects

Dynamics, geometry, groups

convex bodies, flat surfaces, moduli spaces, polygonal billiards

Samuel Lelièvre
samuel.lelievre@math.cnrs.fr

Mathematics, U Paris-Sud, Orsay, France

ICERM, 2019-09-06

about me

research

translation surfaces and their special linear group orbits

projects [involved in]

SageMath · IMAGINARY · OpenDreamKit · Software Carpentry

computational skills

shell · version control · make · Python · SageMath

interests

code · compute · draw · help · install · listen · make · try

goals for the semester

compute, draw, learn, make

- Akiyama polyhedra: n vertices, fixed volume, least area
- "busy spaces, empty spaces" in the golden Stern-Brocot tree
- Lagrange and Markov spectra for square-tiled surfaces

consider submitting to

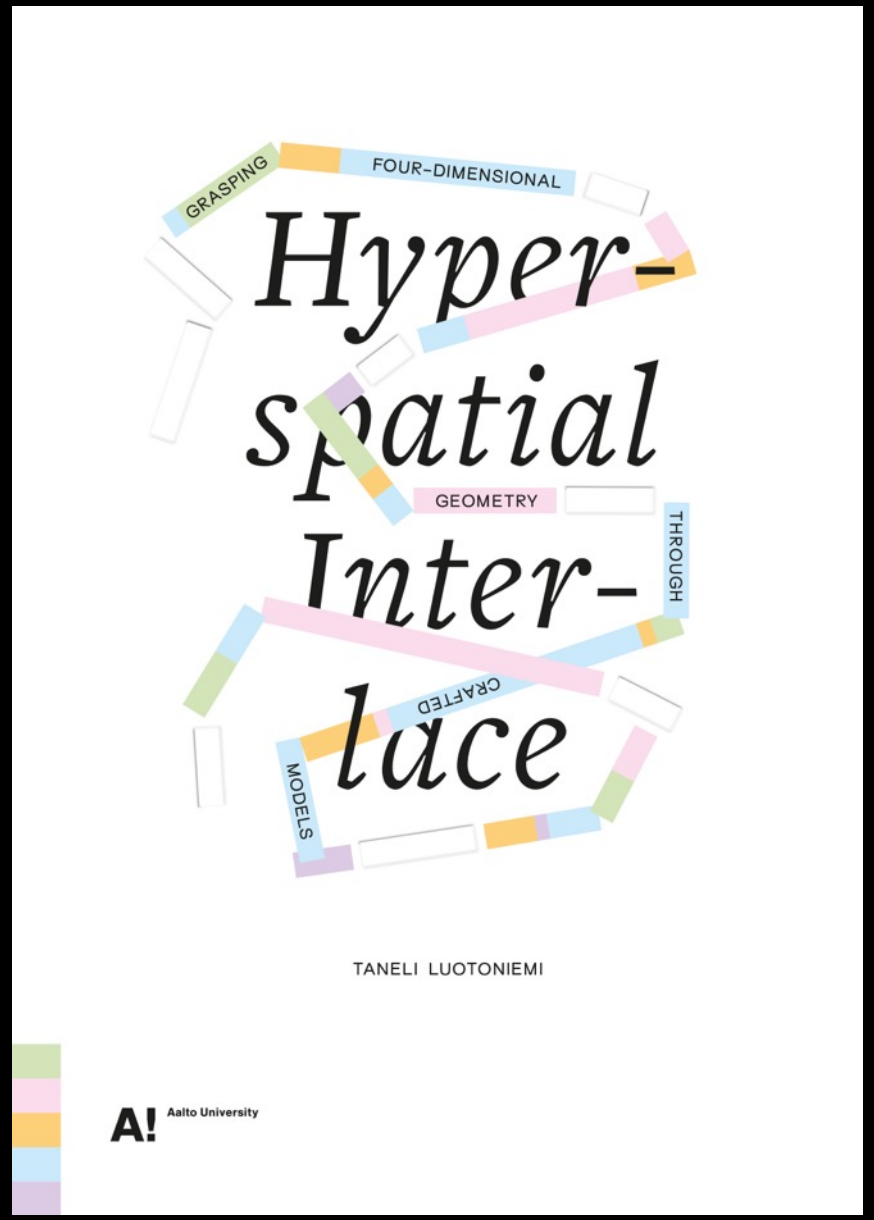
- BRIDGES art and math conference
- IMAGINARY platform for math exhibits
- SciPy John Hunter excellence in plotting contest

TANELI LUOTONIEMI

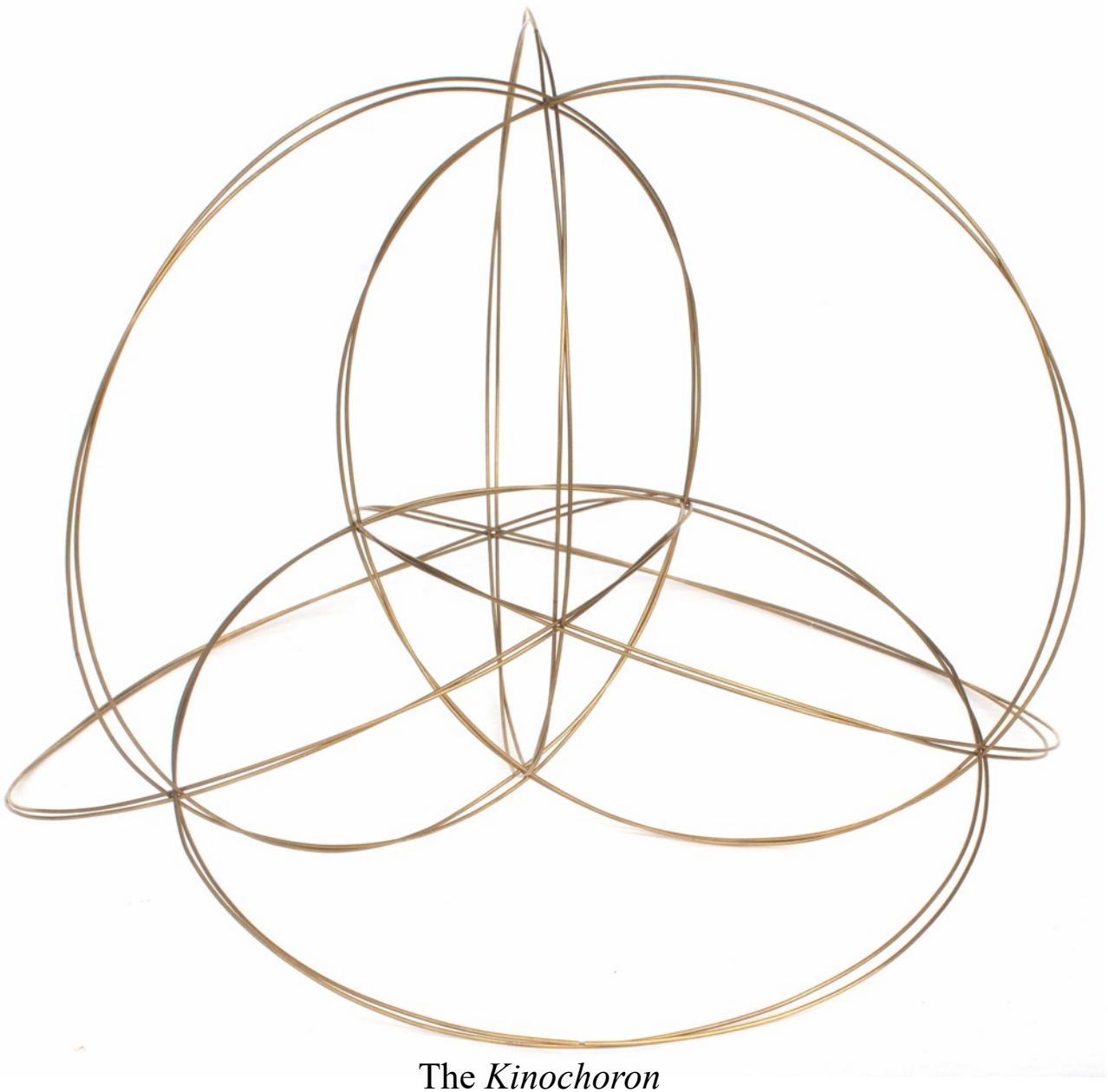
POSTDOCTORAL RESEARCHER

AALTO UNIVERSITY
SCHOOL OF SCIENCE
DEPARTMENT OF MATHEMATICS
AND SYSTEMS ANALYSIS

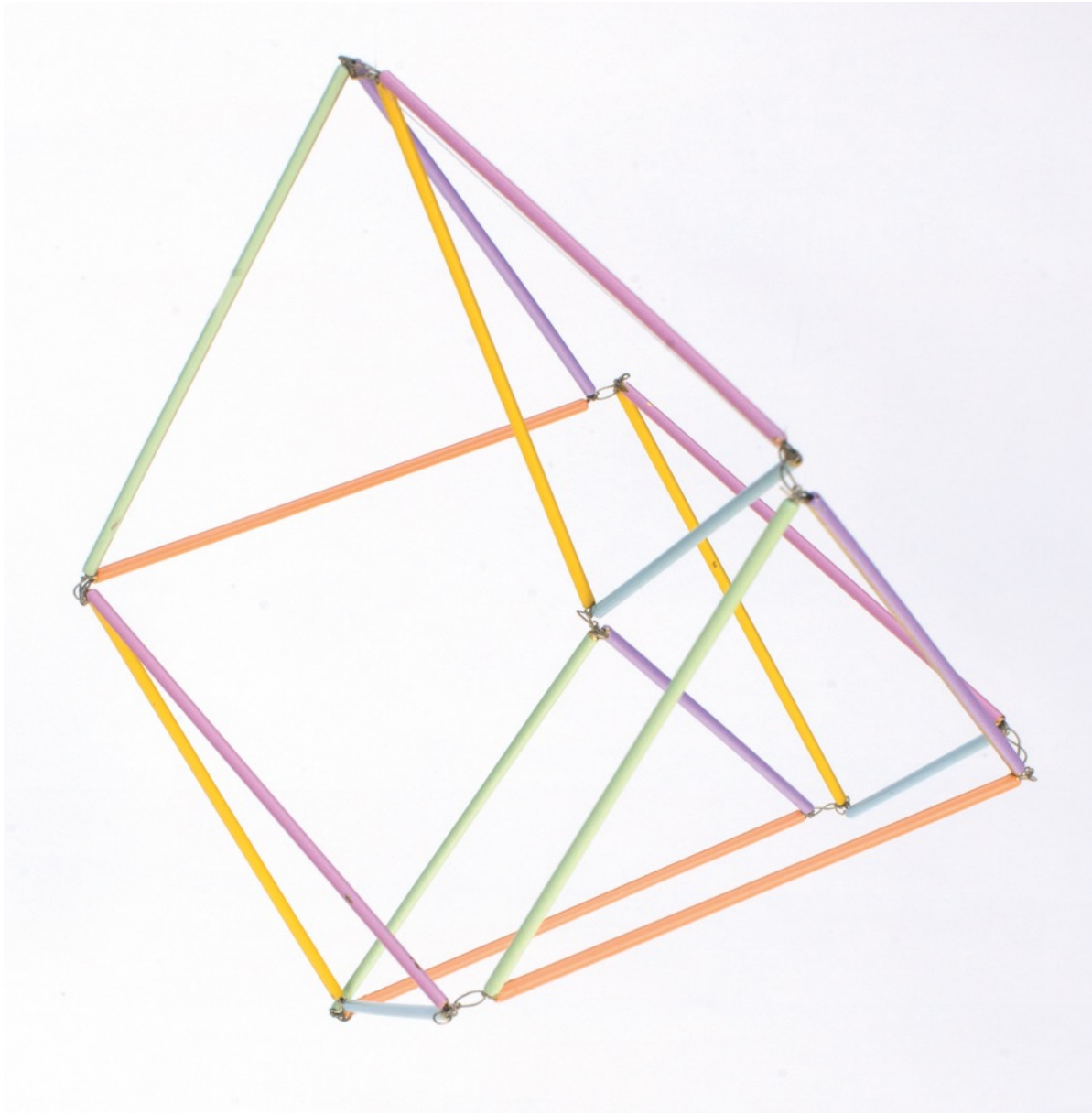
Aalto University



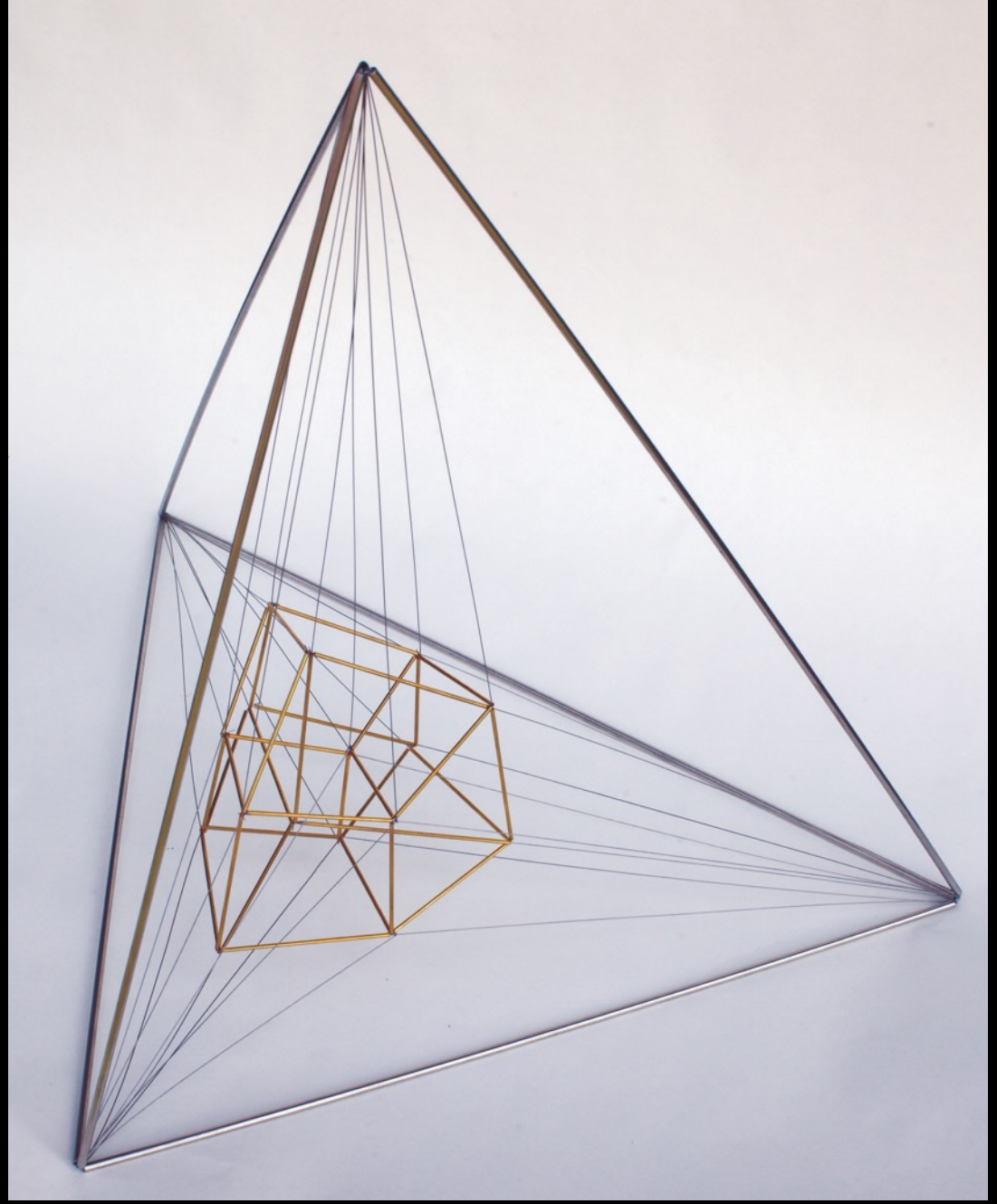
PAST PROJECTS



The *Kinochoron*
a stereographic projection of the hexadecachoron



The *Prismary*
a cavalier projection of the 3–3 duoprism



Breadth & Length & Depth & Height
a tesseract construction with four vanishing points



Cube at Large
a solidified frame of the tesseract in four-point perspective



Crooked House I
a topological embedding of the bitruncated pentachoron



Crooked House I
a topological embedding of the bitruncated tesseract

ONGOING PROJECTS

PROJECTIVE GEOMETRY:

point–line duality
projective transformations
projective configurations



3-MANIFOLDS:

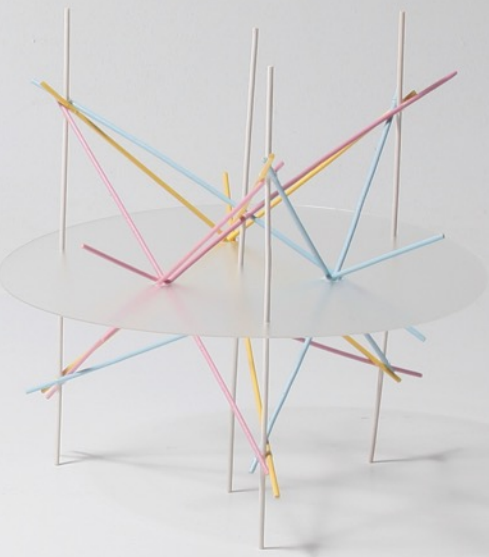
hands-on models of the 3–torus and
the Poincaré holomology sphere





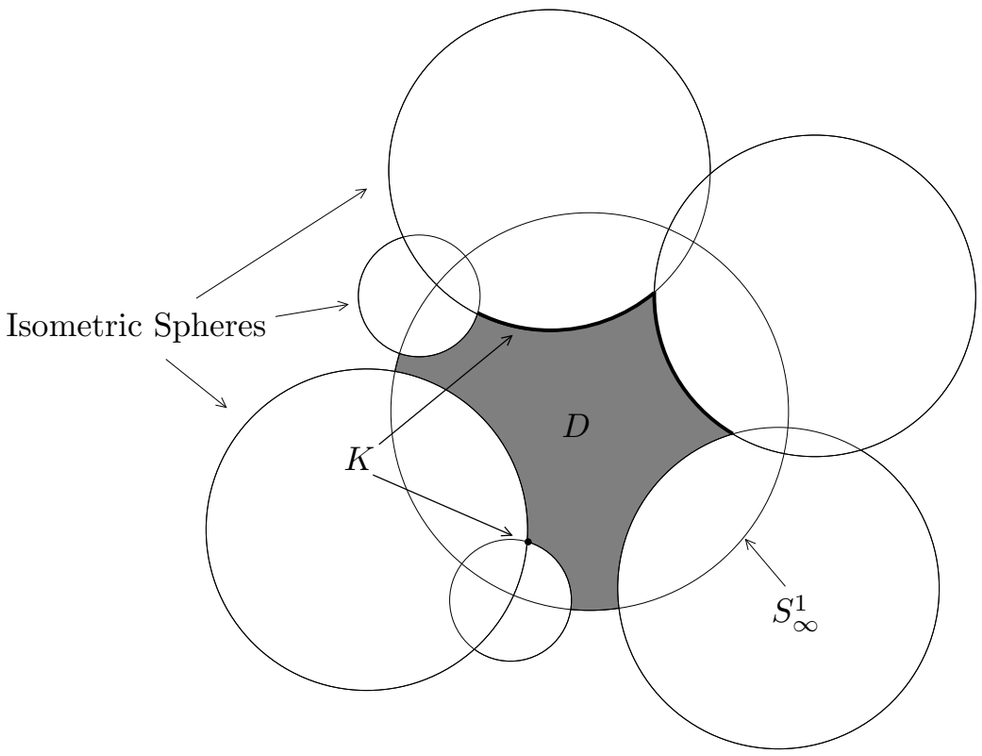
FOUR-DIMENSIONAL GEOMETRY:

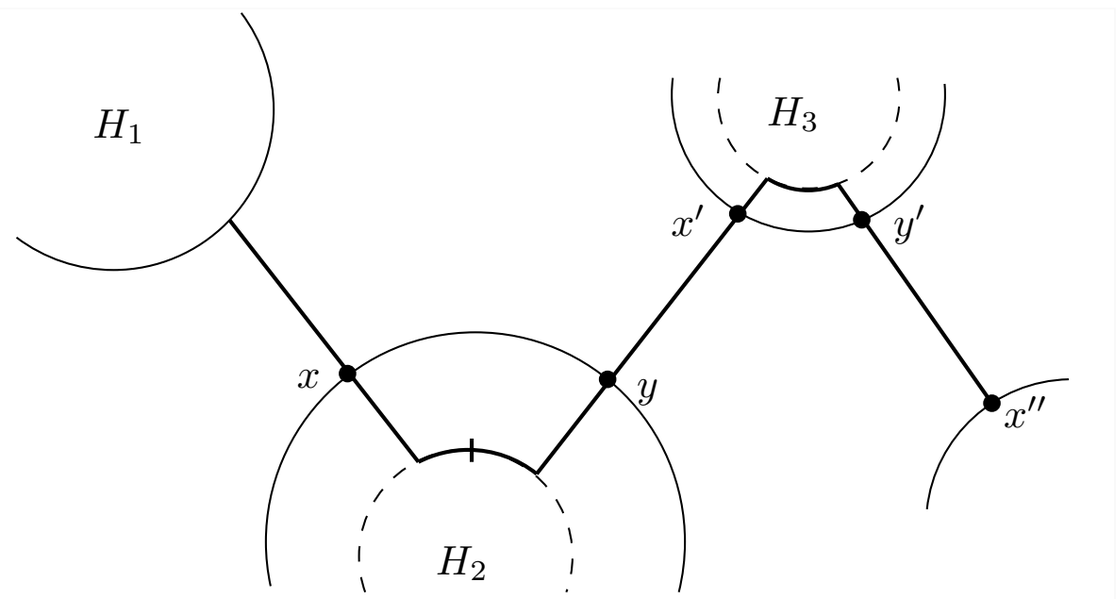
4D fictional universe



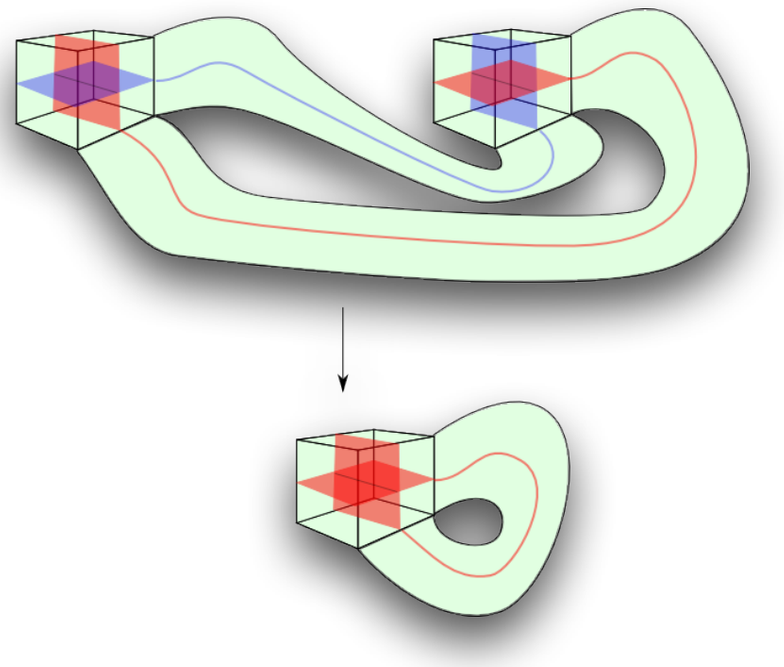
Jason Manning

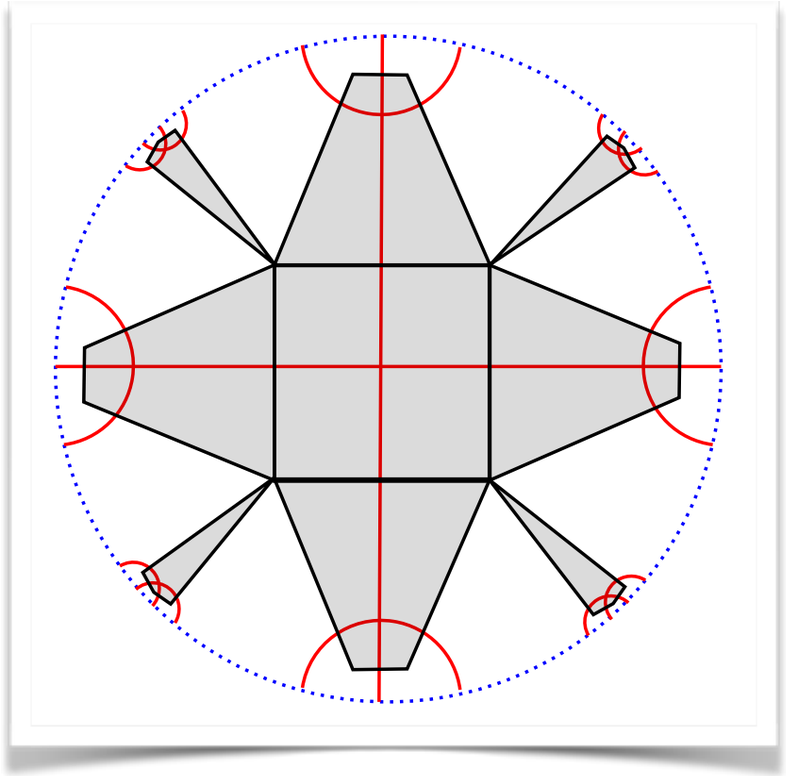
Cornell University



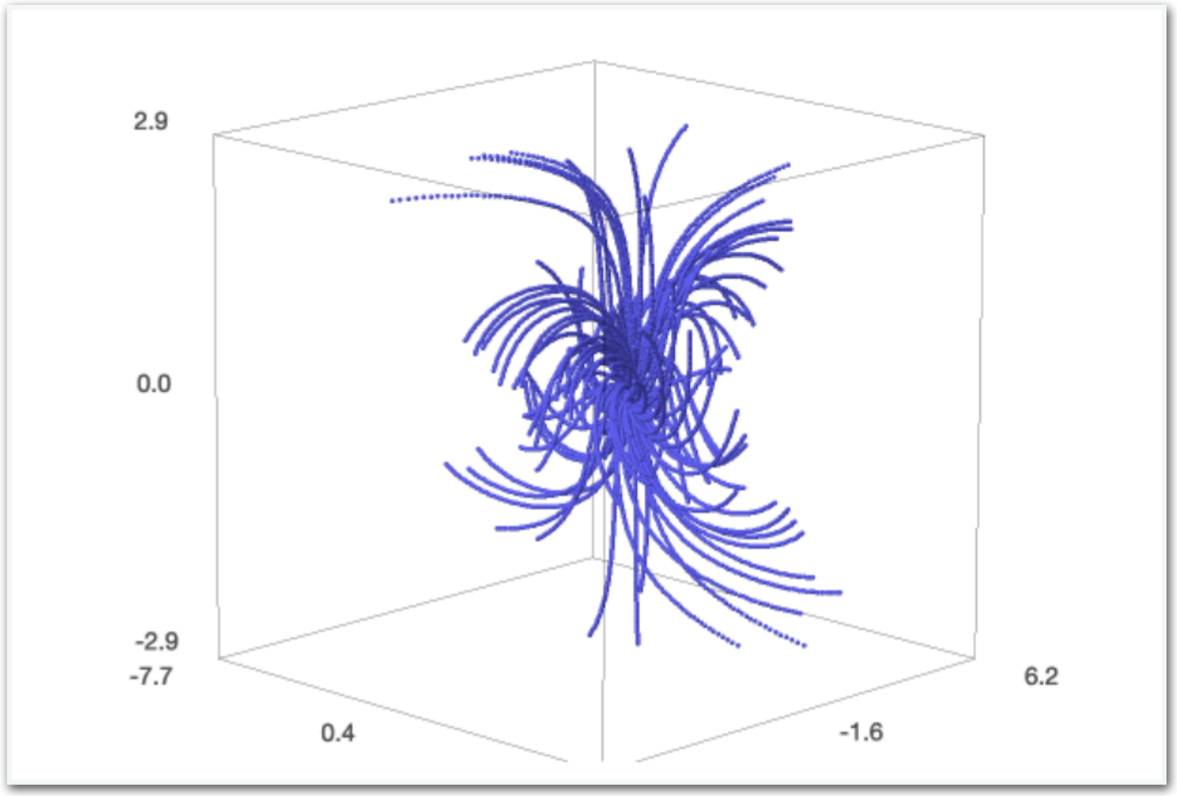


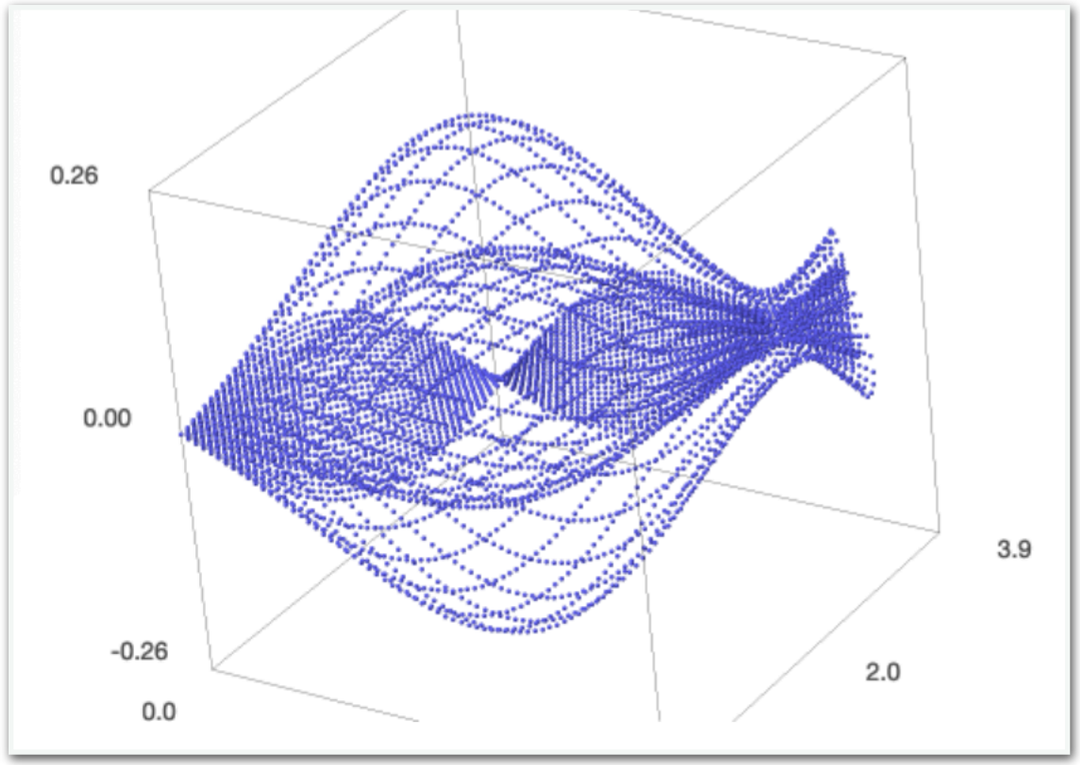
Hyperbolic(-ish) things





Cube complexes





Three-manifolds

ICERM Illustrating Mathematics

Michael Musty (Dartmouth College)

Fall 2019

Belyi maps and dessins

- A database of Belyi maps
  (with Sam Schiavone, Jeroen Sijsling, and John Voight)
  http://beta.lmfdb.org/Belyi

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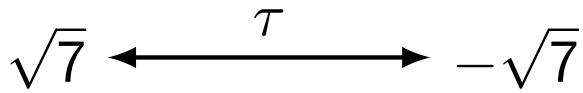
  https://math.dartmouth.edu/~mjmusty/32nh.html
- Computational stuff
  - `Magma`, `SageMath`
  - `LMFDB`
  - `R`, `C/C++`

Galois action



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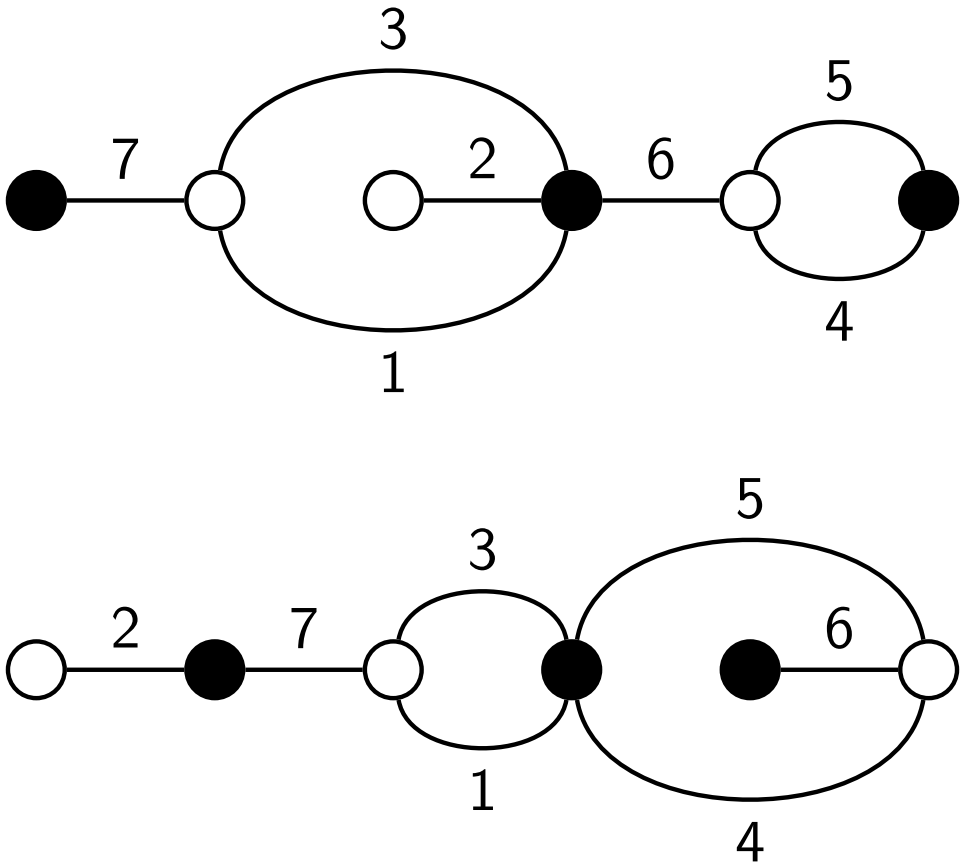
Topological dessins



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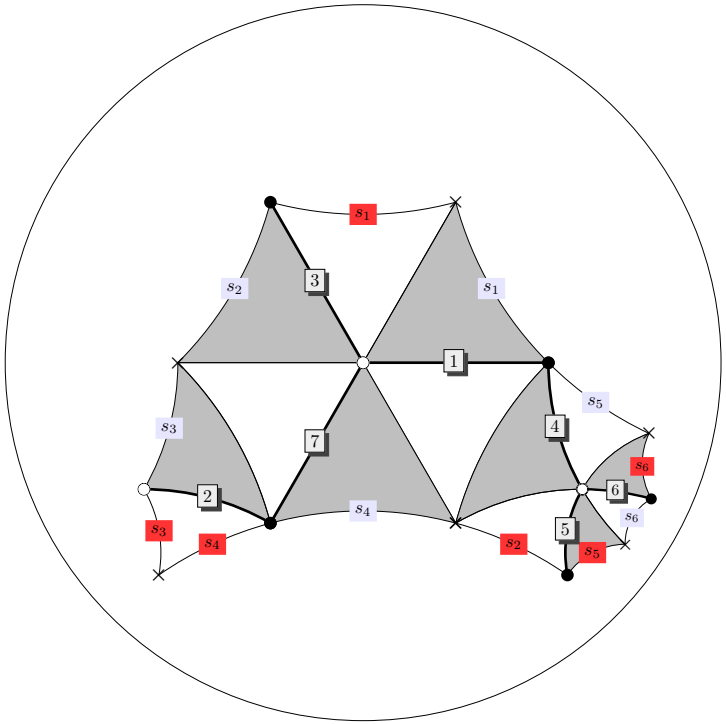
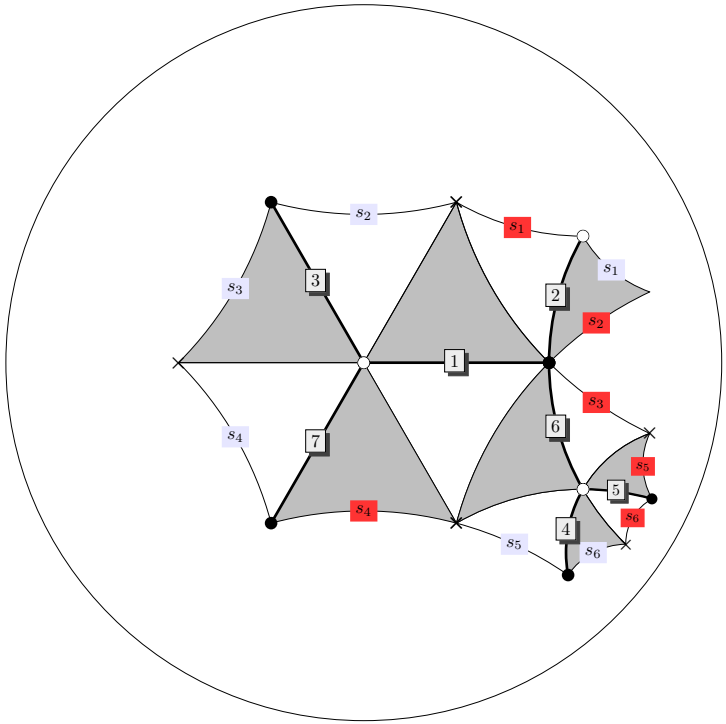
Conformal dessins





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Goals

- How do we draw a dessin?

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- Organizing 2-group Belyi maps in an interactive graph
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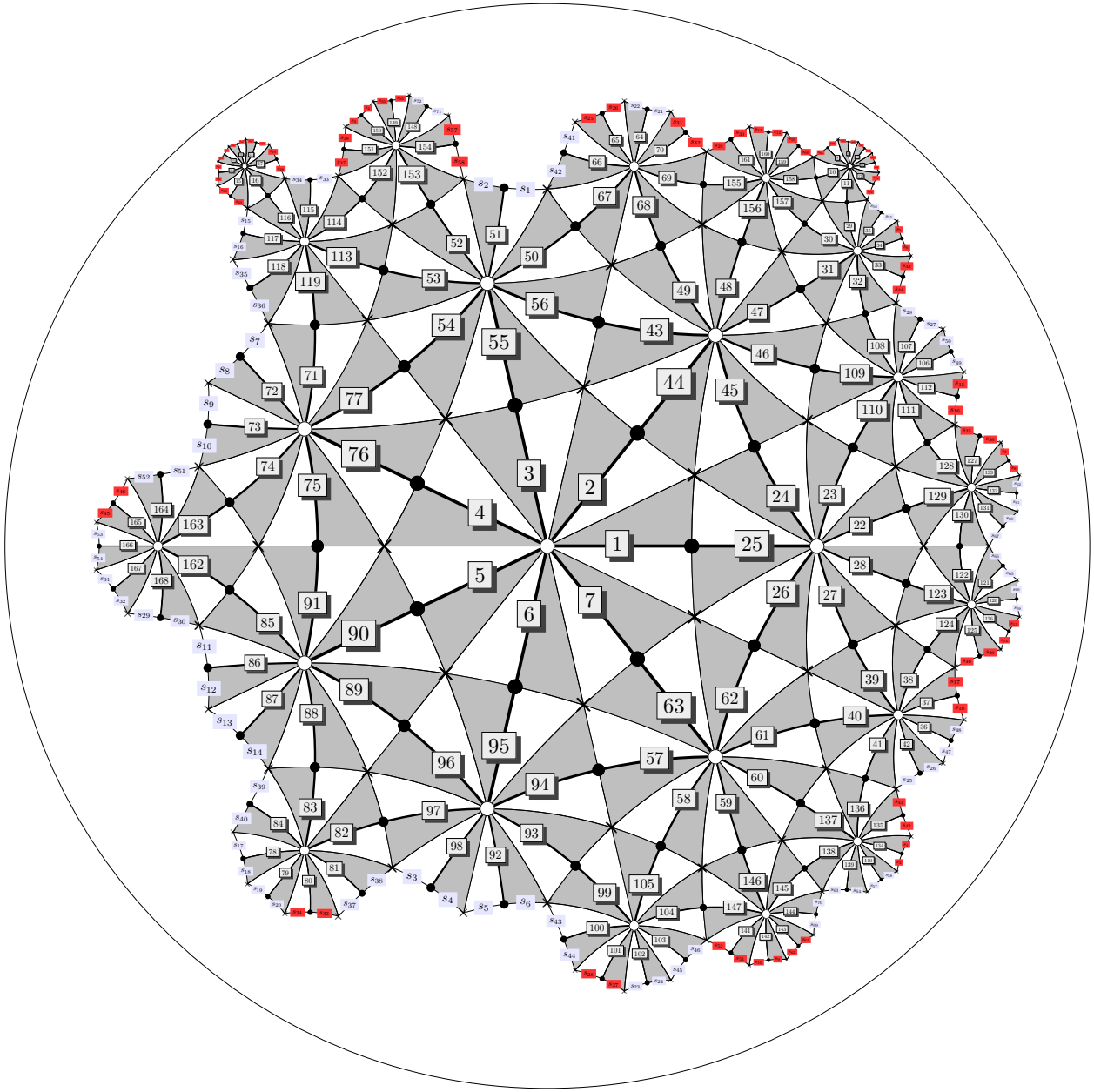
- How can we visualize a modular form?
  http://www.lmfdb.org/ModularForm/GL2/Q/holomorphic/
- Learning what other people are working on!

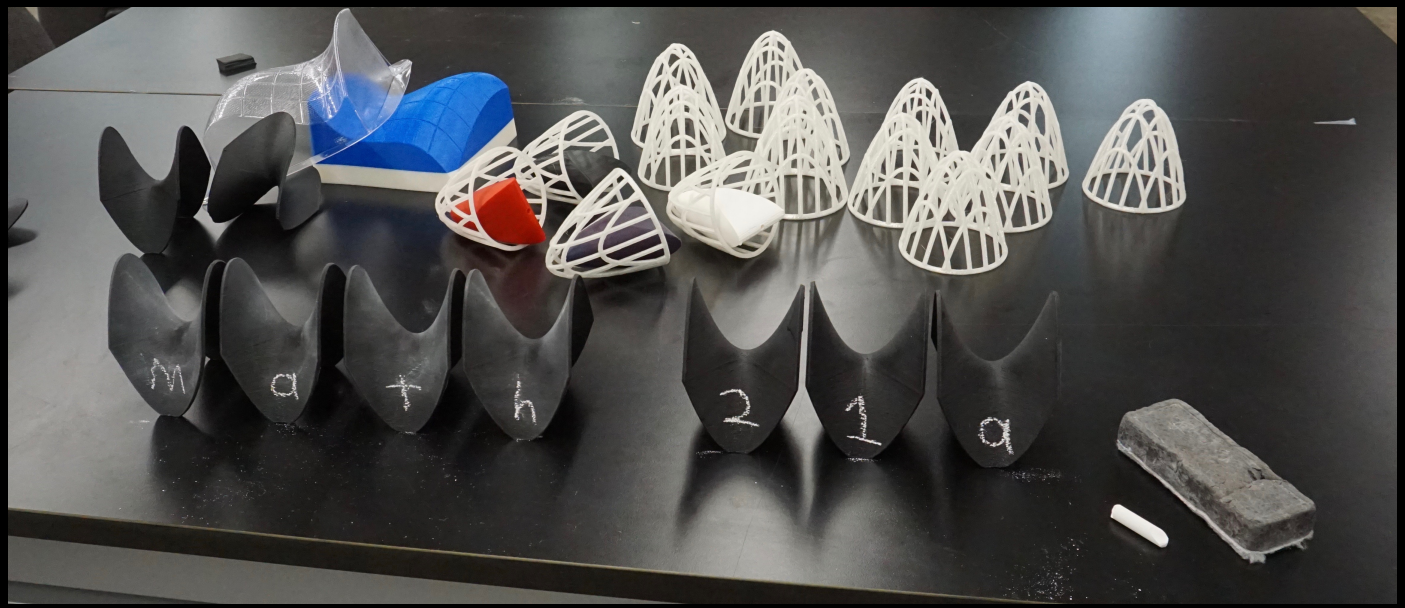
Thanks for listening!



Stepan Paul

Harvard University

spaul@math.harvard.edu

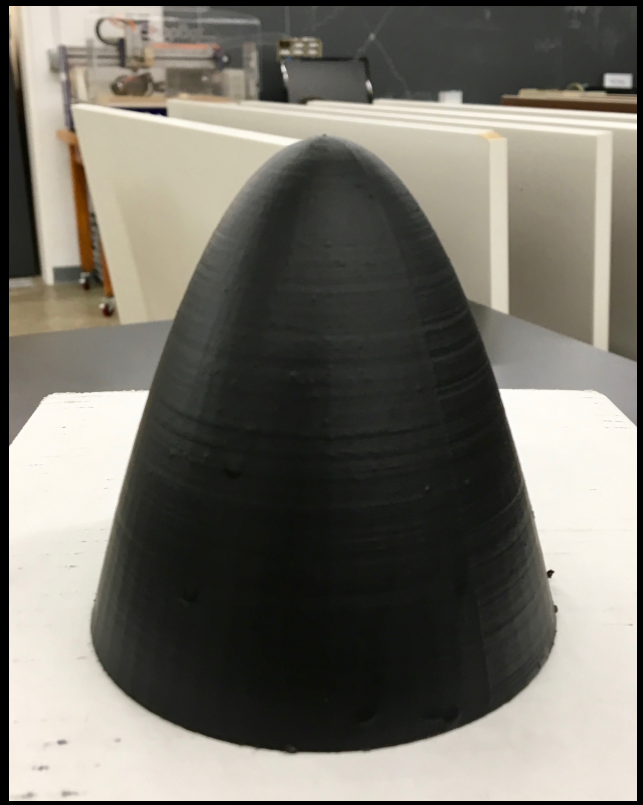


Example from multivariable calculus

Parameterize the paraboloid $z = x^2 + y^2 + 1$. What are the grid curves for your parameterization?

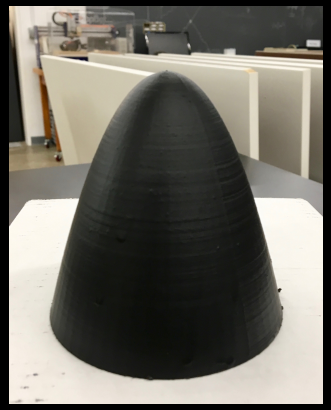
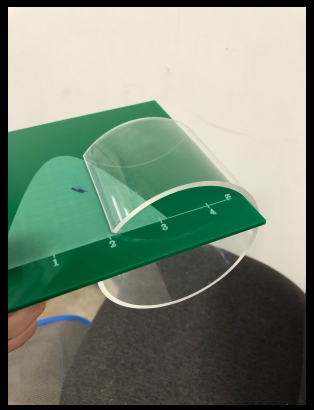
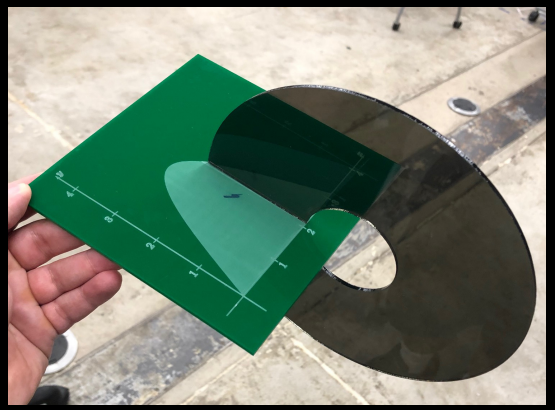
Example from multivariable calculus

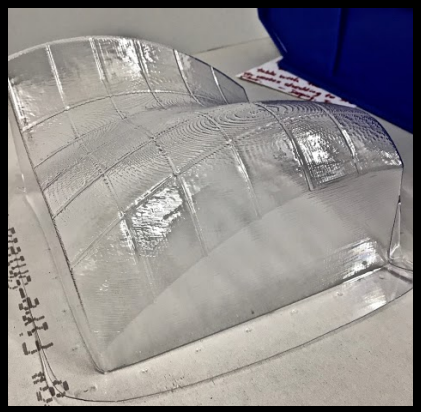
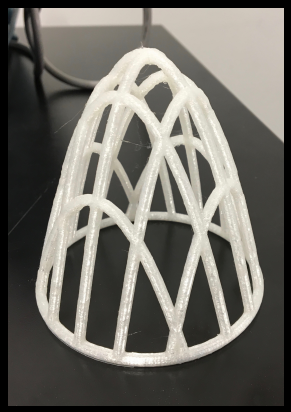
Parameterize the paraboloid $z = x^2 + y^2 + 1$. ~~What are the grid curves for your parameterization?~~ On your model of the paraboloid, sketch the grid curves defined by your parameterization.



Manipulative Calculus



Let's talk!

- Manipulative Calculus project (www.manipulativecalculus.com)
- Education/pedagogy projects
- Public build or other fun event for math majors

Stepan Paul
spaul@math.harvard.edu



walking on a Moëbius band on the campus
of Université de Rennes 1

Olga Paris-Romaskevich
Post-doctorate researcher at
University of Rennes 1

Illustrating Mathematics
Brown University, Providence, September 2019



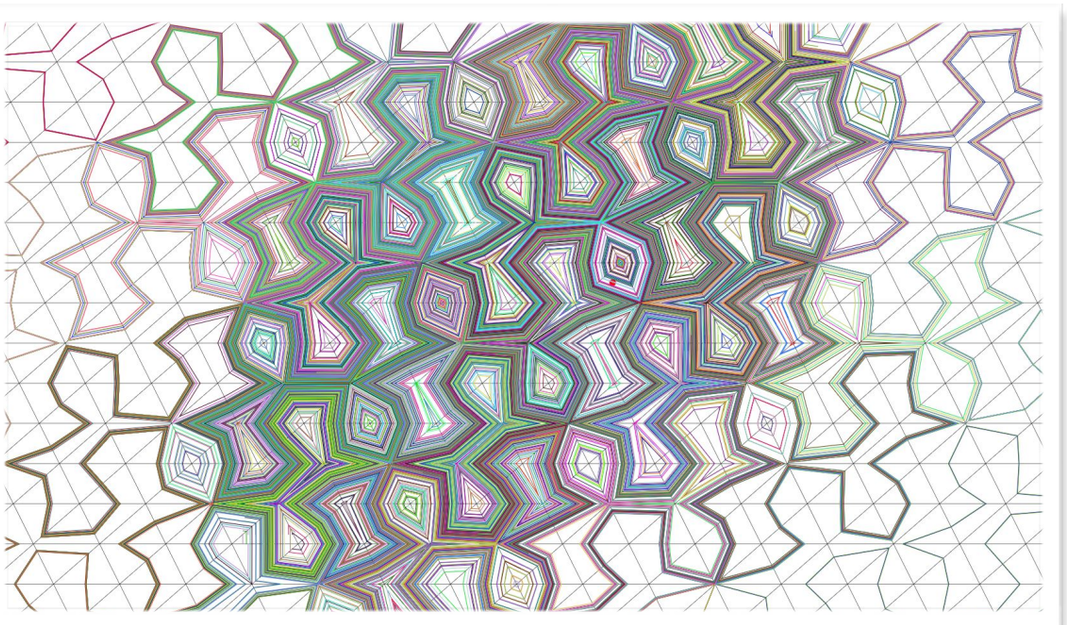
Mathematical clown (ongoing theatre project): clowns verifying the right angle

Areas of interest :

- Mathematics
  (dynamical systems (billiards (tiling billiards)))
- Storytelling
  (cinema, theatre - both acting and directing;
  sharing math through storytelling)
- Sport and dance

Anything that is related to movement (transformation, change), interests me: stories, dances, humans, dynamical systems…
I like looking at objects. I like telling stories.

My computational skills: I am bad at programming, and I am ok with it.



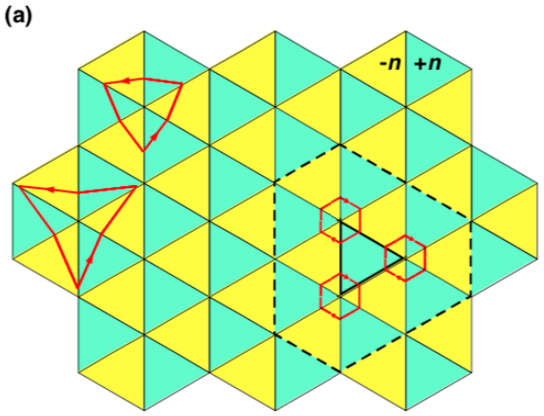
Tiling billiard foliations: picture by Ofir David of foliations I have discovered that come from the dynamics of tiling billiards

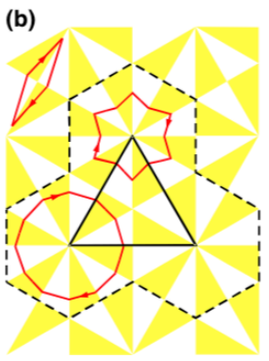


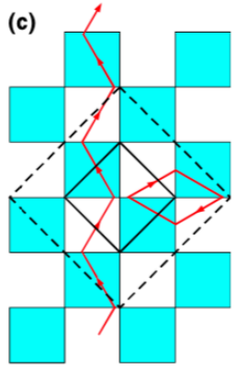
Mathematics of the sky: virtual exhibition (a site!) telling the stories of three-body problem, in collaboration with M. Lhuissier and V. Seigneur

My research at the moment : understand and describe the dynamics of tiling billiards



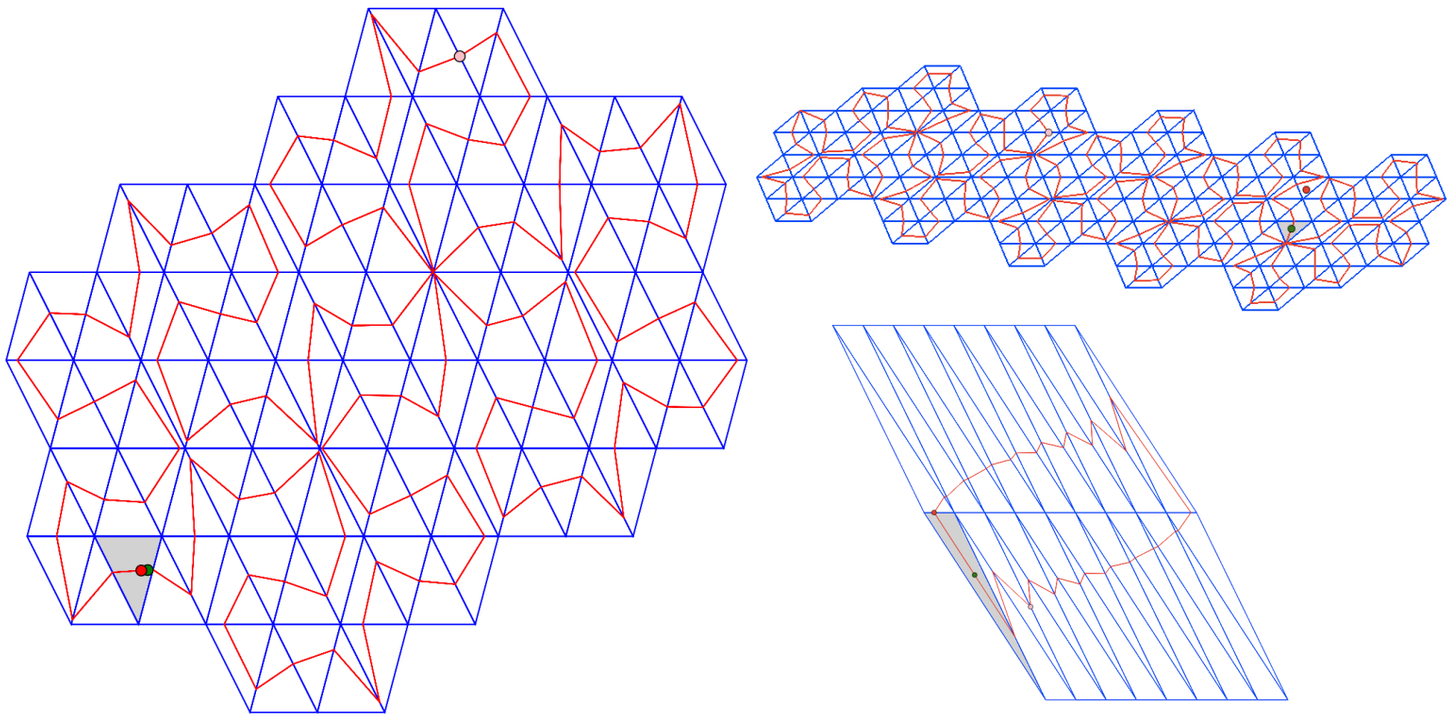




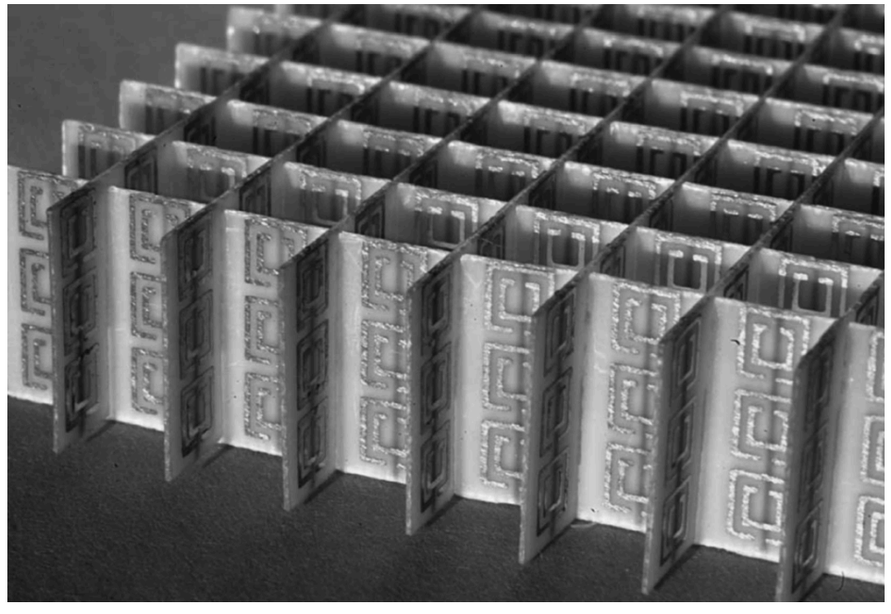


© a non-published preprint by A. Mascarenhas, B. Fluegel

Antisymmetry and the breakdown of Bloch's theorem for light (2015)



© triangle tiling billiards, images generated by the program: Pat Hooper & Alex StLaurent



© A split ring structure etched into copper circuit board plus copper wires giving negative refraction material, from J. Pendry *Negative refraction (2009)*

Goals : learn and do math, share what I know about tiling billiards, work on some collaborative projects on-the-spot, meet you :)



Illustrating mathematics…

I will be in Providence from ***today to 20 September.***
I will be very happy to exchange in order to learn, and also to engage in projects, where my skills and ideas can be useful. I am actively searching for collaborations with artists and makers.

My e-mail : olga@pa-ro.net

5 minute intro - Illustrating Mathematics

Alba Marina MÁLAGA SABOGAL

September 6, 2019

Interests

Mathematical research

Billiards!
Wind-trees!
Infinite measure translation surfaces!

I work on (Baire) generic dynamical properties of the line flow on some infinite measure translation surfaces, like those arising from irrational billiards, infinite staircases or the Ehrenfest wind-tree model.

Outreach



Teamwork

- *Lorentz chamber*
- Imaginary in France

3D printing

- Algebraic surfaces
- Pseudospherical Earth
- Akiyama polyhedra

Billiards

- Mirror rooms

Outreach



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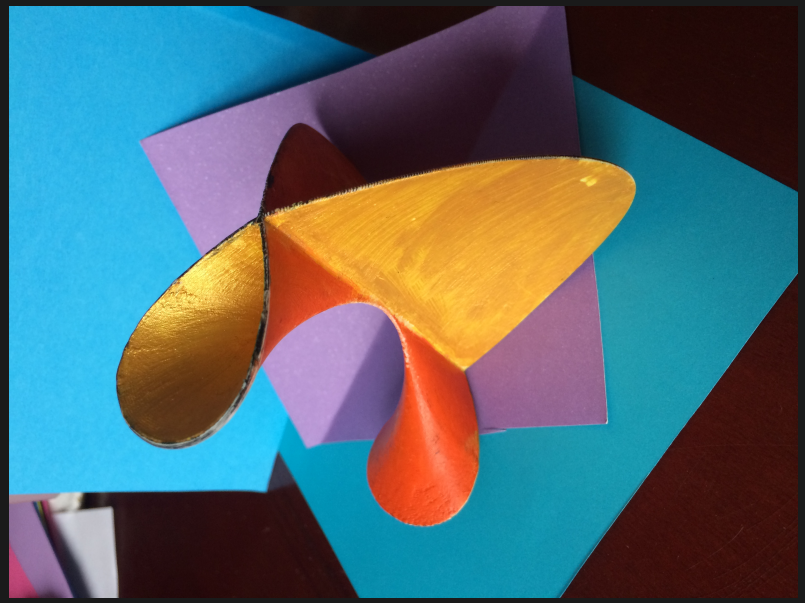

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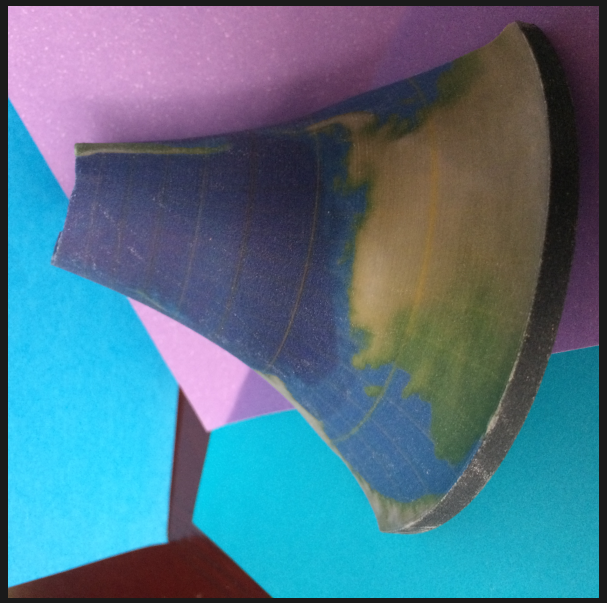

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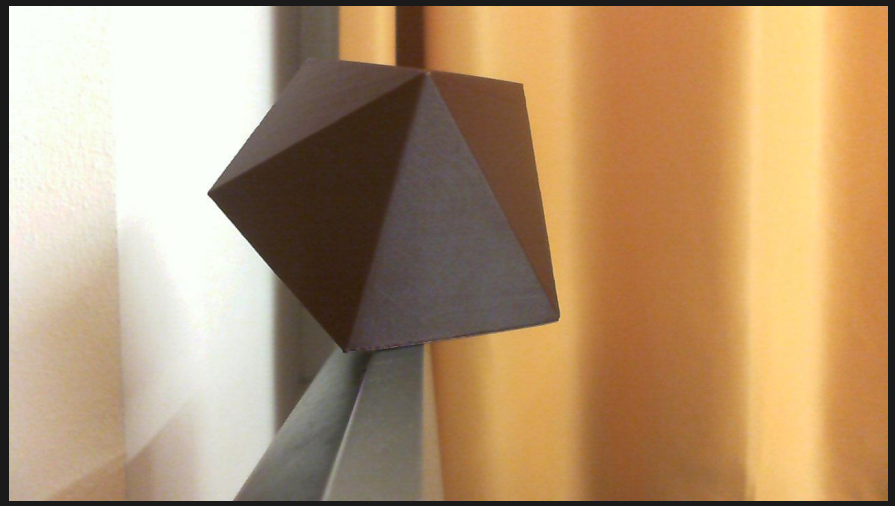

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Billiards

- *Mirror rooms*

Goals in the ICERM

Improving all of the above

- further work on translation surfaces
- document creation of 3D-printable (algebraic) surfaces
- document usage scenarios for Akiyama polyhedra
- 3D print colorful earth maps and other geographic data on surfaces
- other mirror room shapes

And more:

Further explore representation techniques beyond 3D printing

- inflatable structures (balloons!)
- laser-cut materials
- aeroMorph (cf Melina Skouras)
- …

Navigating formal proof databases

- logipedia.science

Formulae detection in texts

TASHRIKA SHARMA

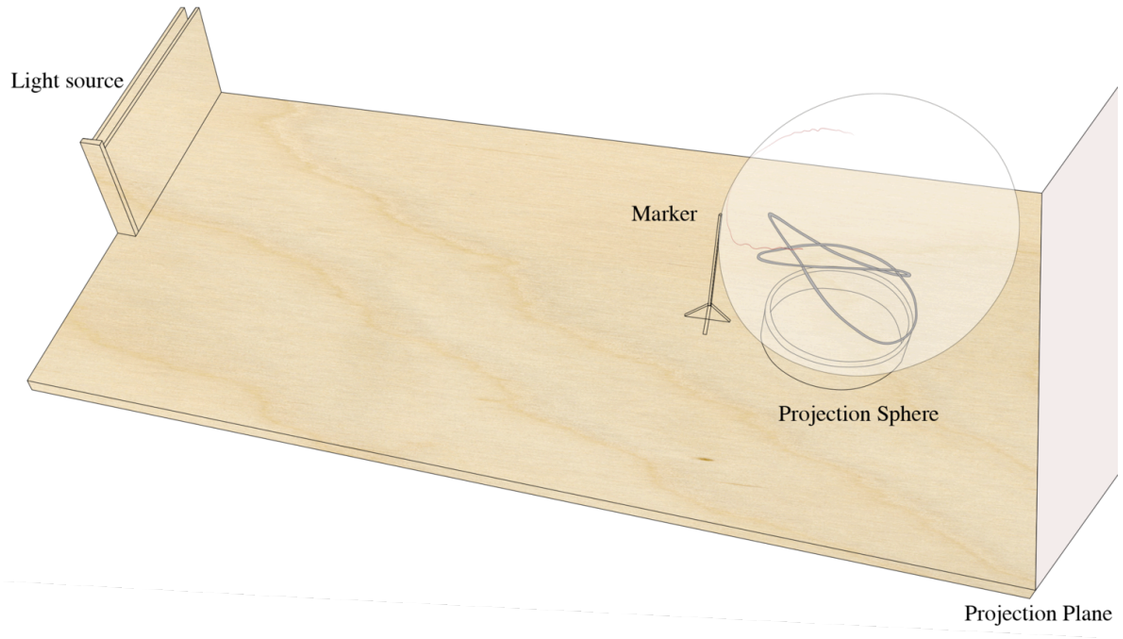
UNIVERSITÄT WIEN

PAST WORK/RESEARCH

Boston College (2011-2015)



Played with the resilience of visual systems.



Illustrated mathematical phenomena.

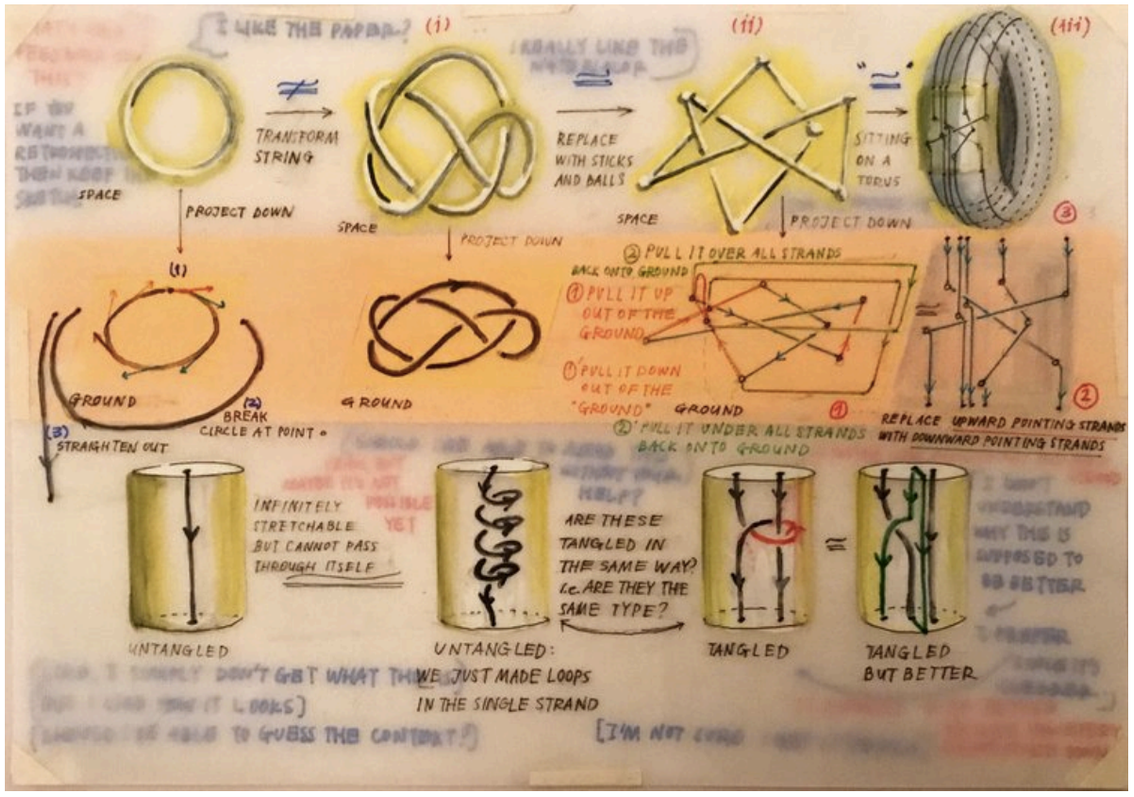
Universität für angewandte Kunst Wien (2015-2017)

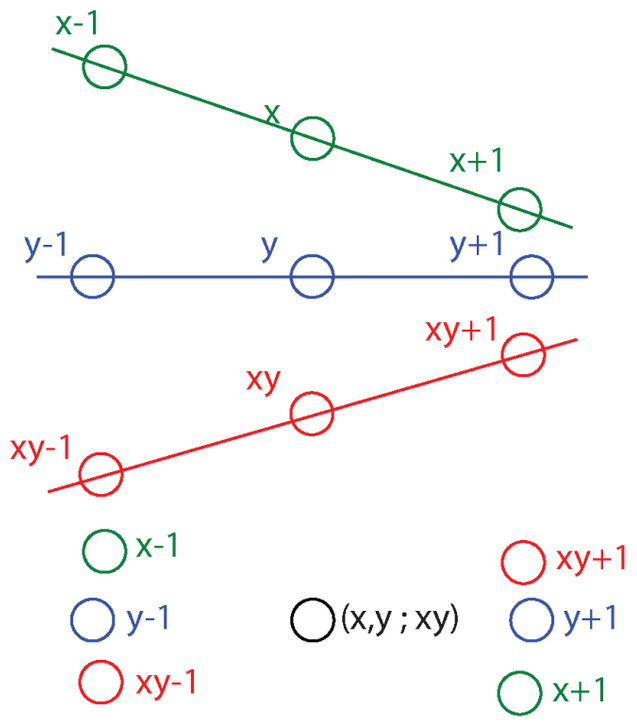
Researched visualization techniques of the mathematical phenomena of nature.

Work took place in notebooks and consisted of readings.

CURRENT WORK/RESEARCH

Universität Wien (2017 - present)



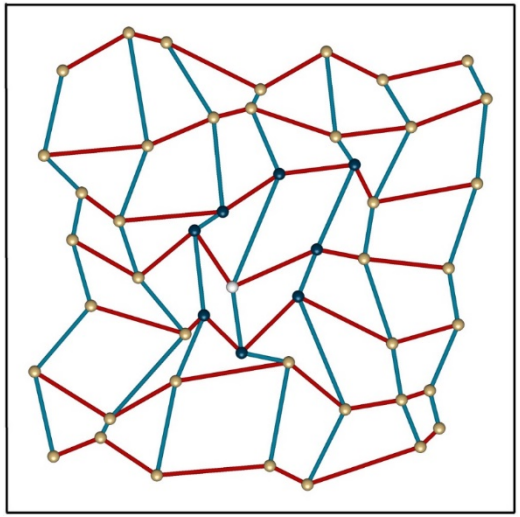


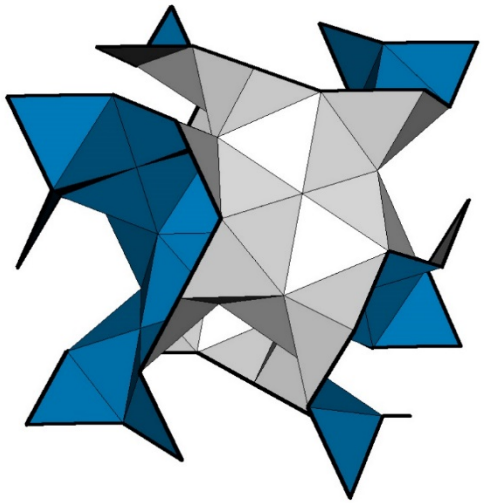
<u>Leading collaborative workshops</u> teaching mathematicians how <u>to design using drawing and model-making</u>.

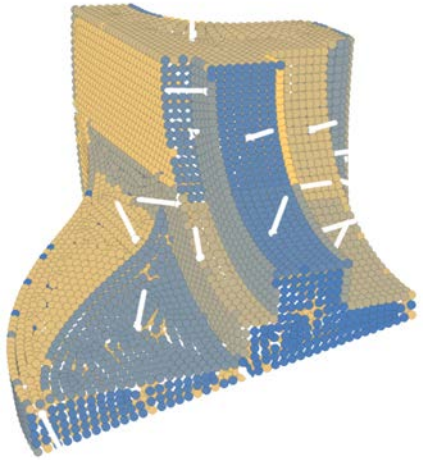
<u>Making a series of animations,</u> each using the design process to iteratively remediate <u>misunderstandings of math concepts/ tools/objects</u> for the purpose of formulating a working and cohesive model

Publishing an archive of designs from the workshops in a printed/digital format.

Freie Universität Berlin







Martin Skrodzki

joint work with S. Das, J. Jansen, H. Lipschütz, U. Reitebuch, K. Polthier, and E. Zimmermann

Supported by Berlin Mathematical School, German National Academic Foundation, Einstein Center for Mathematics, SFB/TRR 109 “Discretization in Geometry and Dynamics”

Freie Universität Berlin and MATH+

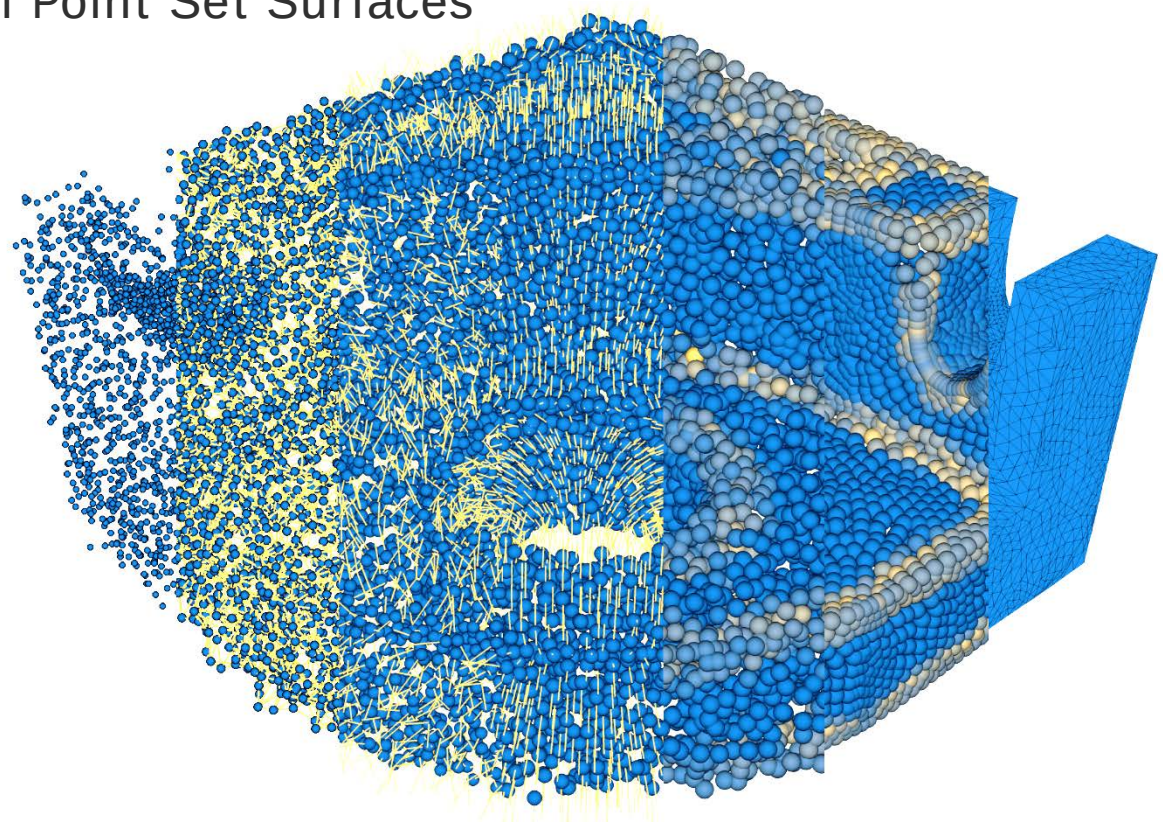
September, 2019

Point-based Geometry Processing Pipeline

PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”

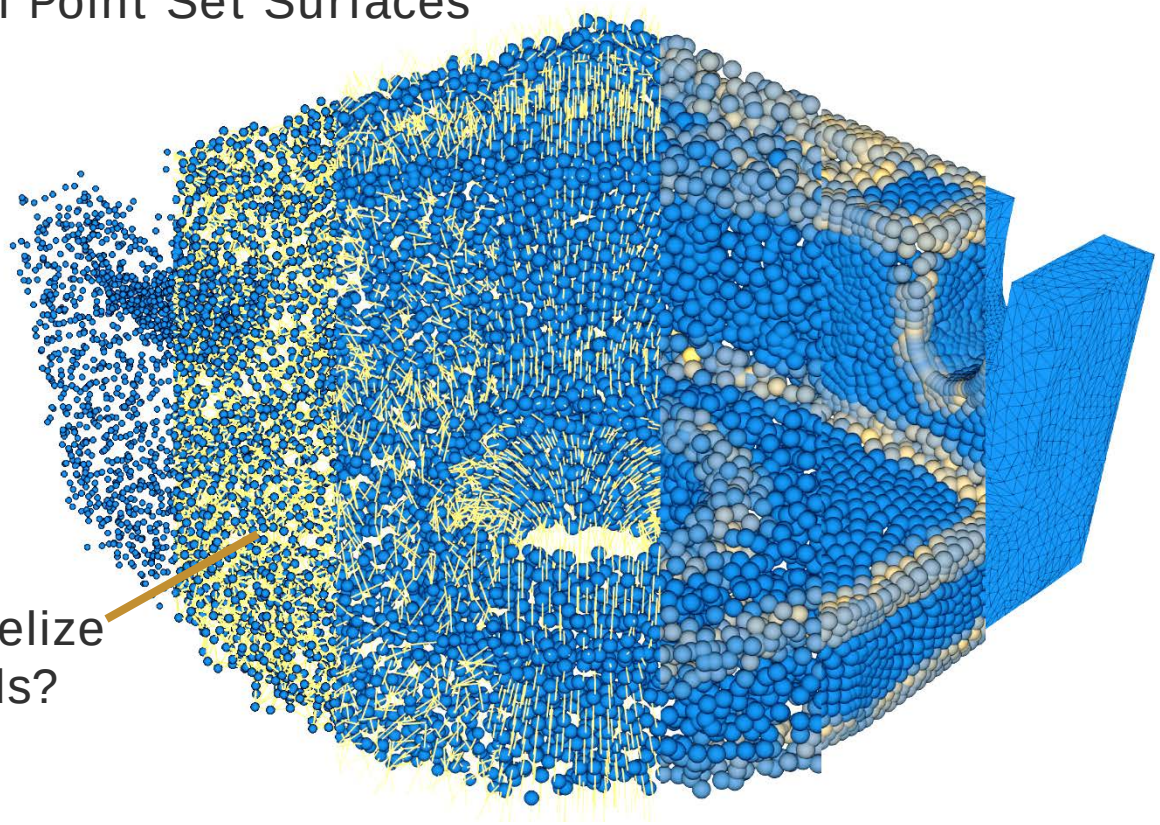
Point-based Geometry Processing Pipeline

PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”



Point-based Geometry Processing Pipeline

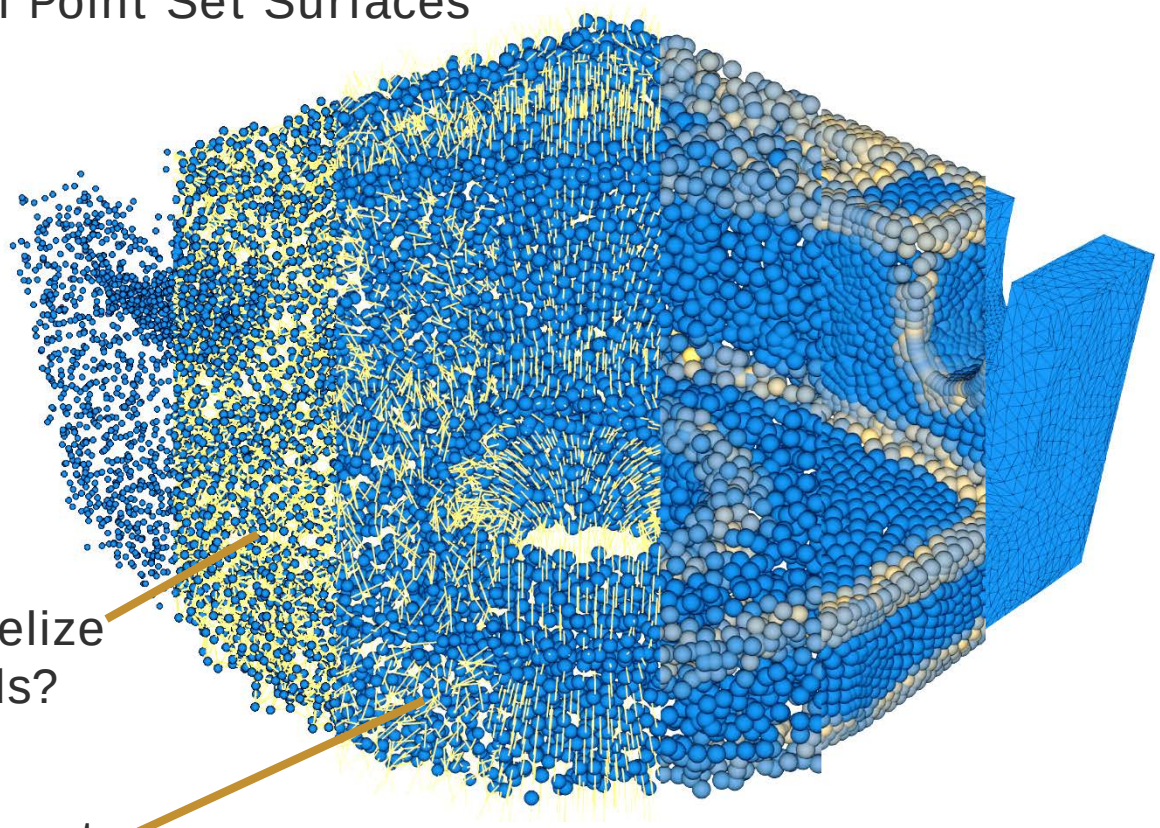
PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”



How to parallelize neighborhoods?

Point-based Geometry Processing Pipeline

PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”

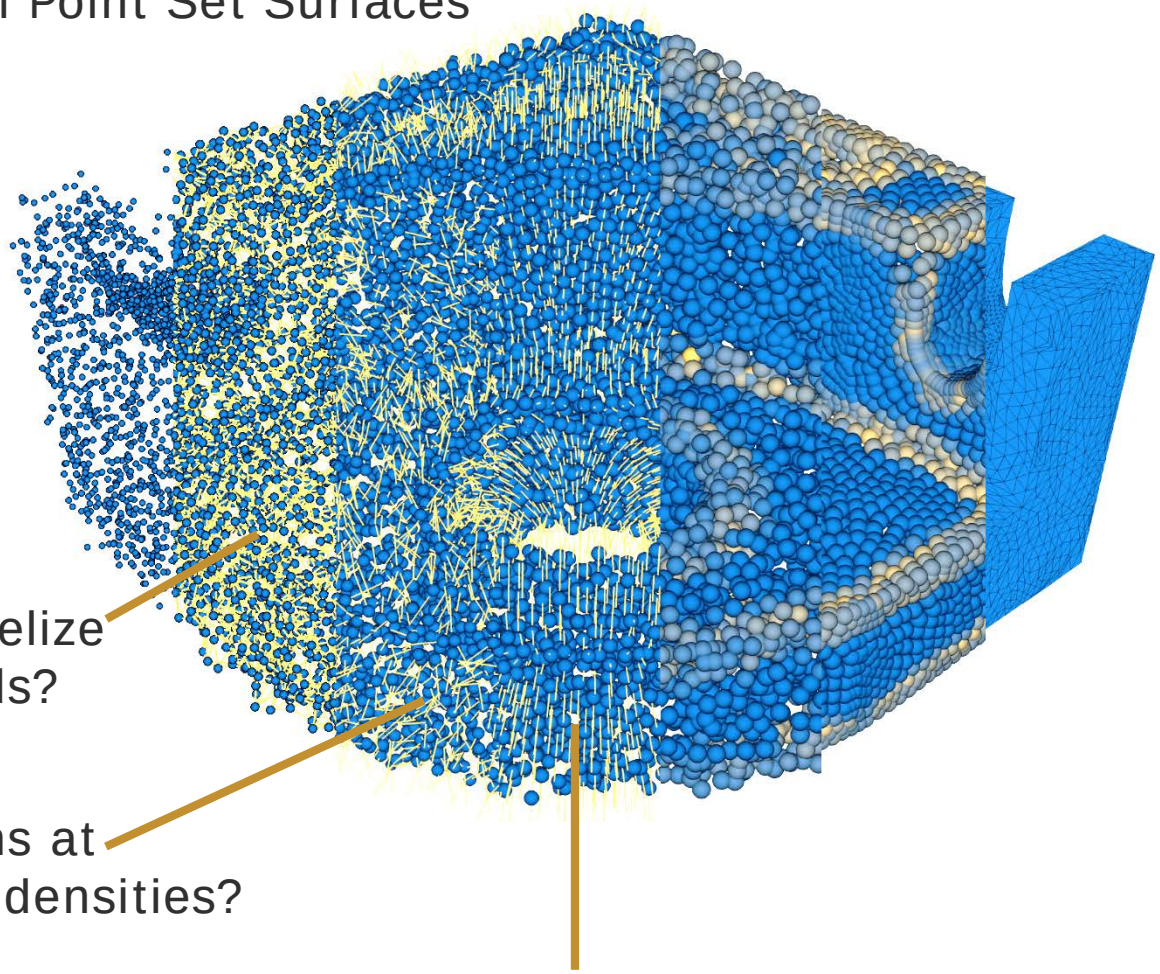


How to parallelize neighborhoods?

What happens at non-uniform densities?

Point-based Geometry Processing Pipeline

PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”



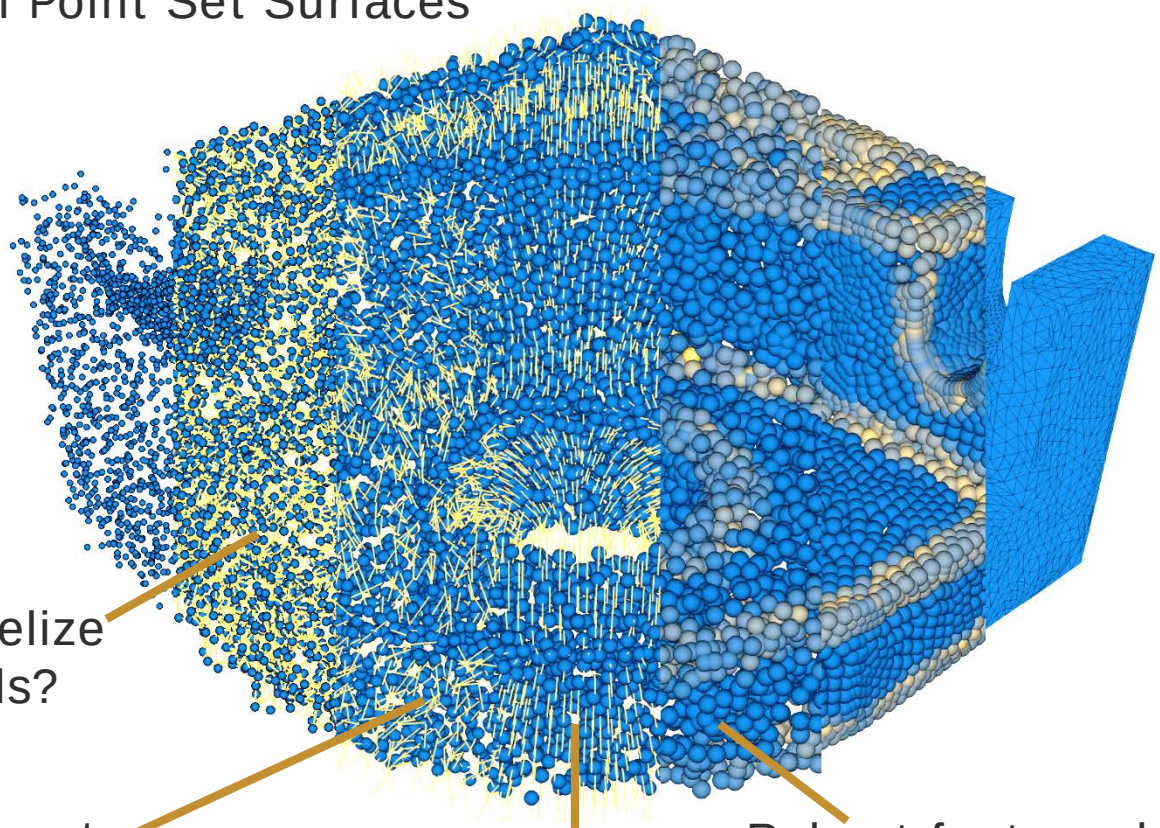
How to parallelize neighborhoods?

What happens at non-uniform densities?

Can normal smoothing and point smoothing be integrated?

Point-based Geometry Processing Pipeline

PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”



How to parallelize neighborhoods?

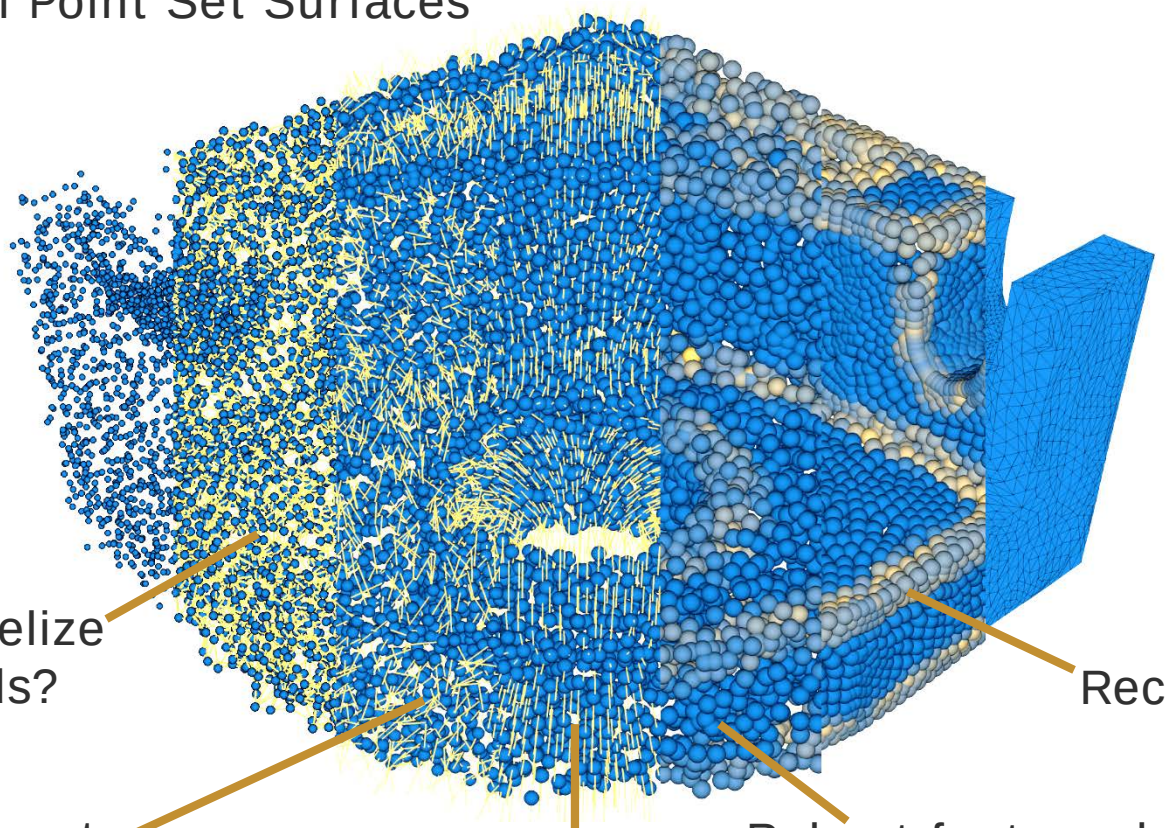
What happens at non-uniform densities?

Robust feature detection in the presence of noise?

Can normal smoothing and point smoothing be integrated?

Point-based Geometry Processing Pipeline

PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”



How to parallelize neighborhoods?

Recover manifold properties?

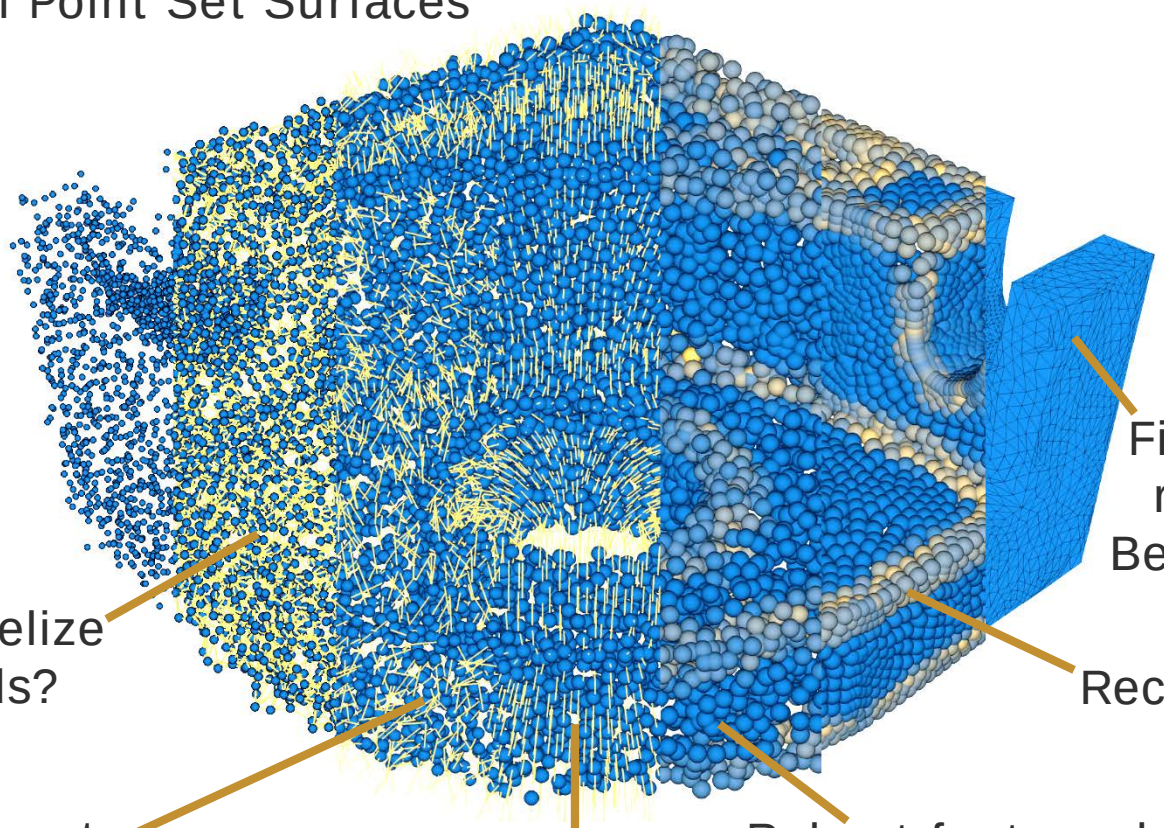
What happens at non-uniform densities?

Robust feature detection in the presence of noise?

Can normal smoothing and point smoothing be integrated?

Point-based Geometry Processing Pipeline

PhD Thesis: „Neighborhood Data Structures, Manifold Properties, and Processing of Point Set Surfaces”



Find a simplified reconstruction? Be shape-aware?

How to parallelize neighborhoods?

Recover manifold properties?

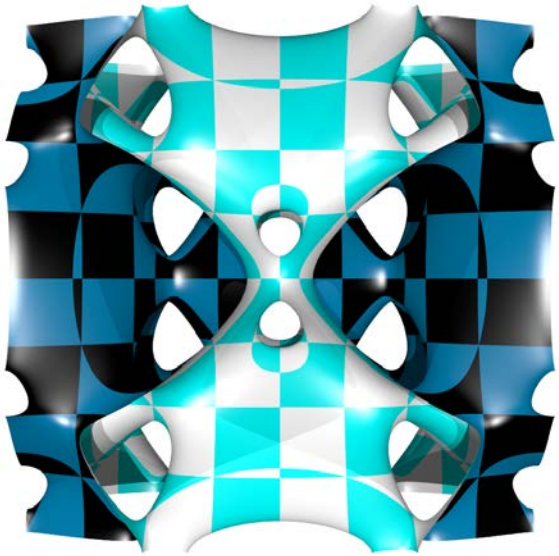
What happens at non-uniform densities?

Robust feature detection in the presence of noise?

Can normal smoothing and point smoothing be integrated?

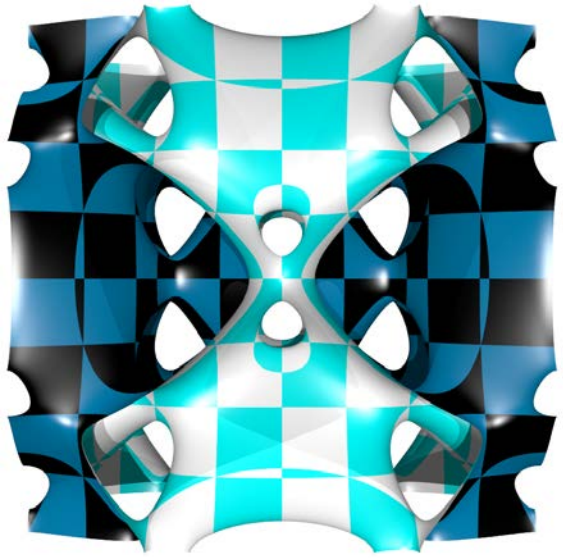
Generalizations of 2D Structures

Generalizations of 2D Structures

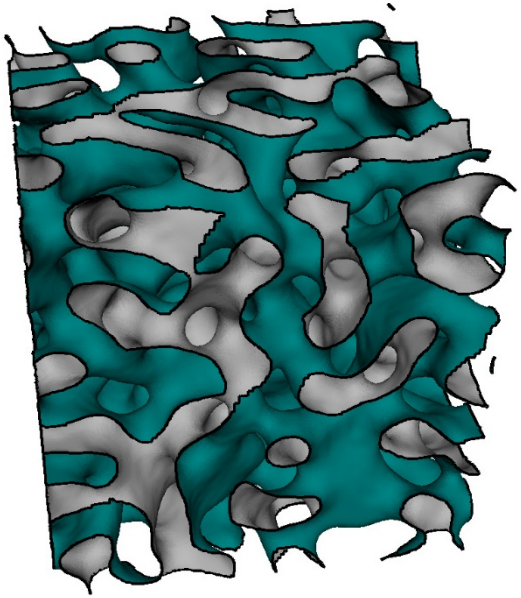


3D Chladni
Figures
Bridges 2016

Generalizations of 2D Structures

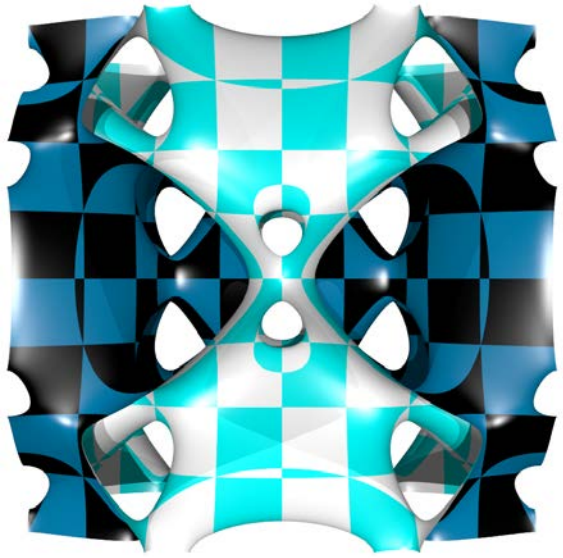


3D Chladni Figures
Bridges 2016

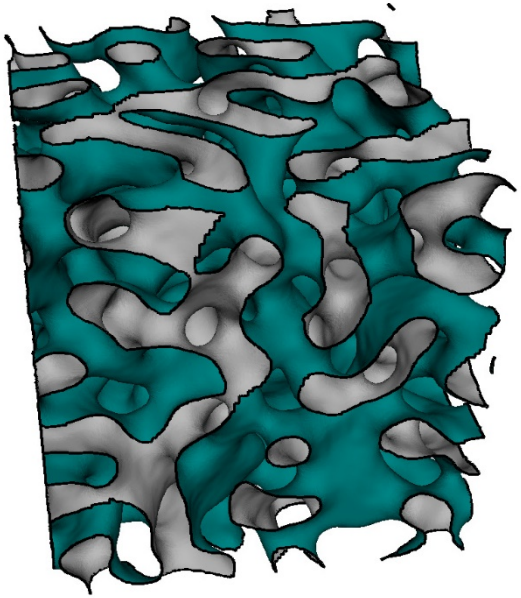


3D Turing-like patterns
Bridges 2017

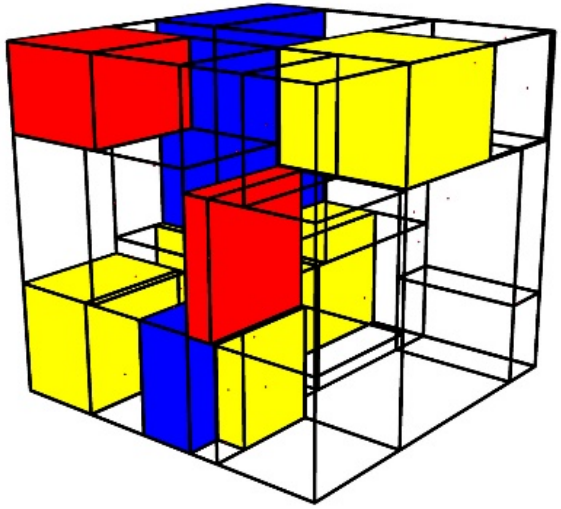
Generalizations of 2D Structures



3D Chladni Figures
Bridges 2016



3D Turing-like patterns
Bridges 2017



3D Mondrian-like Sculptures
Bridges 2018

Skills and Projects / Goals for the Semester

Skills and Projects / Goals for the Semester

Skills:

- Programming (Java, C++, Python)
- Geometry Processing Frameworks (JavaView, CGAL, CindyJS)
- Webdesign (JS, HTML, CSS)
- Discrete Geometry, Combinatorics, Algorithms

Skills and Projects / Goals for the Semester

Skills:

- Programming (Java, C++, Python)
- Geometry Processing Frameworks (JavaView, CGAL, CindyJS)
- Webdesign (JS, HTML, CSS)
- Discrete Geometry, Combinatorics, Algorithms

Projects / Goals:

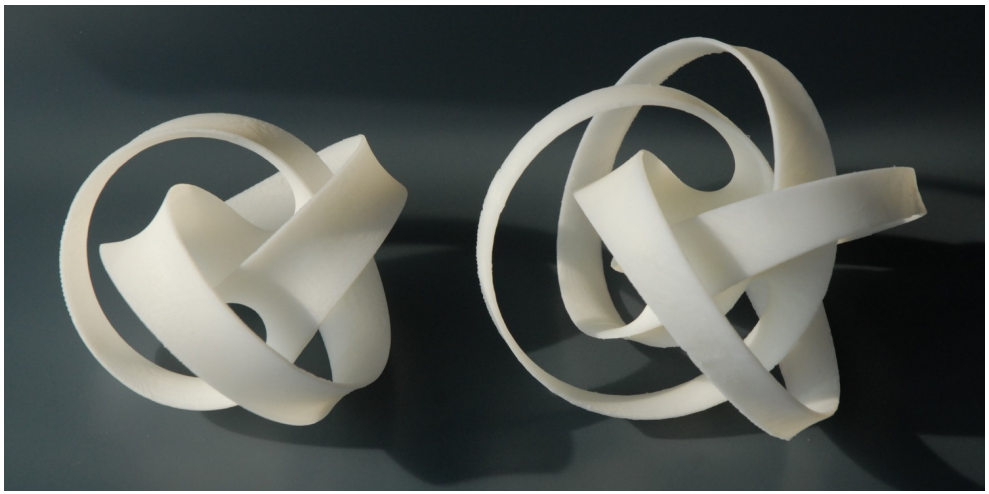
- Illustration of high-dimensional Data (t-SNE)
- Machine Learning in Computer Graphics
- Further visualizations at the intersection of computer graphics and arts

Optimal Geometry as Art

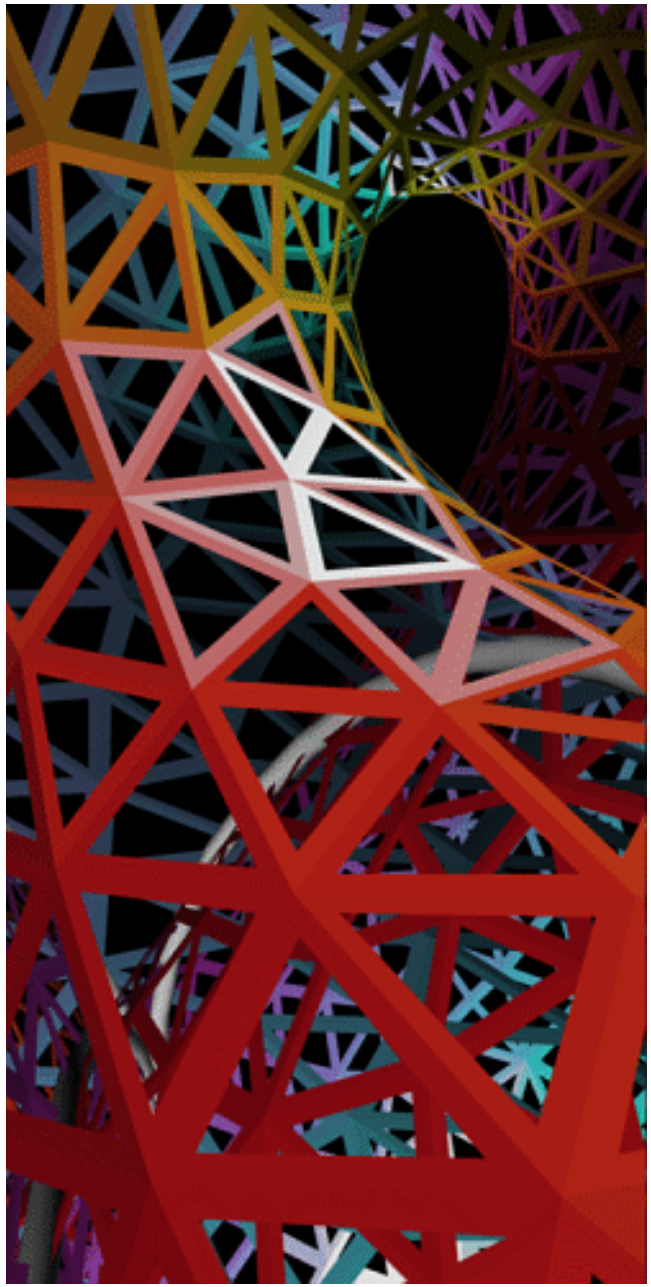
John M. Sullivan

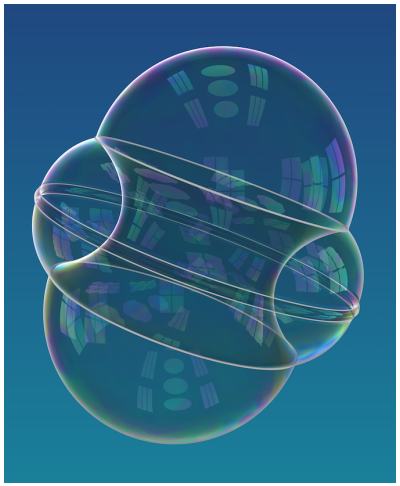
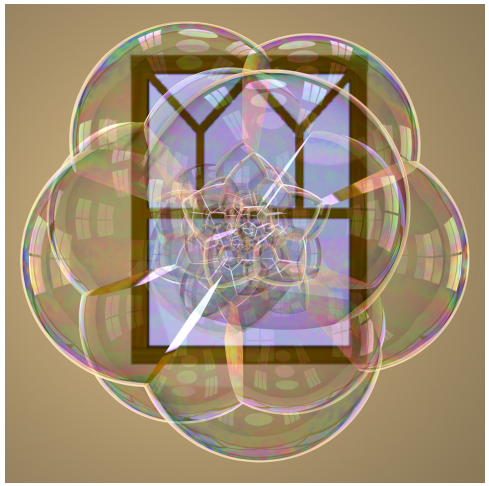
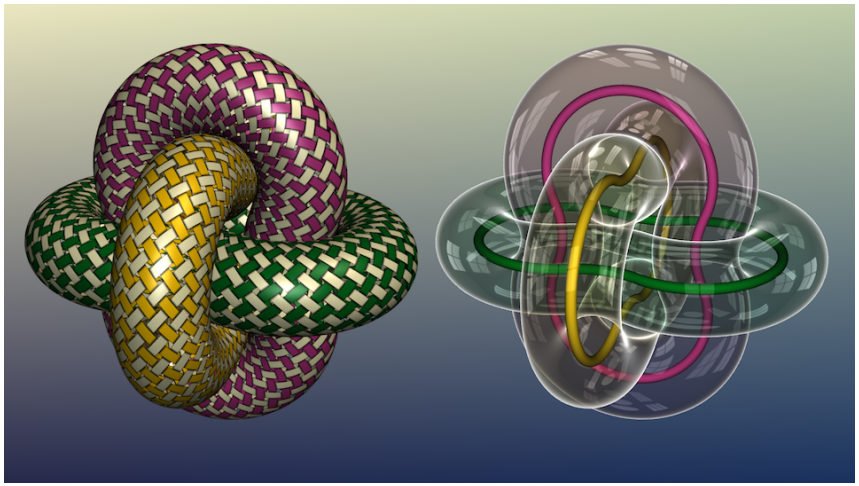
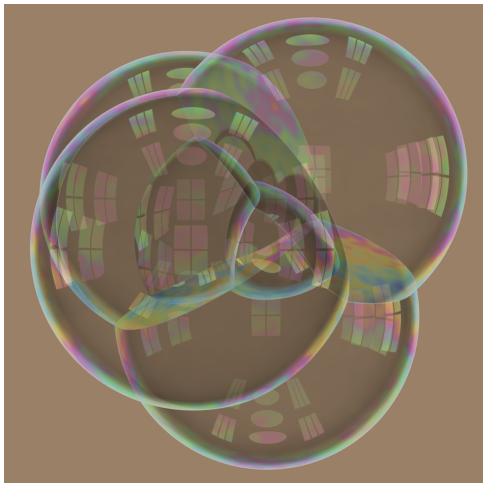
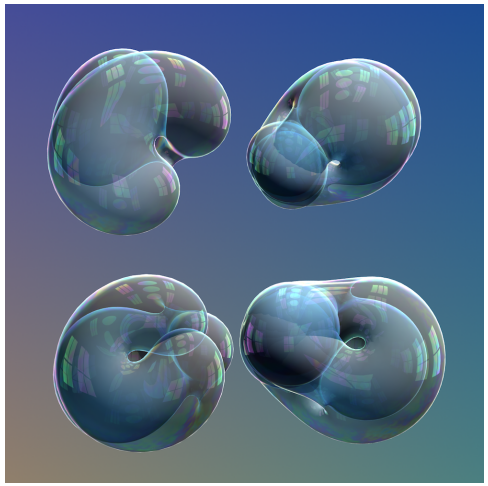
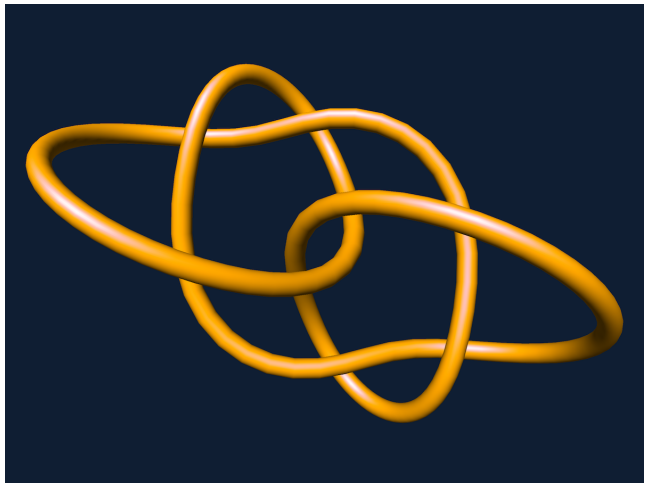
Professor, Institut für Mathematik, TU Berlin
Chair, Berlin Mathematical School

Illustrating Mathematics, Program Opener, 2019 September 5/6
ICERM, Brown University, Providence, RI

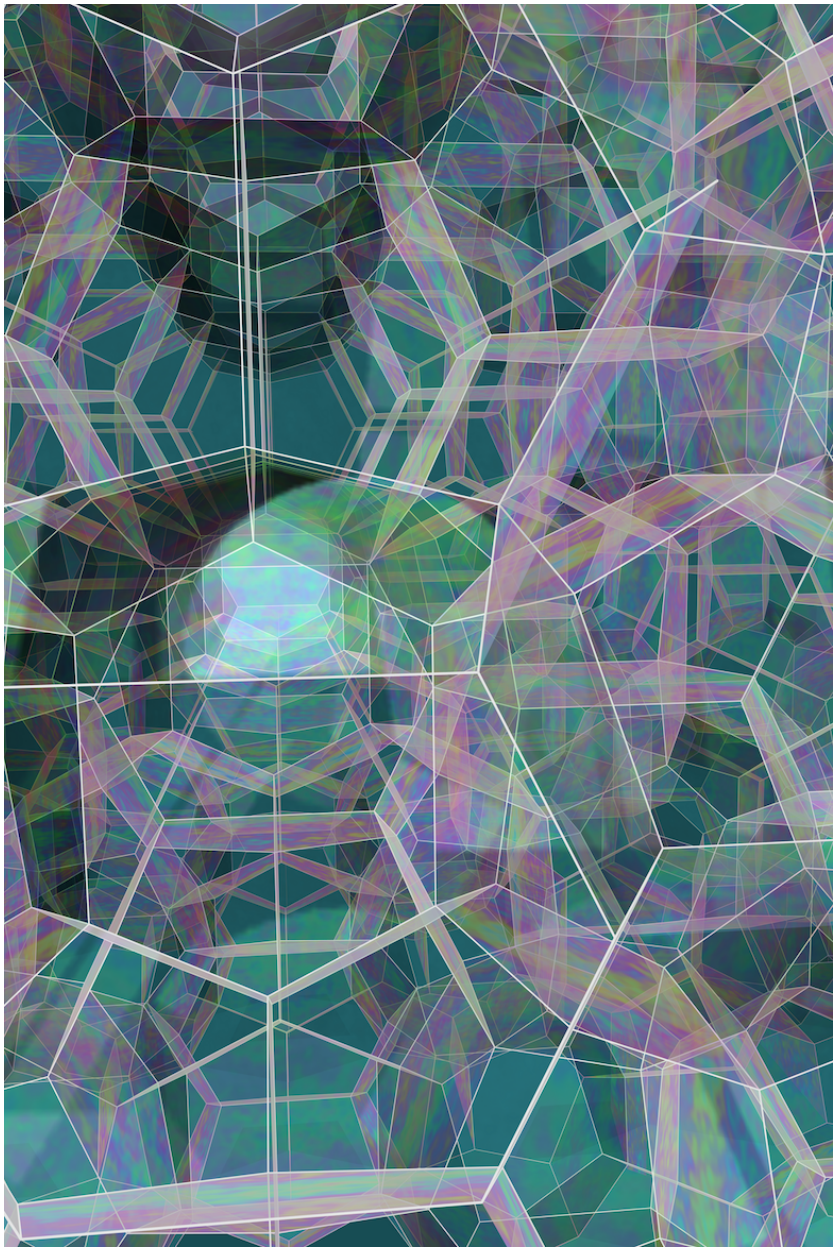


- Research in geometric optimization
- Find best shape for topological object
- Computer graphics since 1989
- Bubble clusters, CMC surfaces
- Sphere eversion via Willmore energy
- Geometric knot theory —
  knot energies, tight knots, distortion
- Videos:
  “The Optiverse”,
  “Knot Energies”,
  “The Borromean Rings”



- Visualization challenges:
  - Internal structure
    - (transparency?)
  - Other ambient spaces
    - (periodic structures)
- Learn new software tools



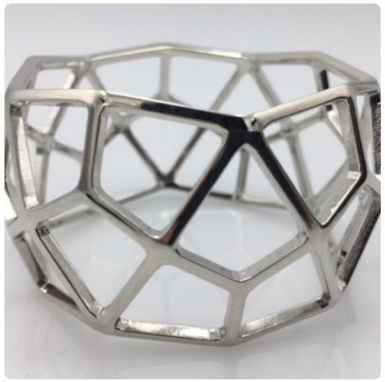


Dr. Laura Taalman

James Madison University
Harrisonburg, Virginia

blog	mathgrrl.com/Hacktastic
work	mathgrrl.com/Designs
free	thingiverse.com/mathgrrl
shop	shapeways.com/shops/mathgrrl
twitter	@mathgrrl

mathgrrl designs



Deltoidal Hexecontahedron Bracelet



Pentomizer



Triakis Icosahedron



Pair of Packable Scutoids



Conversions Art Generator



Bowers Circle Packing



Sunburst Clock – Bubbles



The Snowflake Machine



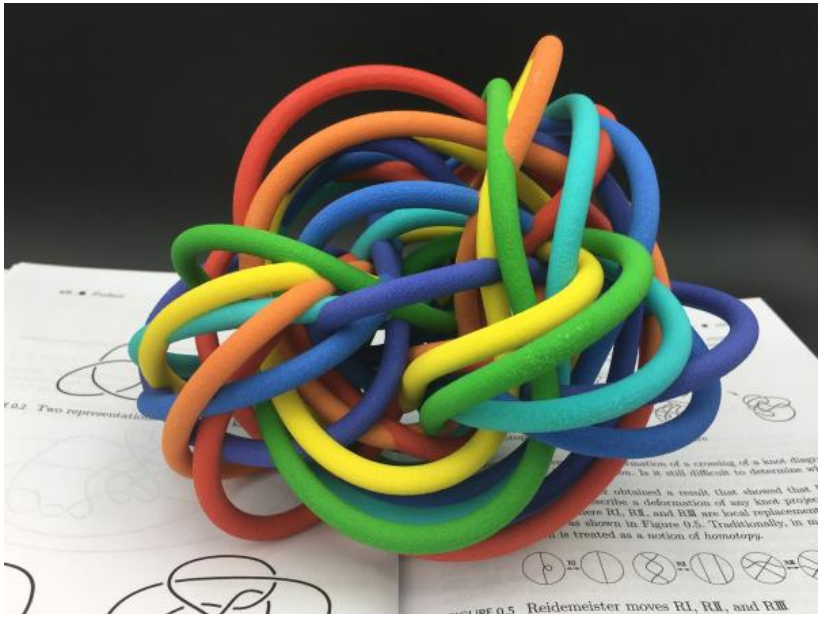
Stainless Steel Knots



Chaotic Attractors

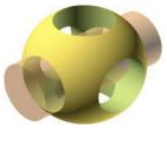


Spiky Perko Knot



Perko Morph

software



OPENSCAD



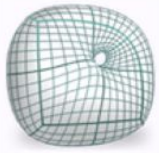
FUSION 360



MESHMIXER



MESHLAB



TOPMOD



MMATICA



STRSYNTH



GRASSHPPR



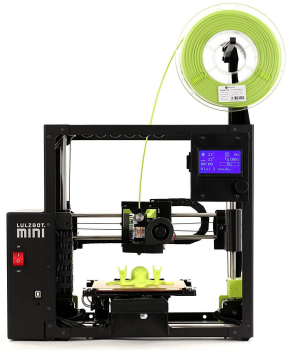
BLENDER



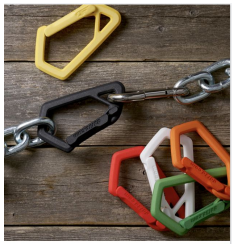
CURA

hardware









Versatile Plastic



Steel



Silver



Brass



MJF Plastic PA12

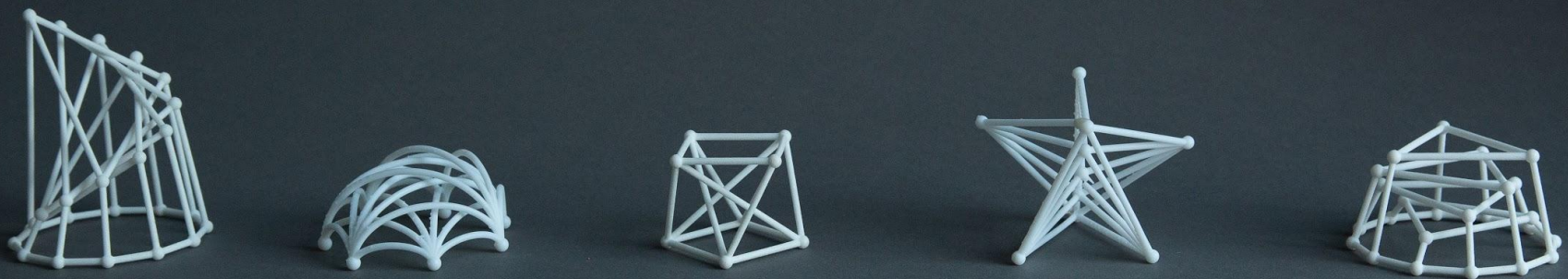
goals

Python + Grasshopper

Processing

design collaborations

spatial graphs

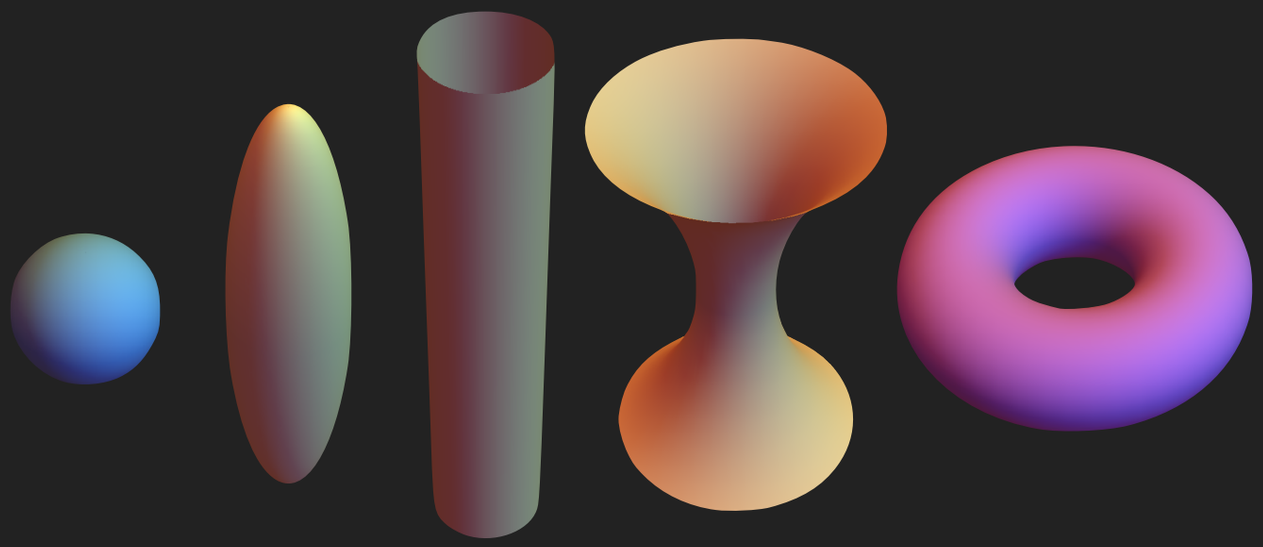


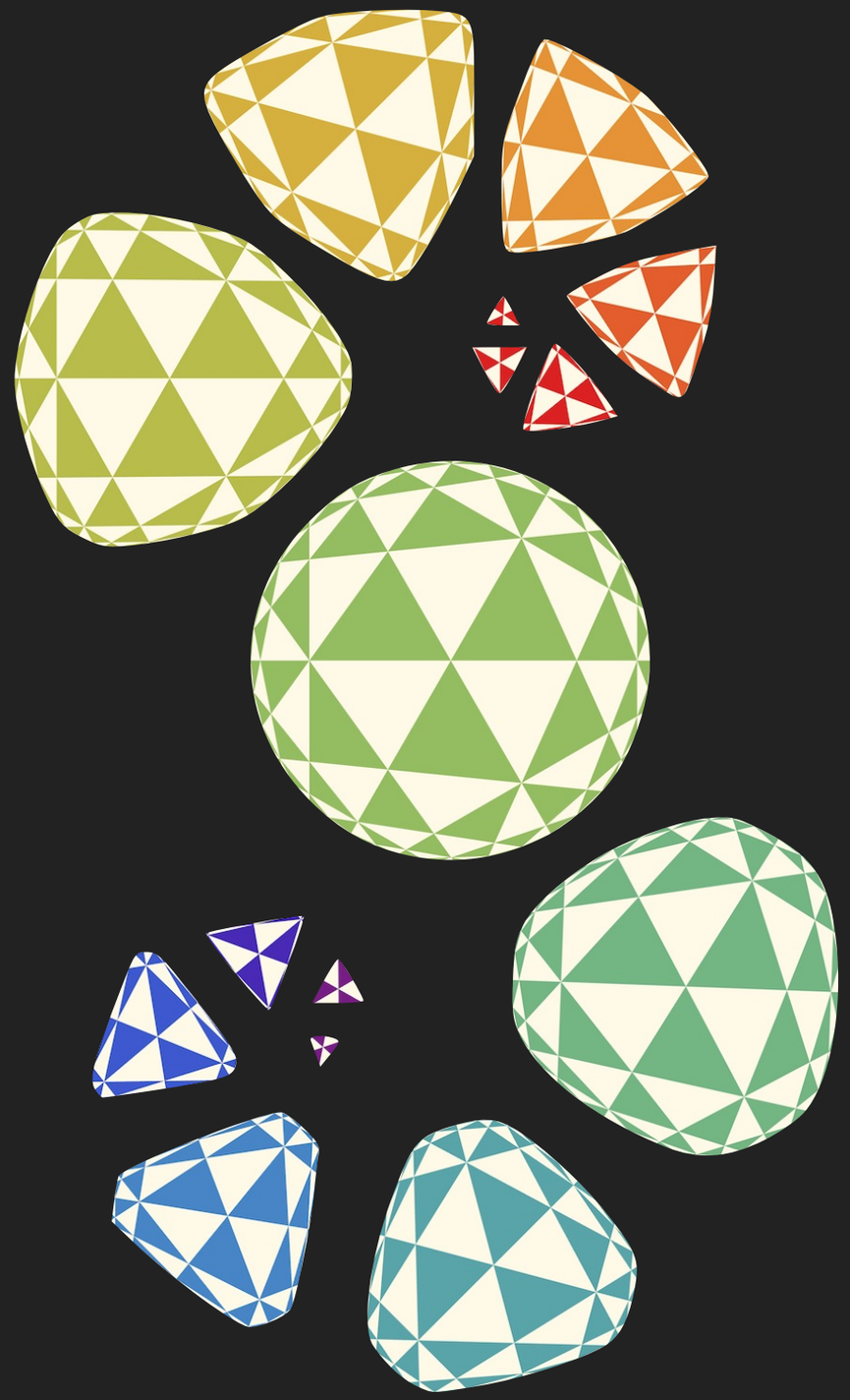
STEVE TRETTEL

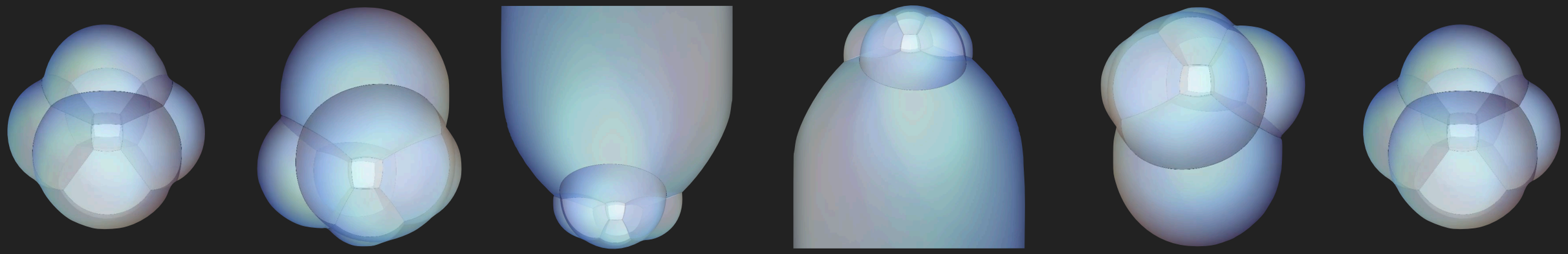
STANFORD UNIVERSITY

PHD: UC SANTA BARBARA 2019

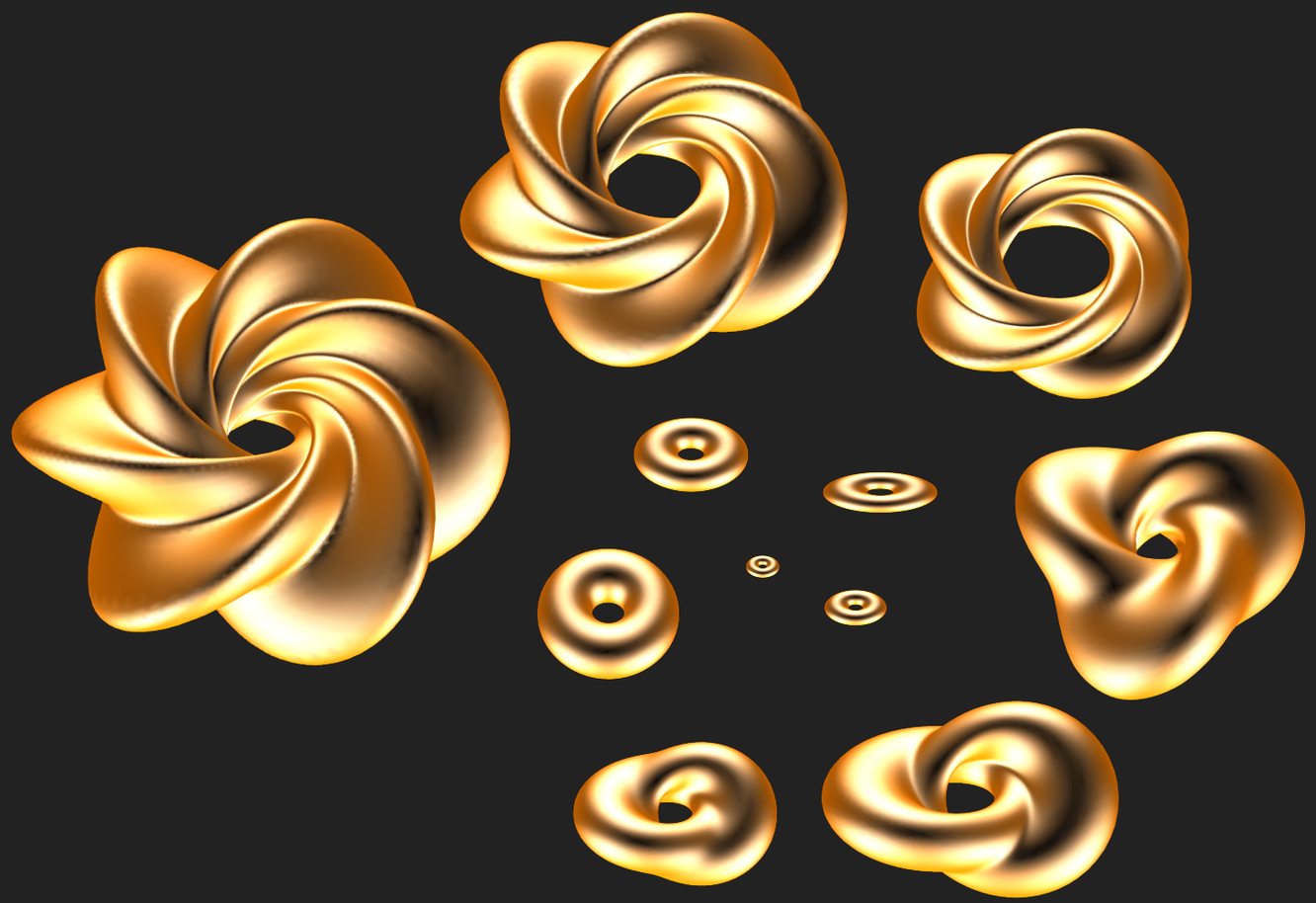
GEOMETRIC TOPOLOGY: RESEARCH

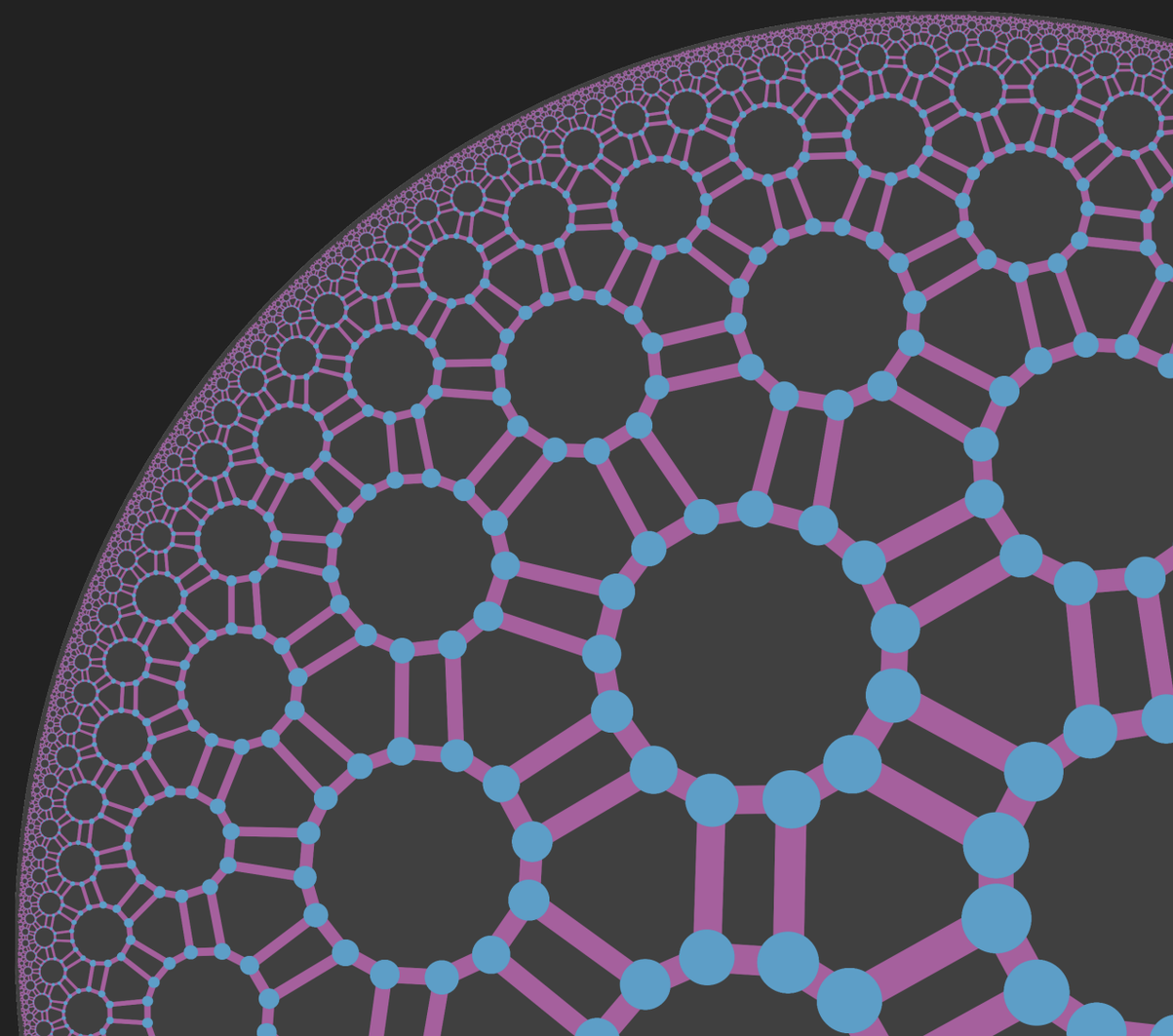




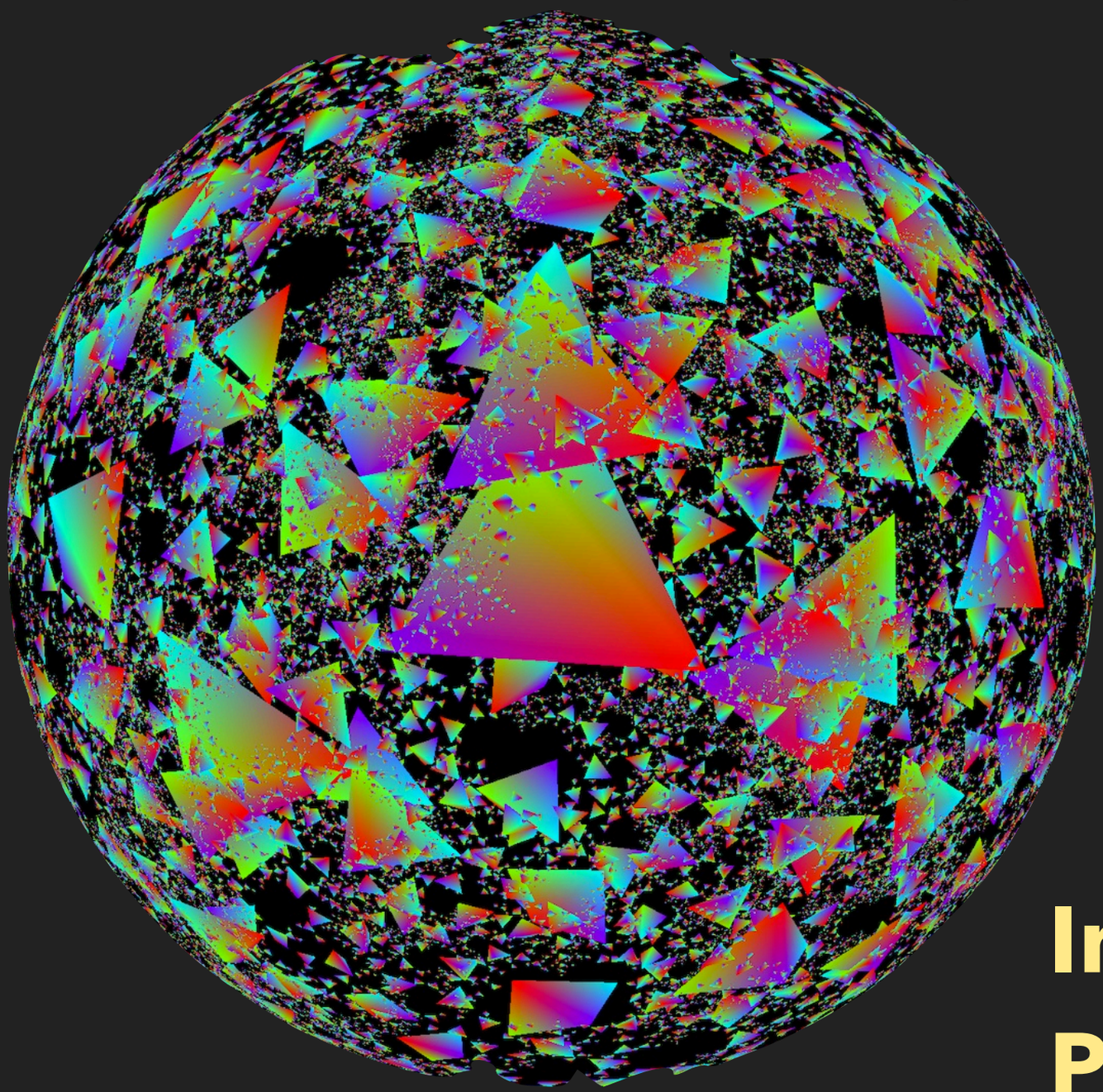


MATHEMATICA: ANIMATION





GOALS



3-Manifolds in VR

Conformal surfaces in 3-Space

3D - Modeling/ Printing

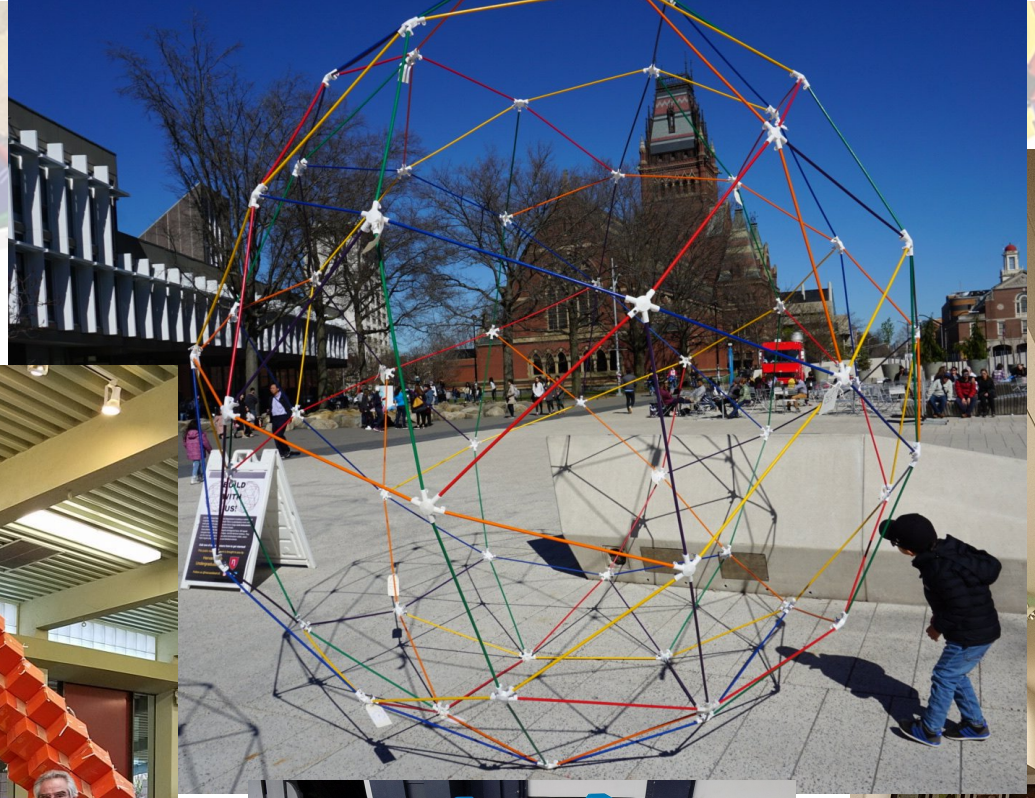
Improve Programming Skills

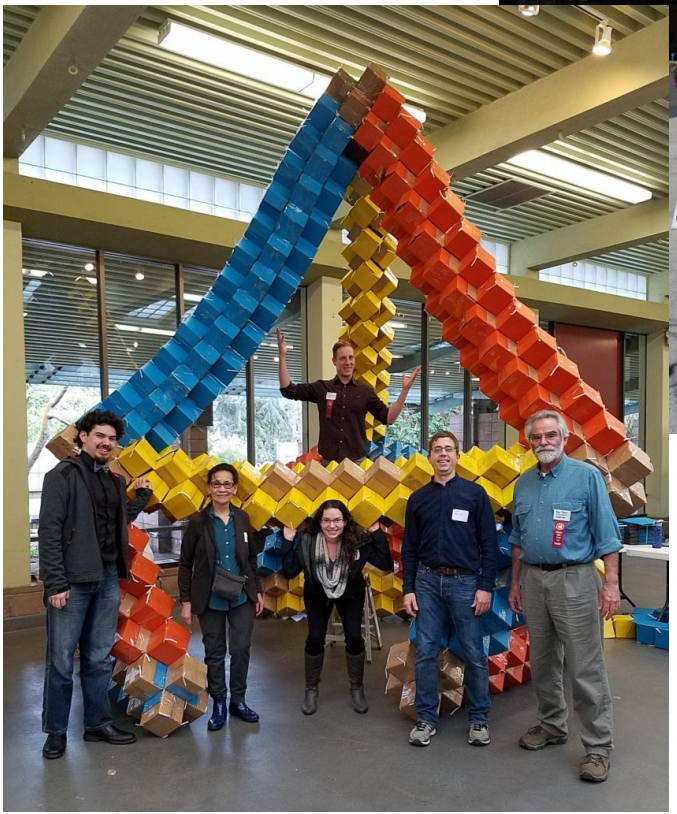


Glen Whitney

studioinfinity.org

Then





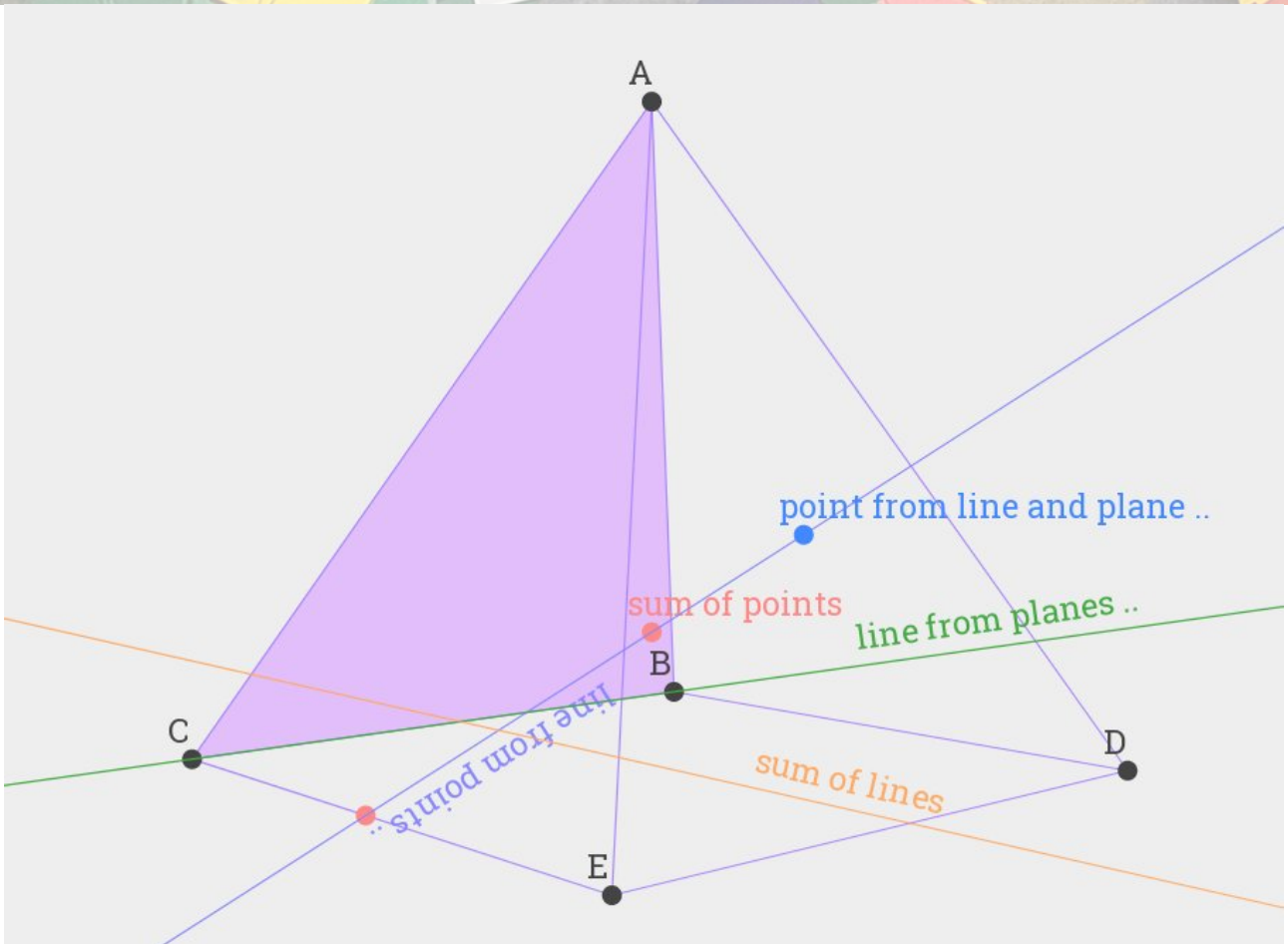




Now

- Organizing collaborative art with Matt Parker (Everyone is invited to participate!)
- Can every convex tessellation be grouted?
- Platonic *Jeopardy!*

Soon



- Dynamic interactive geometry
- Fully 3-dimensional from the ground up
- Constraint-based, rather than construction-based.

Carolyn Yackel

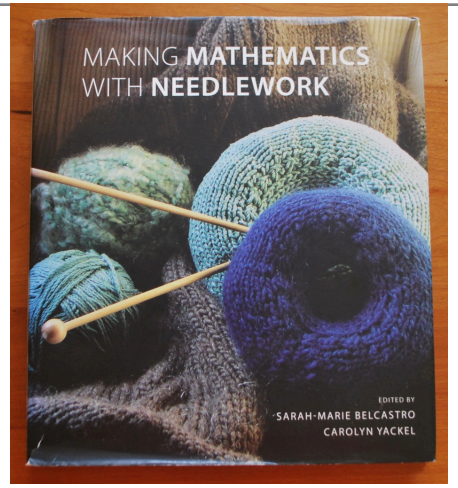
Professor of Mathematics

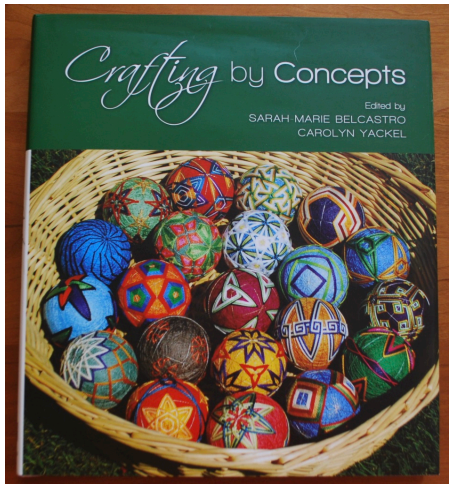
MERCER UNIVERSITY

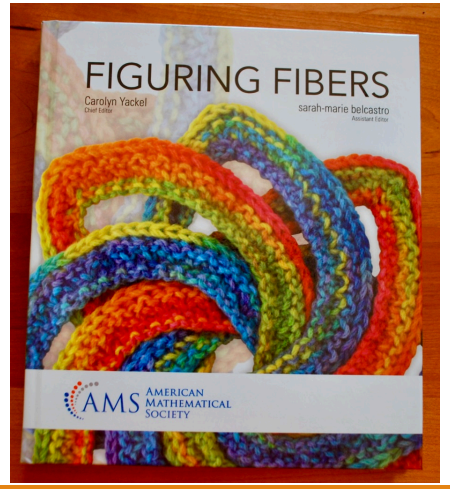
Mathematics and Fiber Arts

The Knitting Circle

Since 2001







3 Edited Volumes
2 Co-Editors
16 Authors
25 Chapters/Minis

Current Projects

Mathematics of Mosaic Knitting with Susan Goldstine





Mathematics of (Itajime and Kumo) Shibori Dyeing

Skills

- Adobe Illustrator
- LaTeX/some TikZ
- Knitting, Crocheting, Temari, Tatting, Sewing

Primary Semester Goals

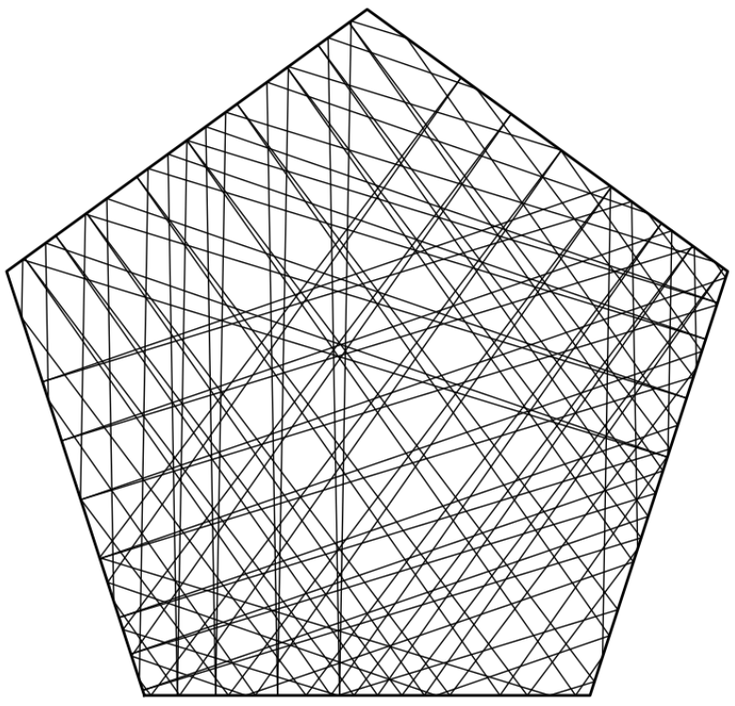
1. Learn to use the laser cutter and the associated software
2. Become better at communicating mathematics
3. Gain new collaborators
4. Learn to use the 3D printer and the associated software
5. Learn more mathematics!
6. Learn to use the knitting machine (if it's here) and the associated software
7. Have Fun

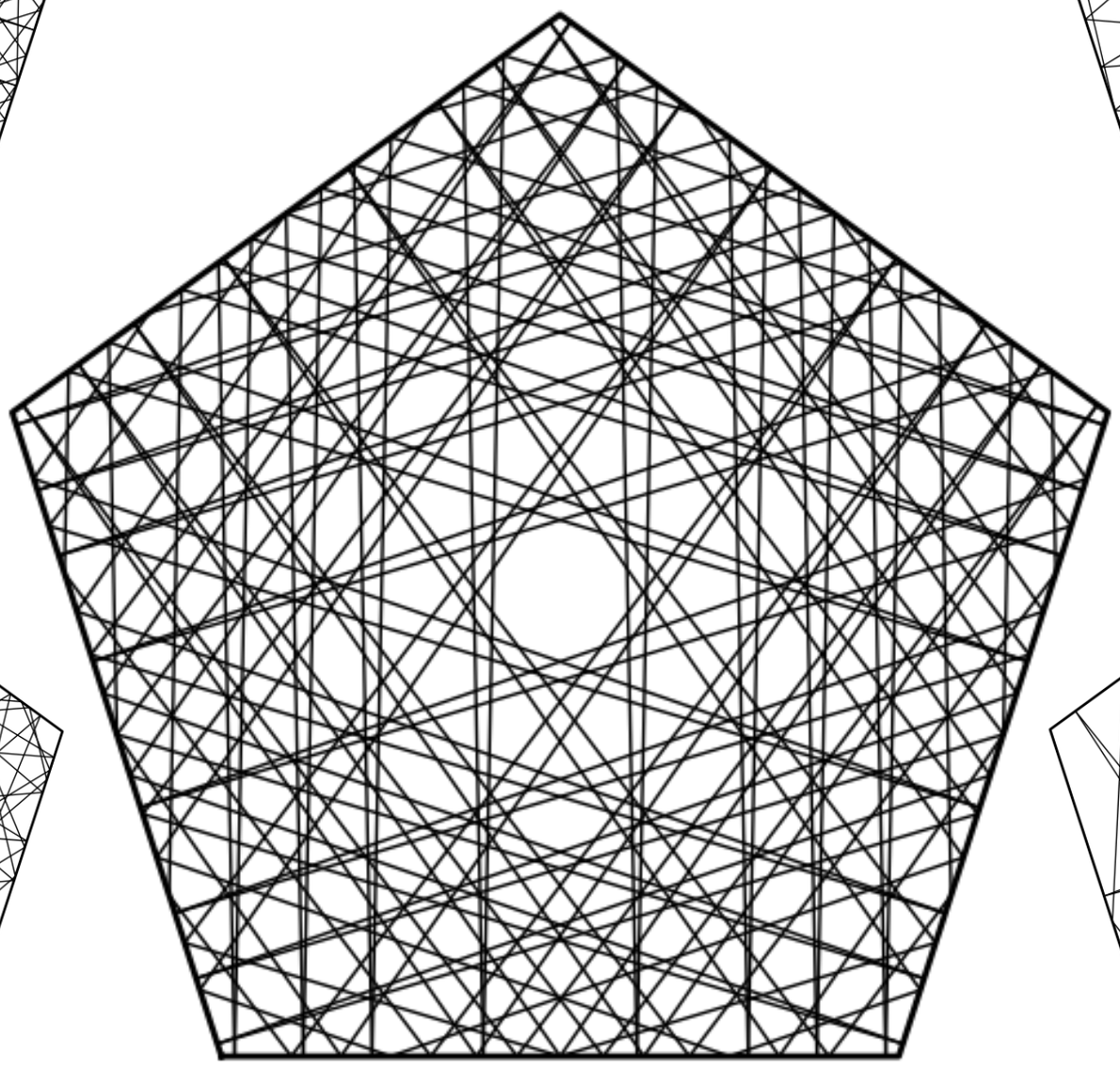
Periodic Paths on the Pentagon

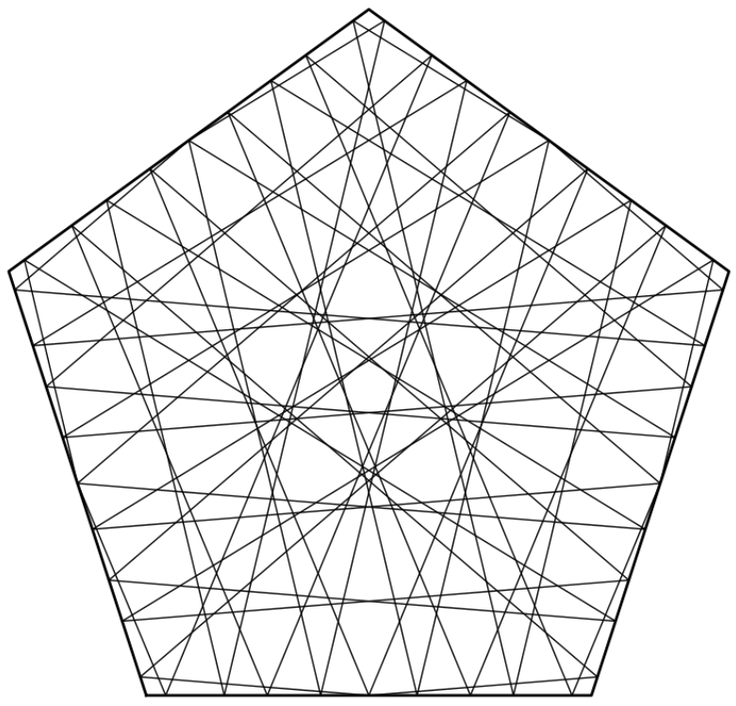
Diana Davis

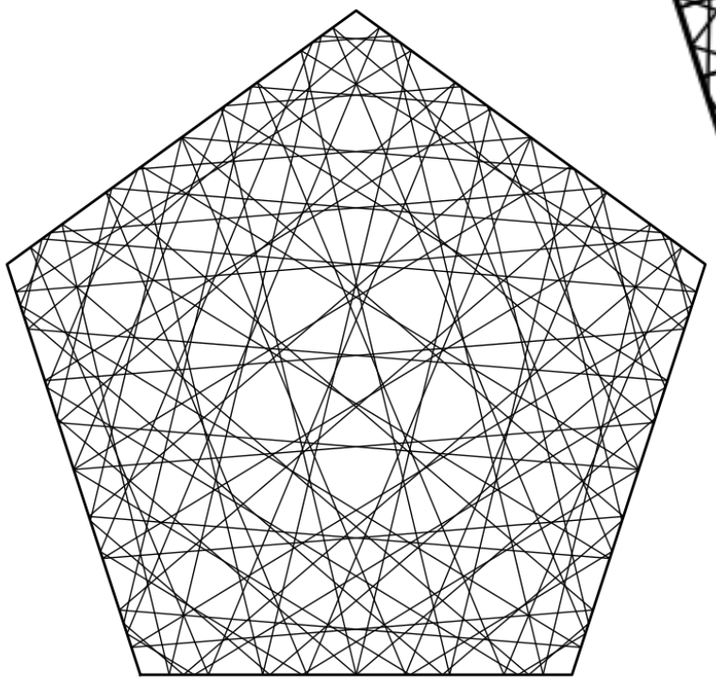
ICERM

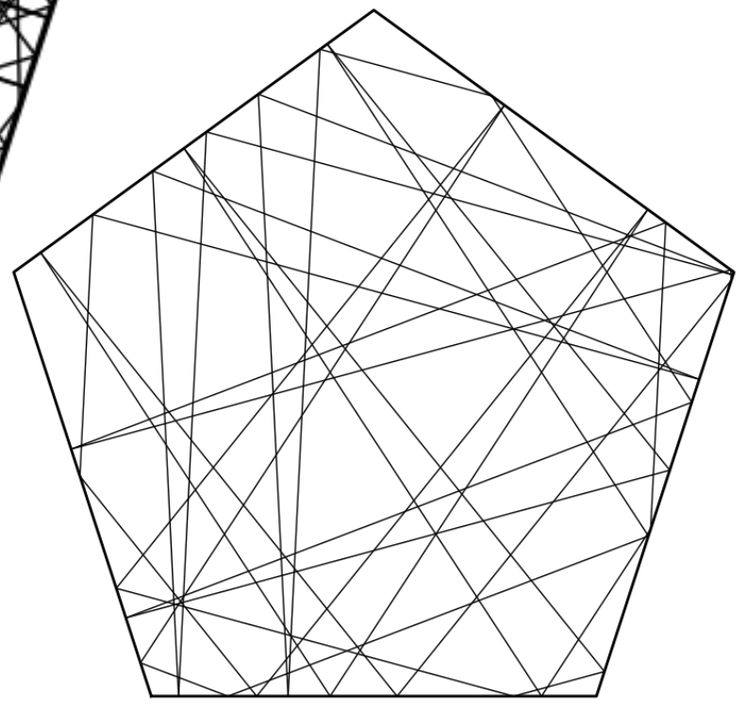
September 6, 2019





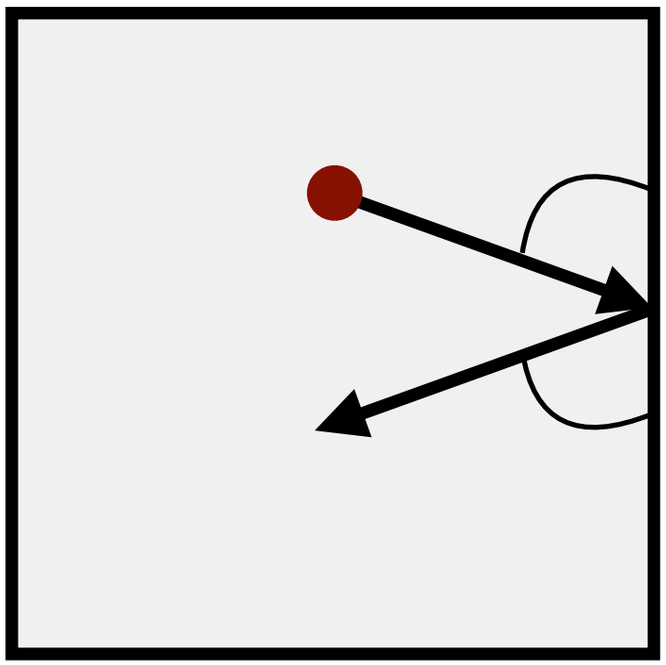


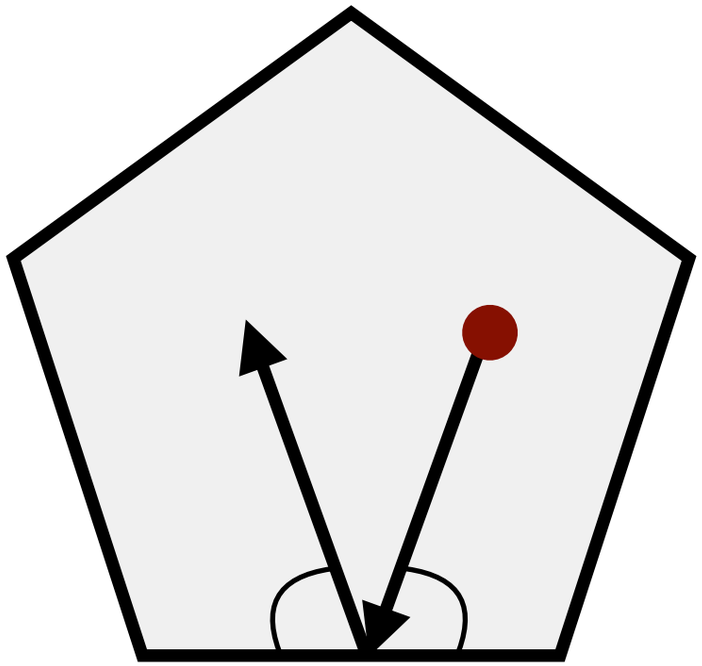




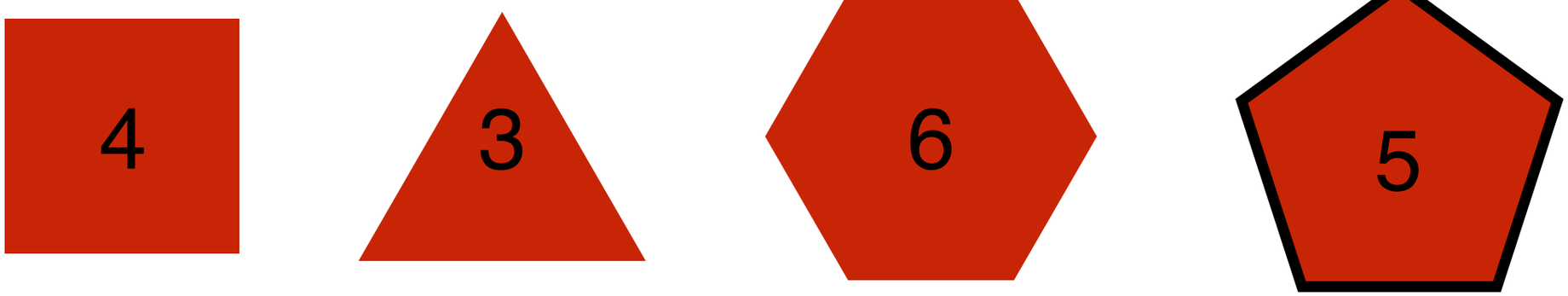
BILLIARDS:

- A particle bouncing around inside a polygon
- The angle of incidence equals the angle of reflection

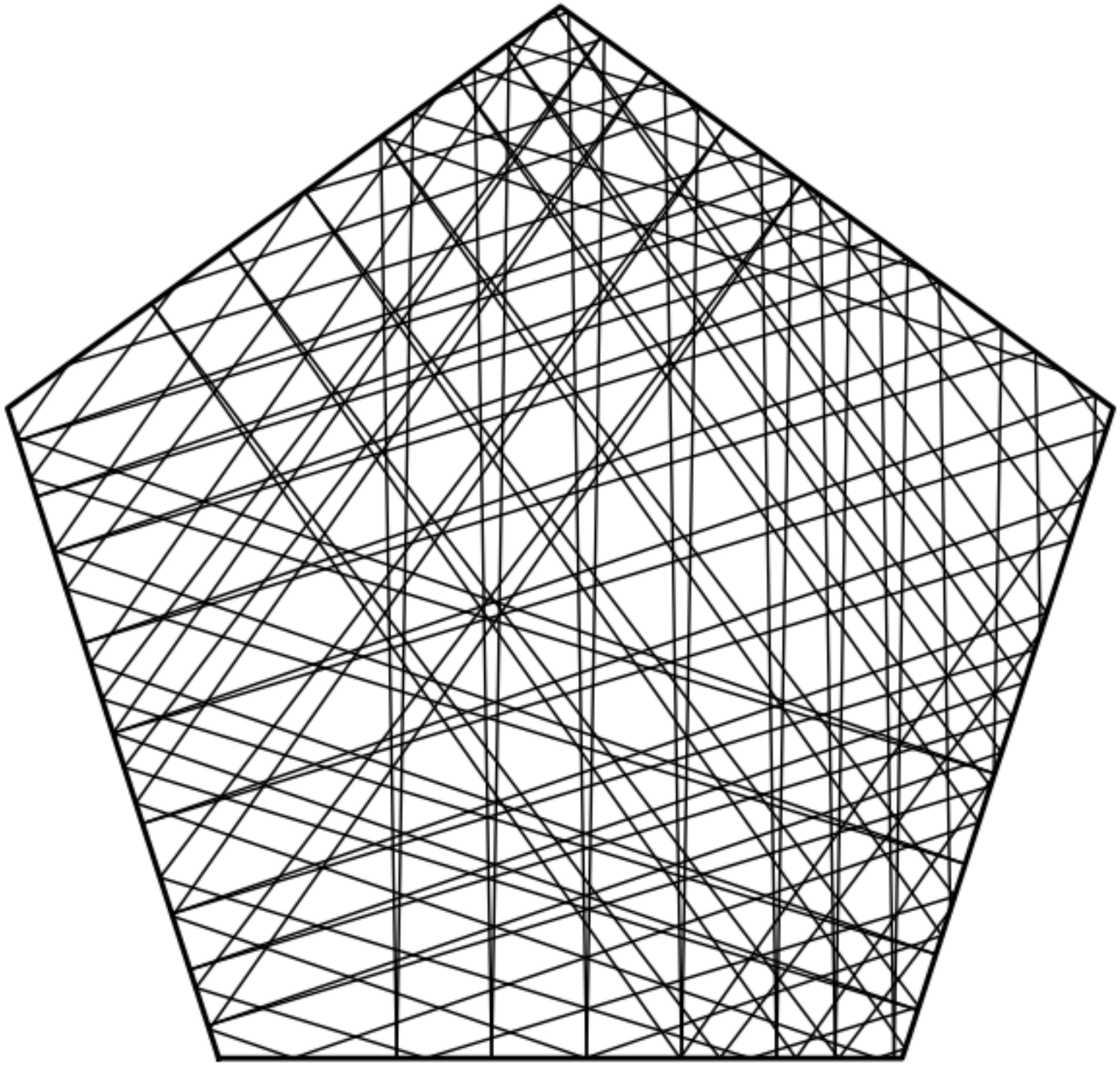




We (humans) understand periodic billiard paths on:



Some examples of periodic trajectories



pictures by Diana Davis and Samuel Lelièvre

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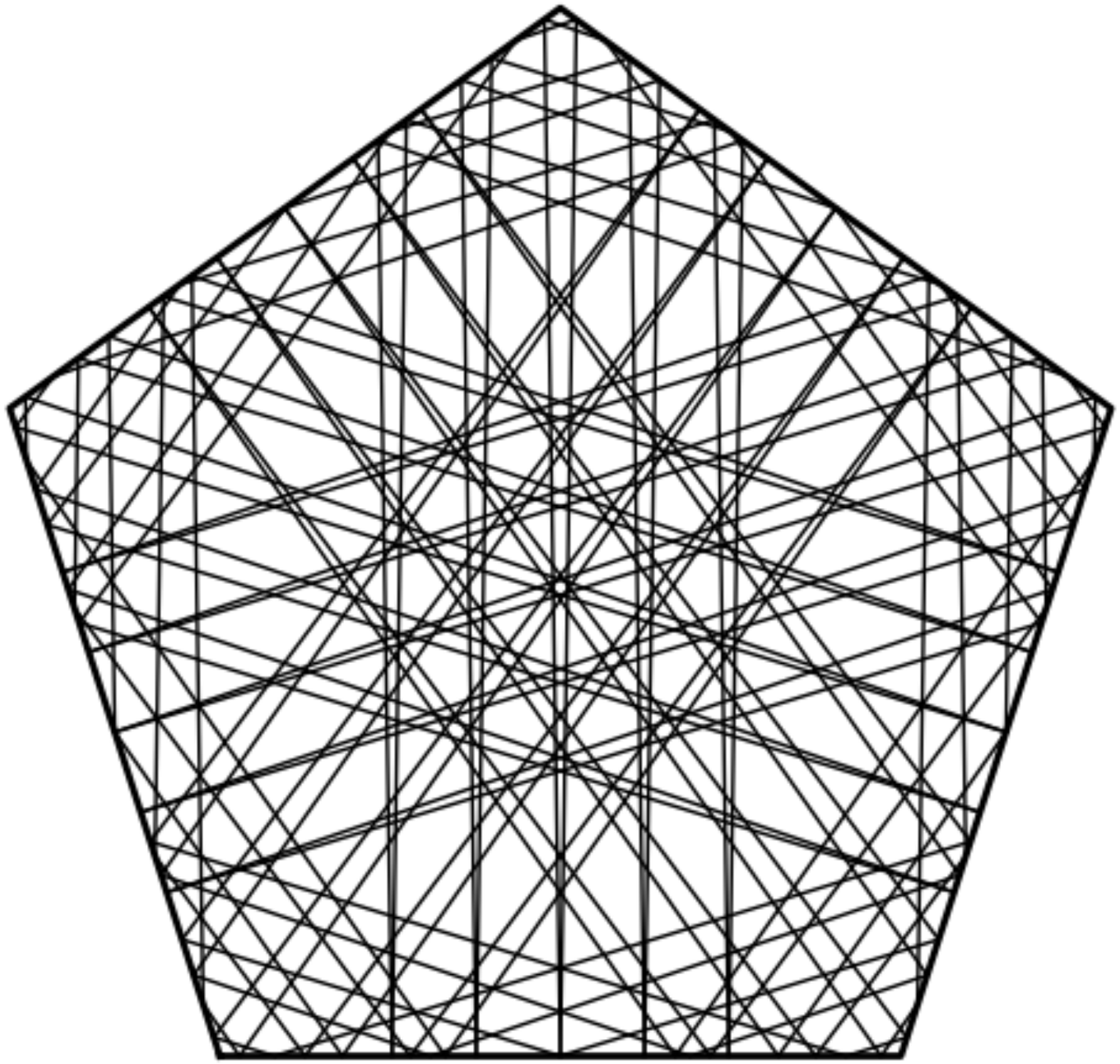

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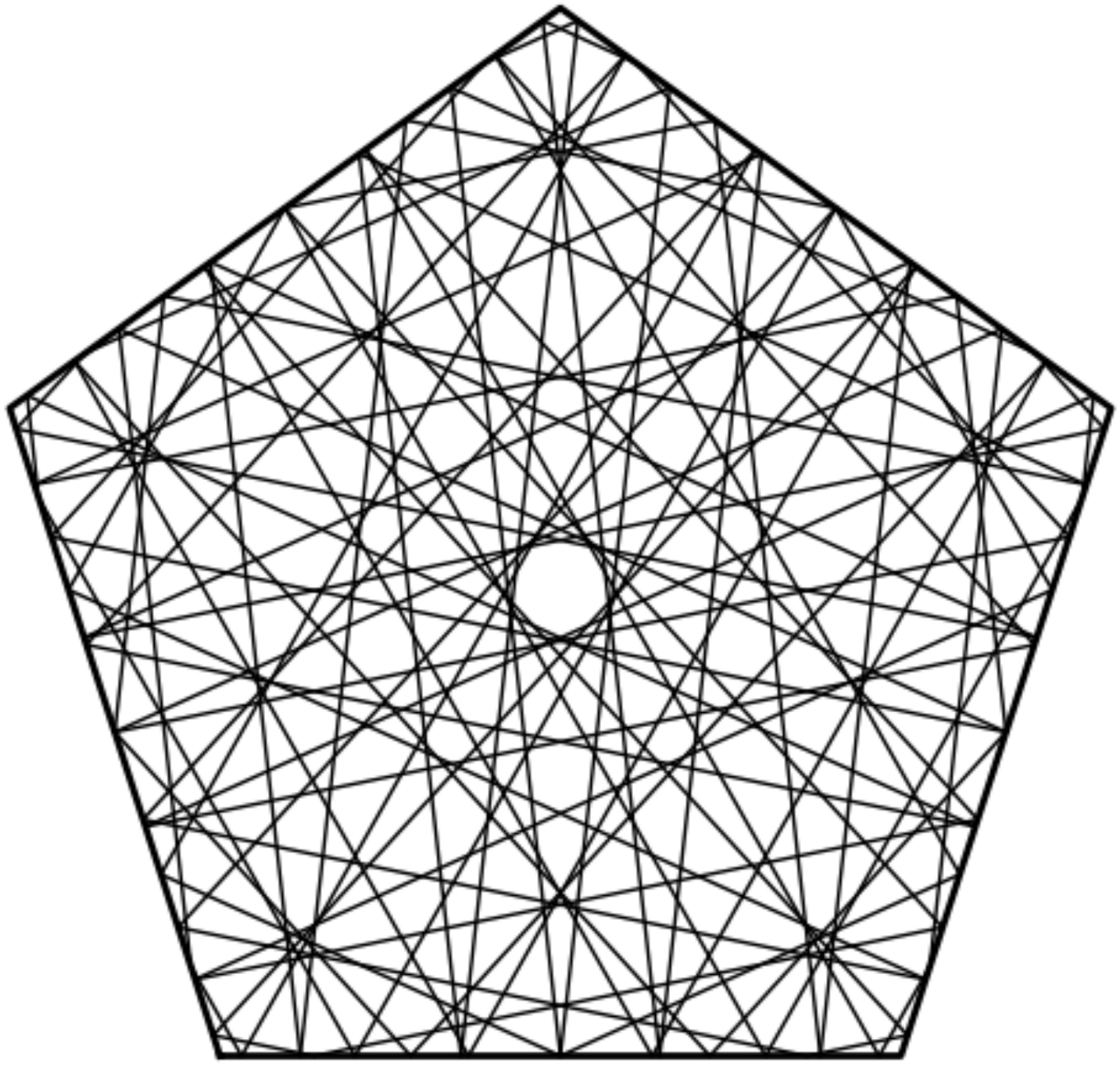

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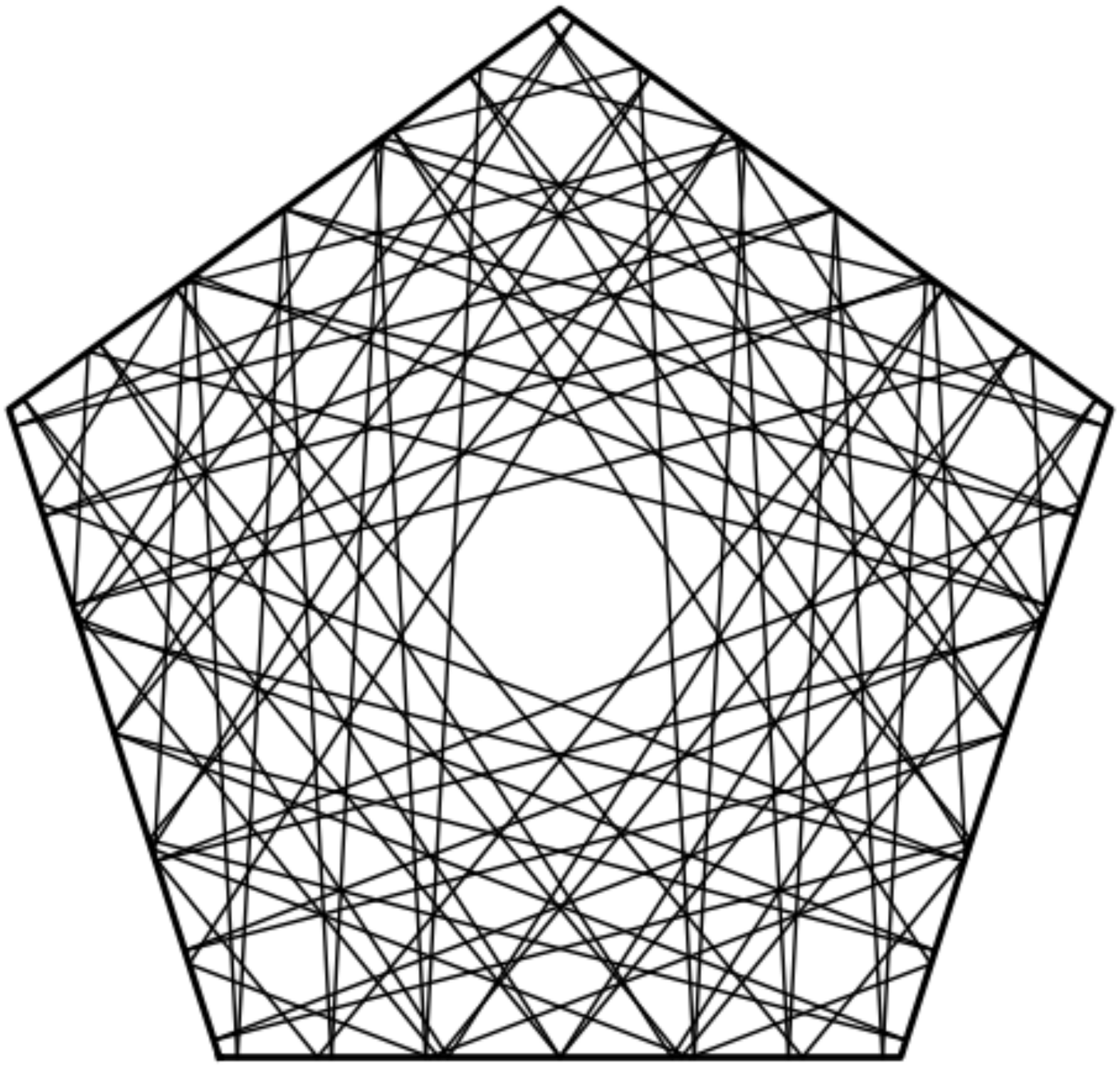

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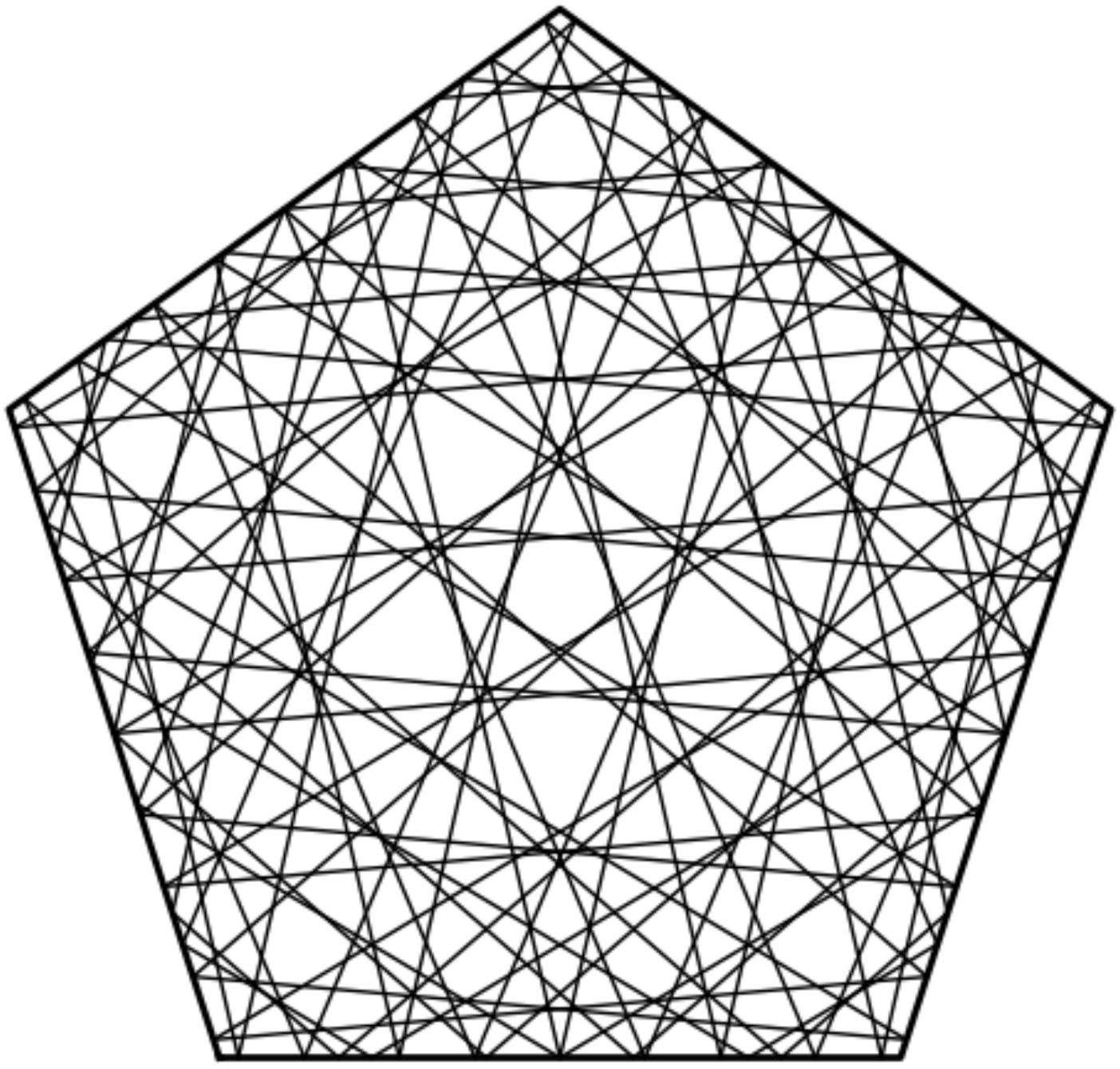
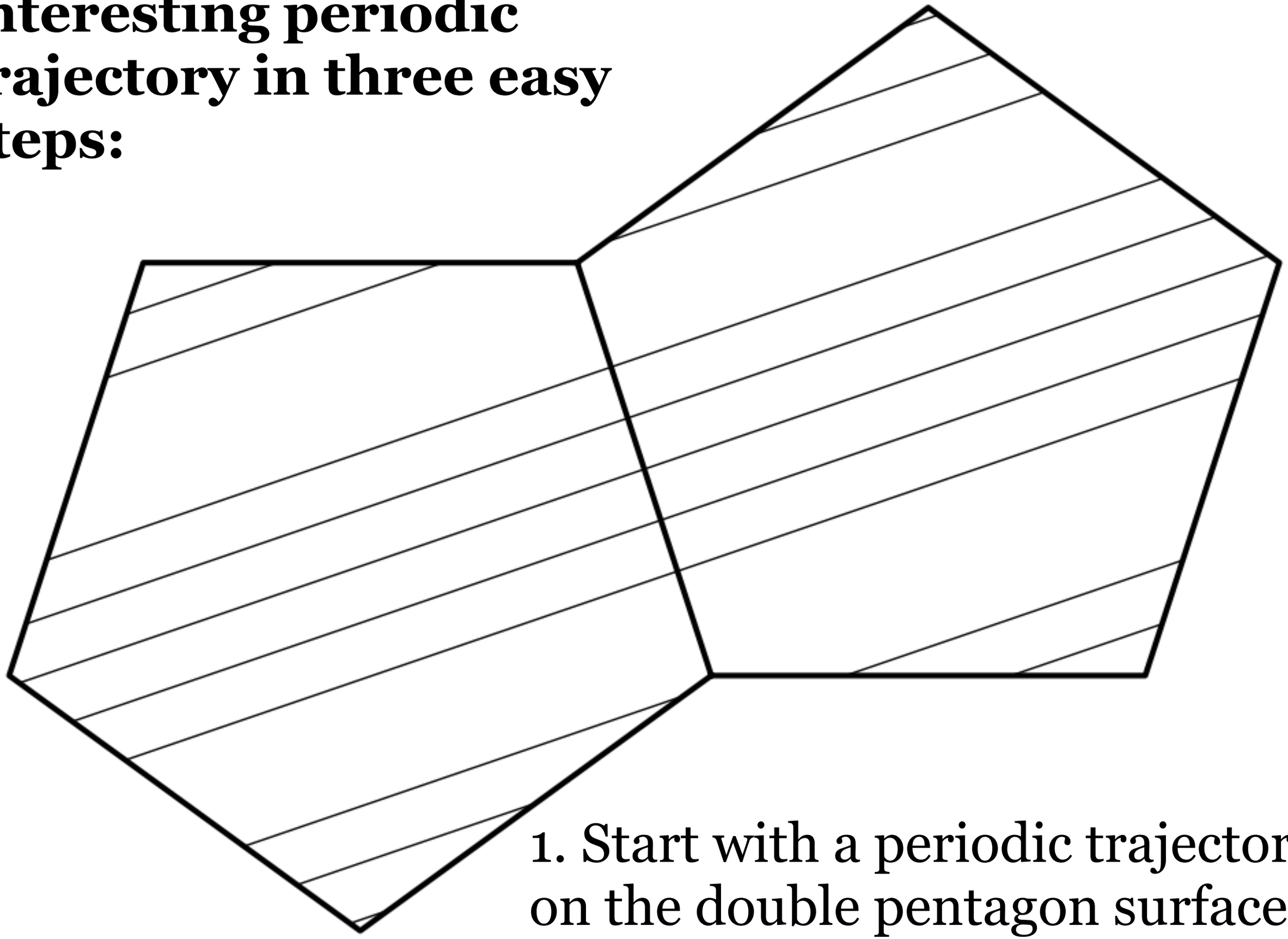


How to get a very long, very interesting periodic trajectory in three easy steps:



1. Start with a periodic trajectory on the double pentagon surface.

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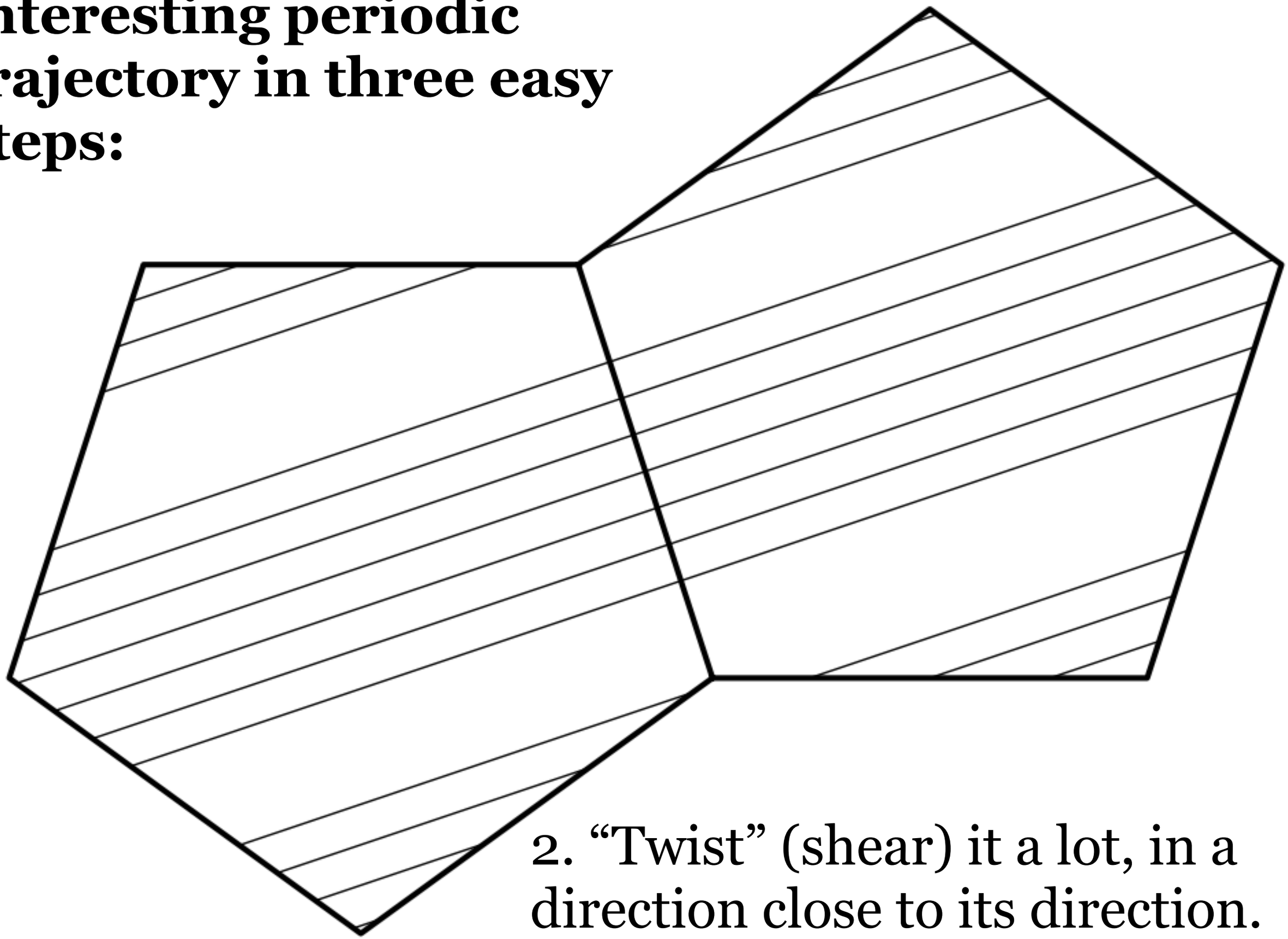

2. “Twist” (shear) it a lot, in a direction close to its direction.

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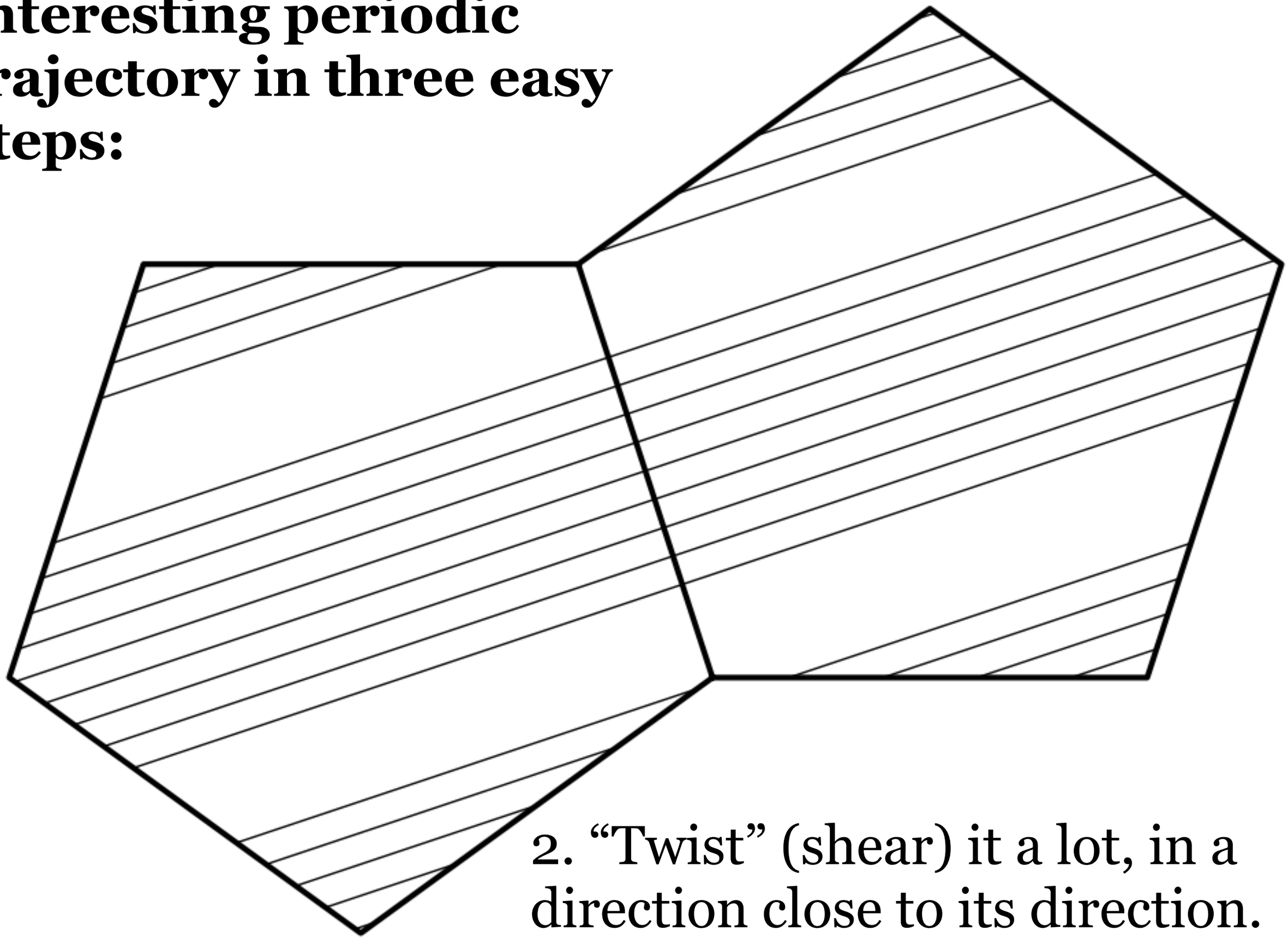

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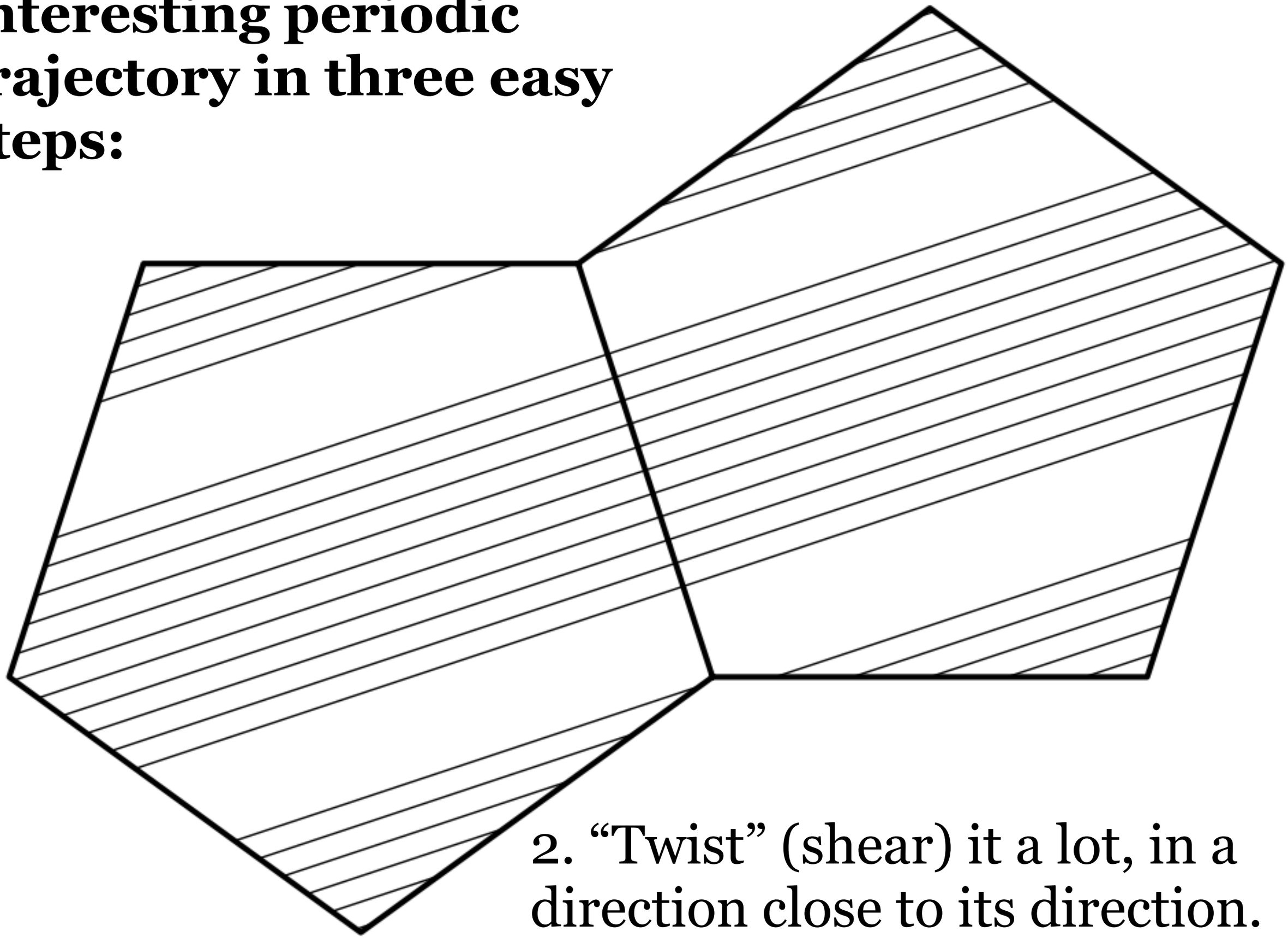

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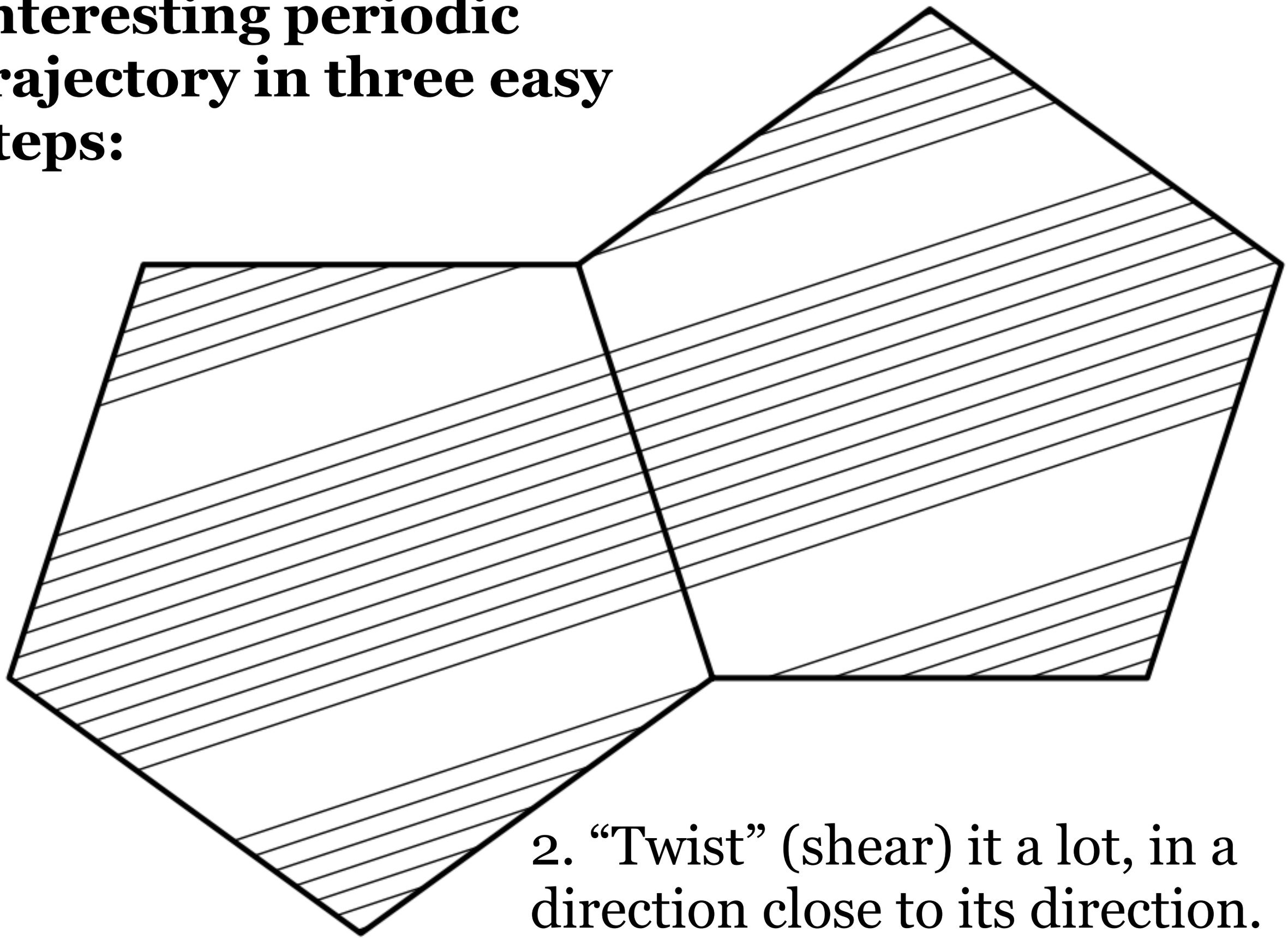

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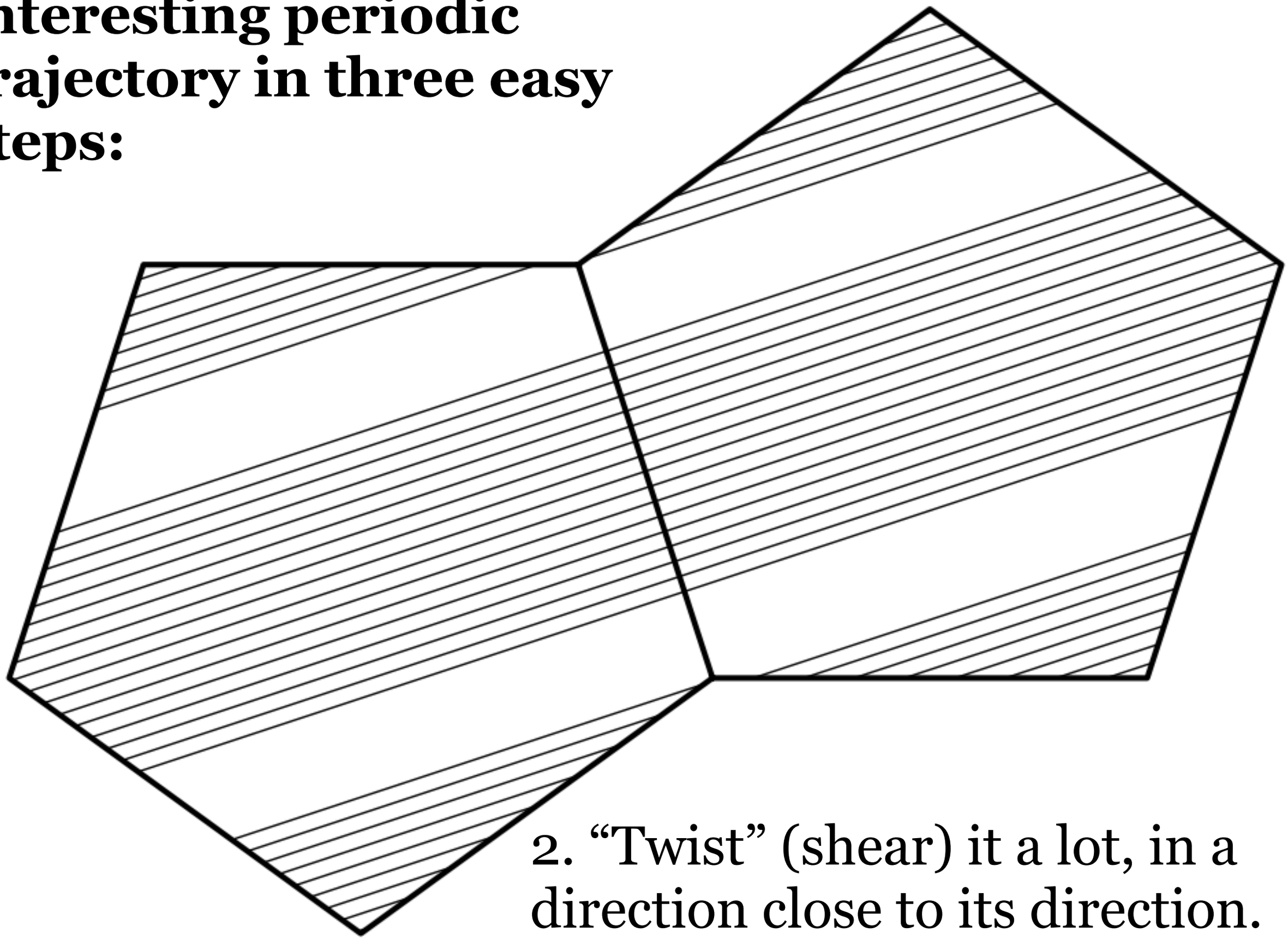

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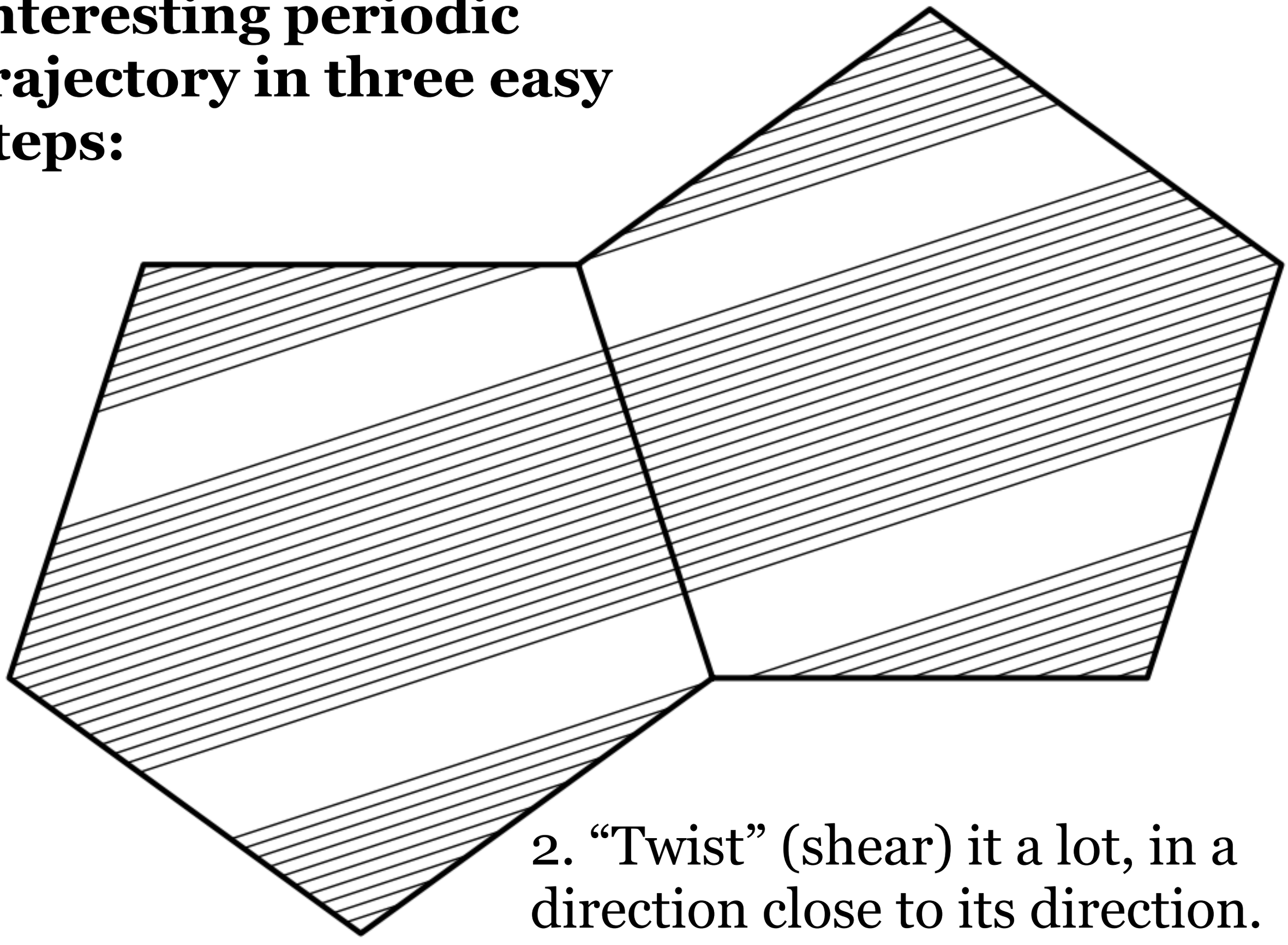

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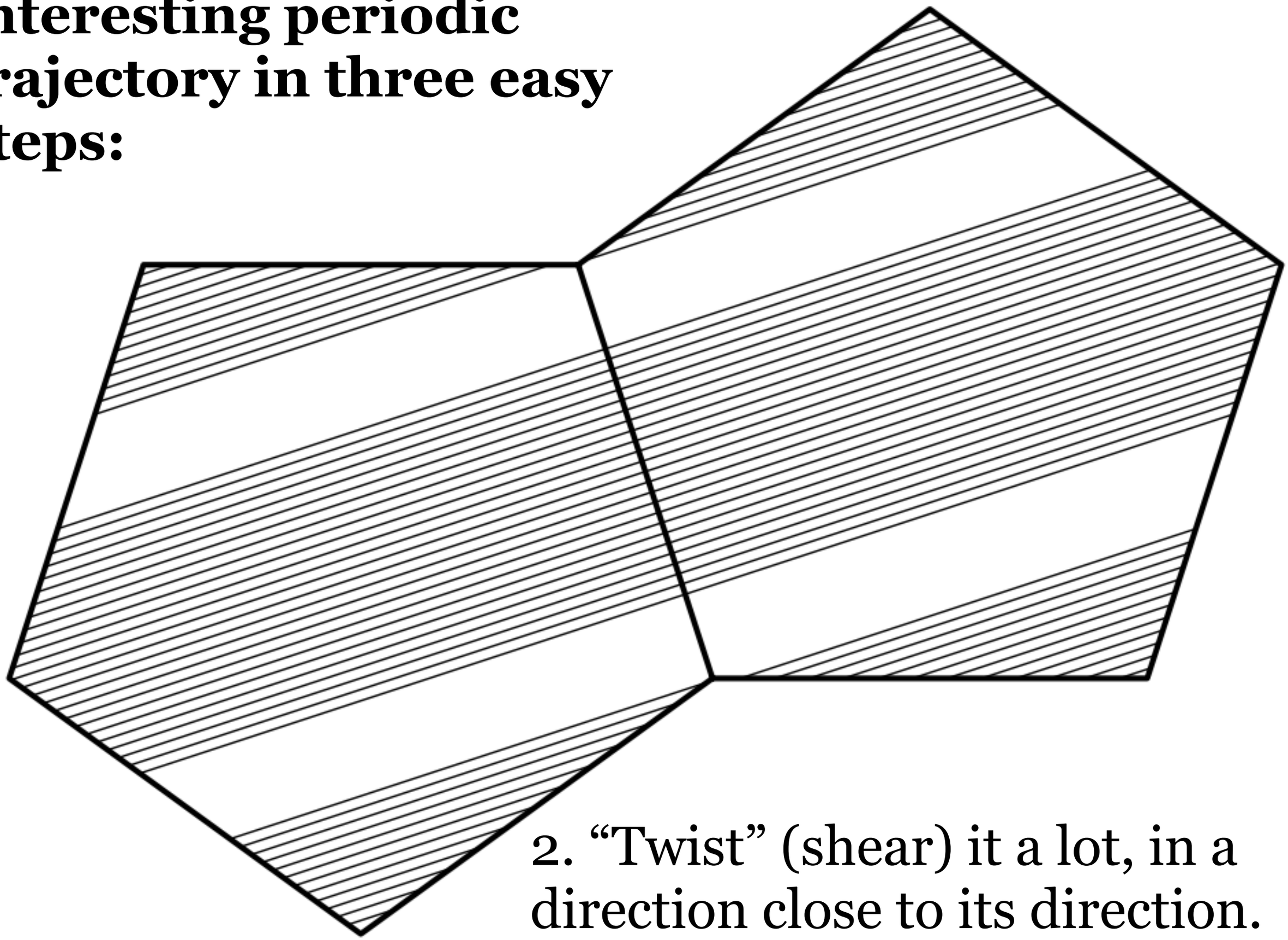

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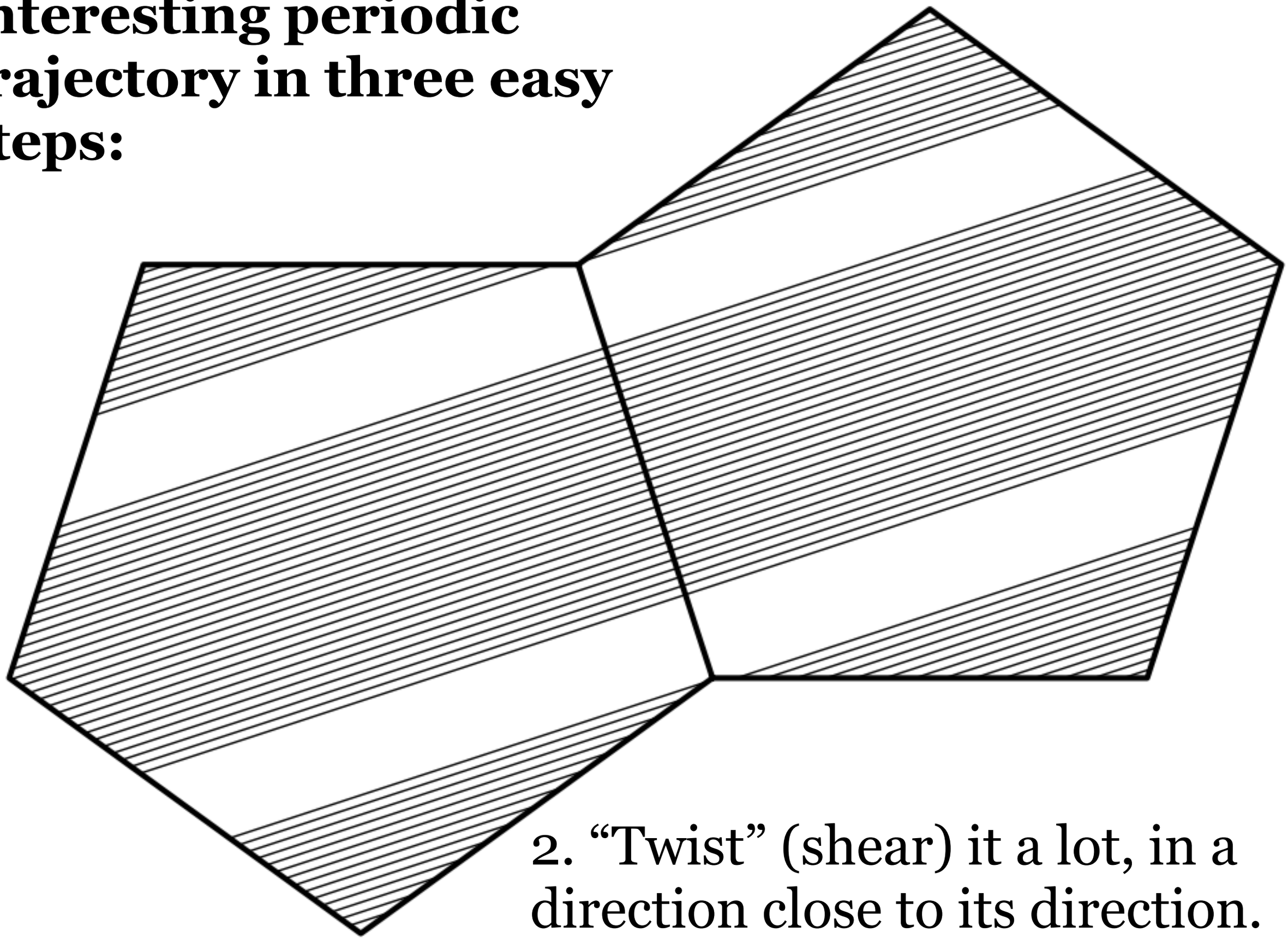

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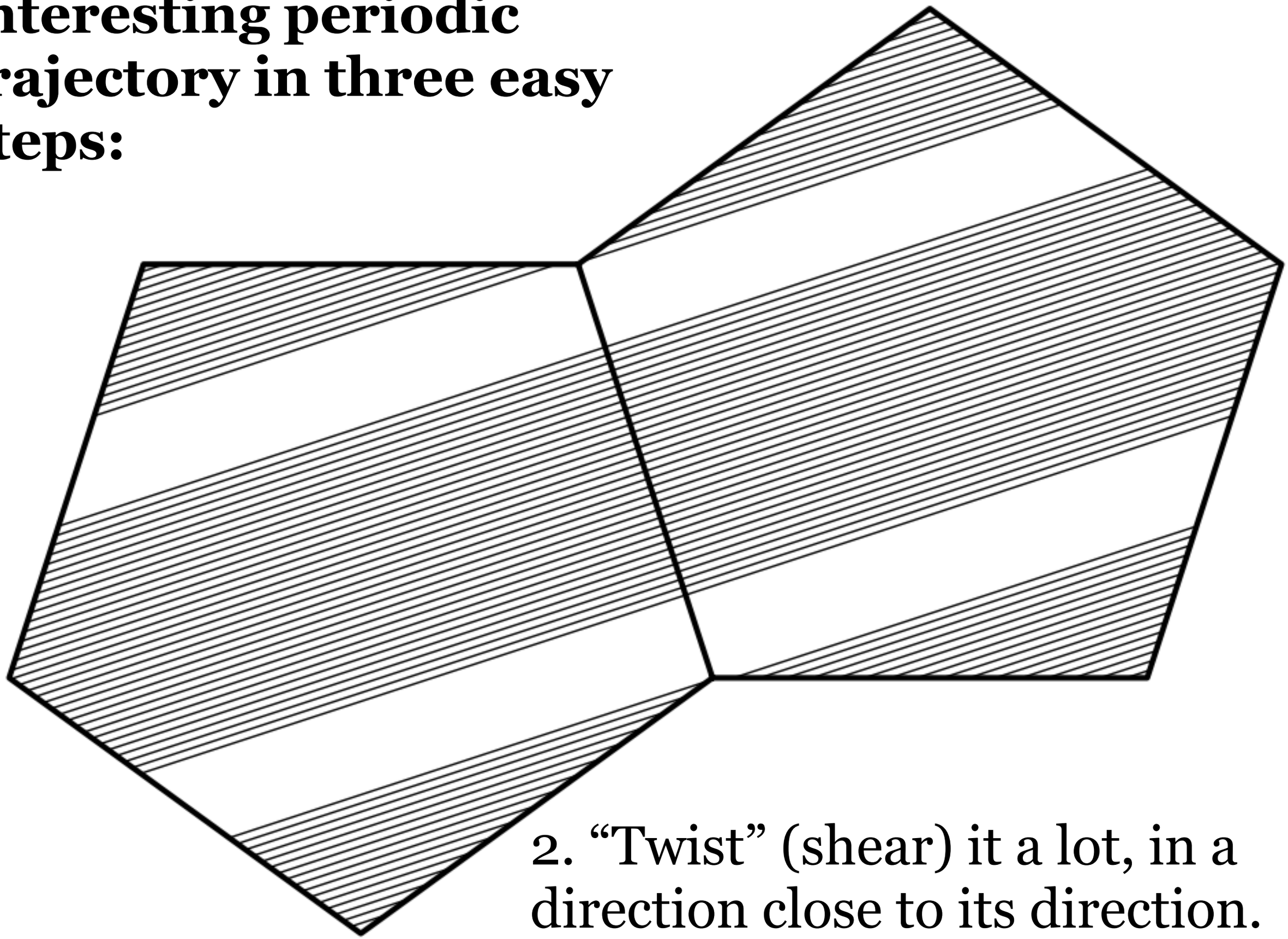

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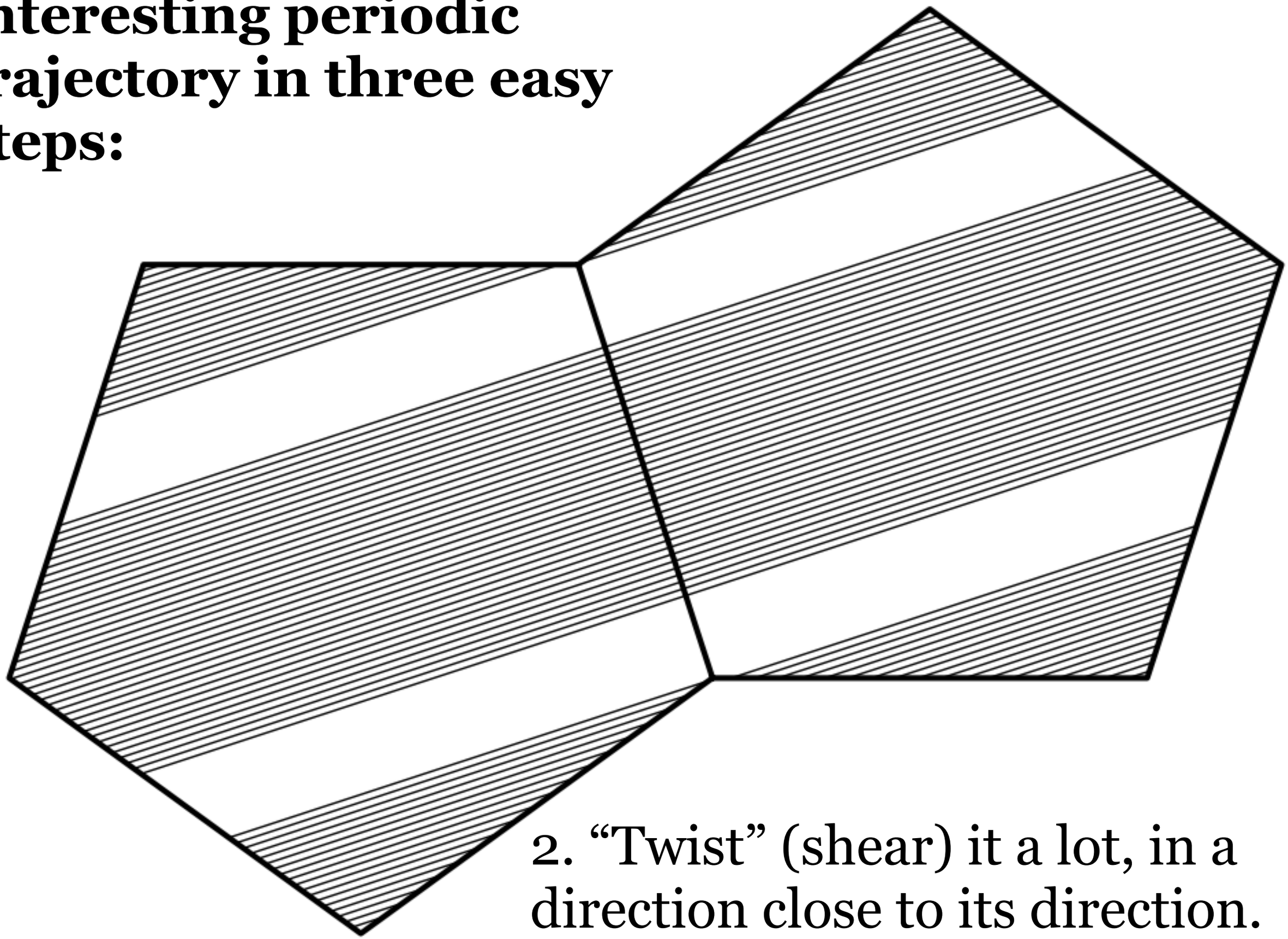

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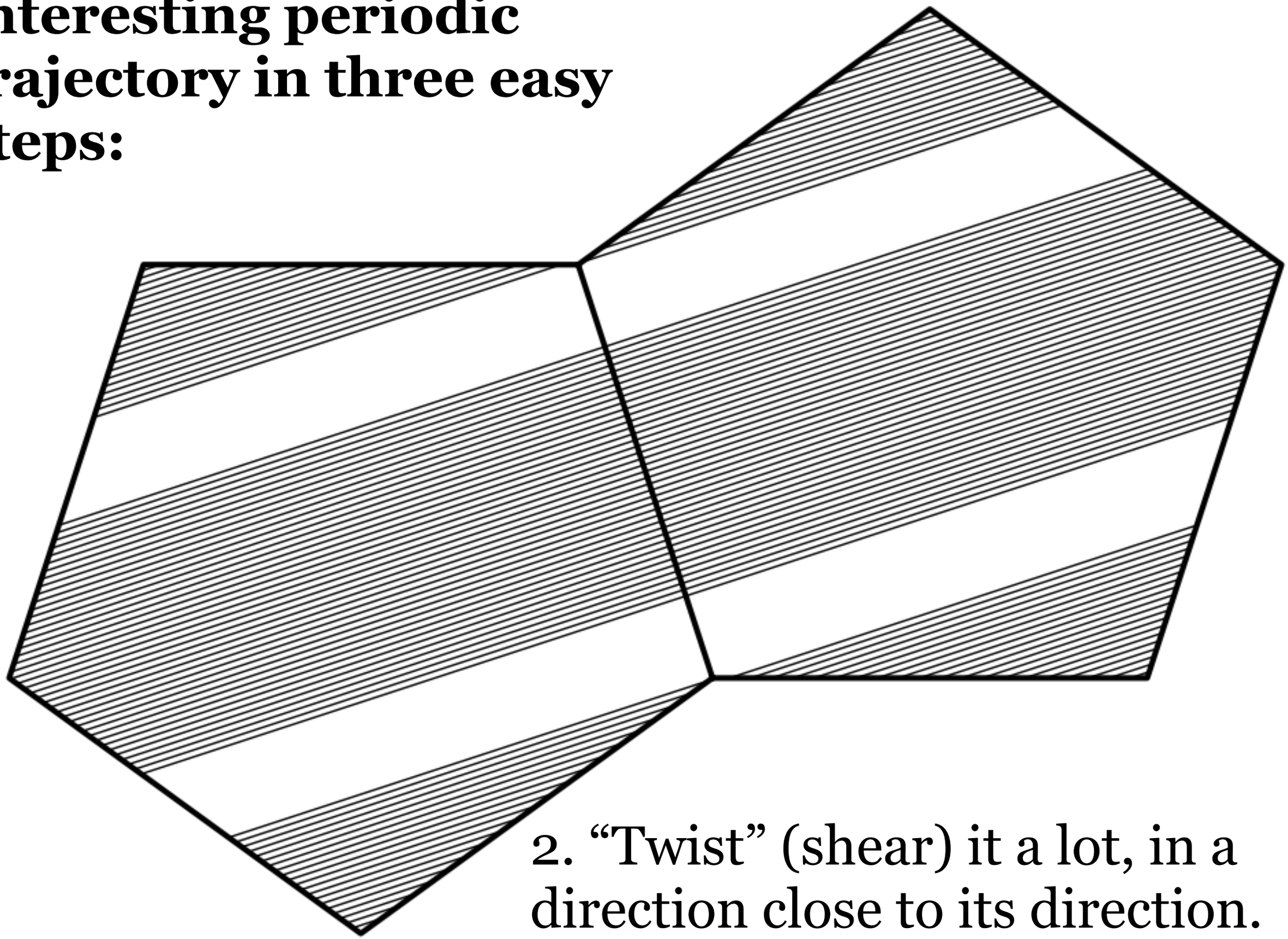

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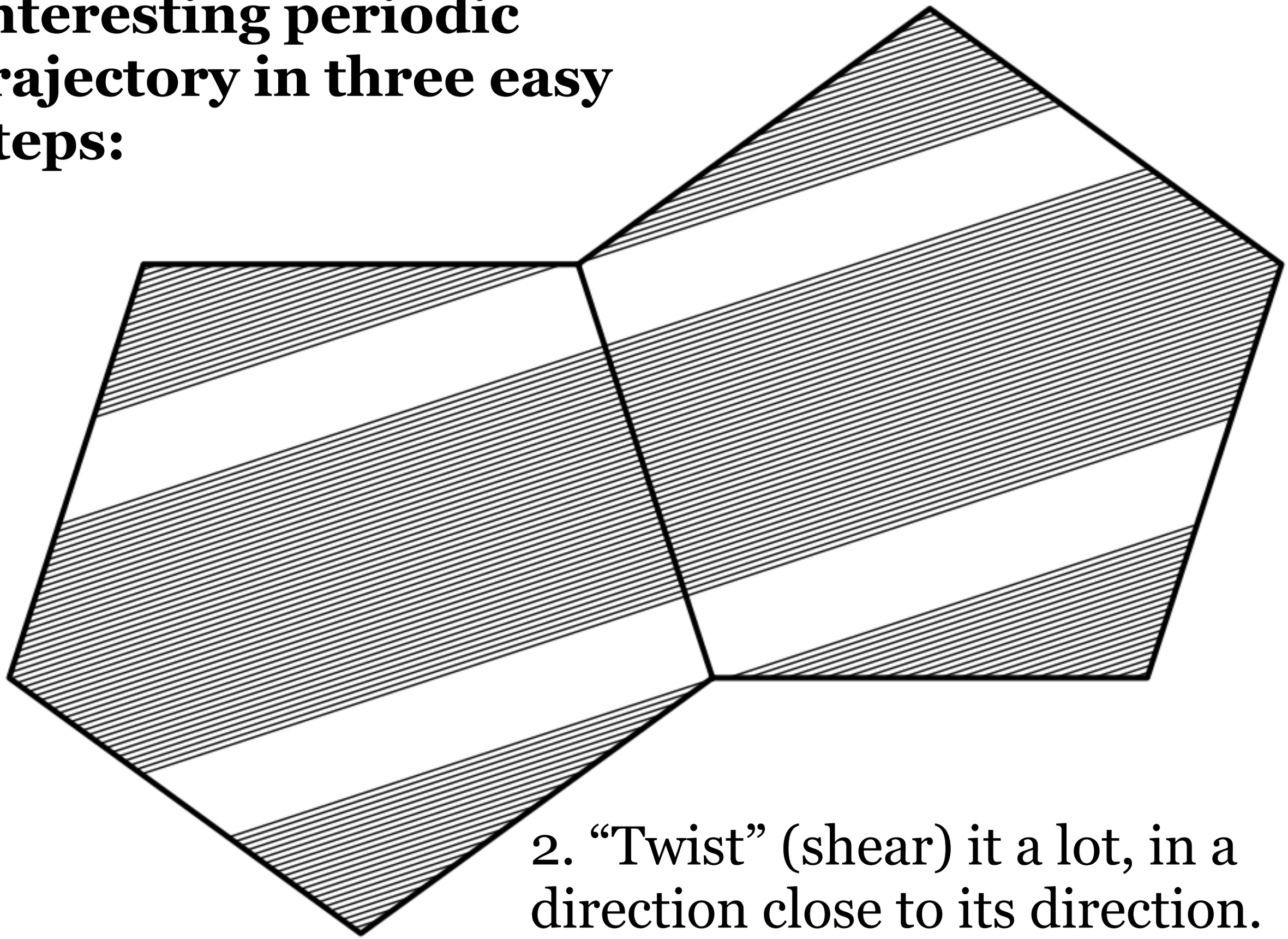

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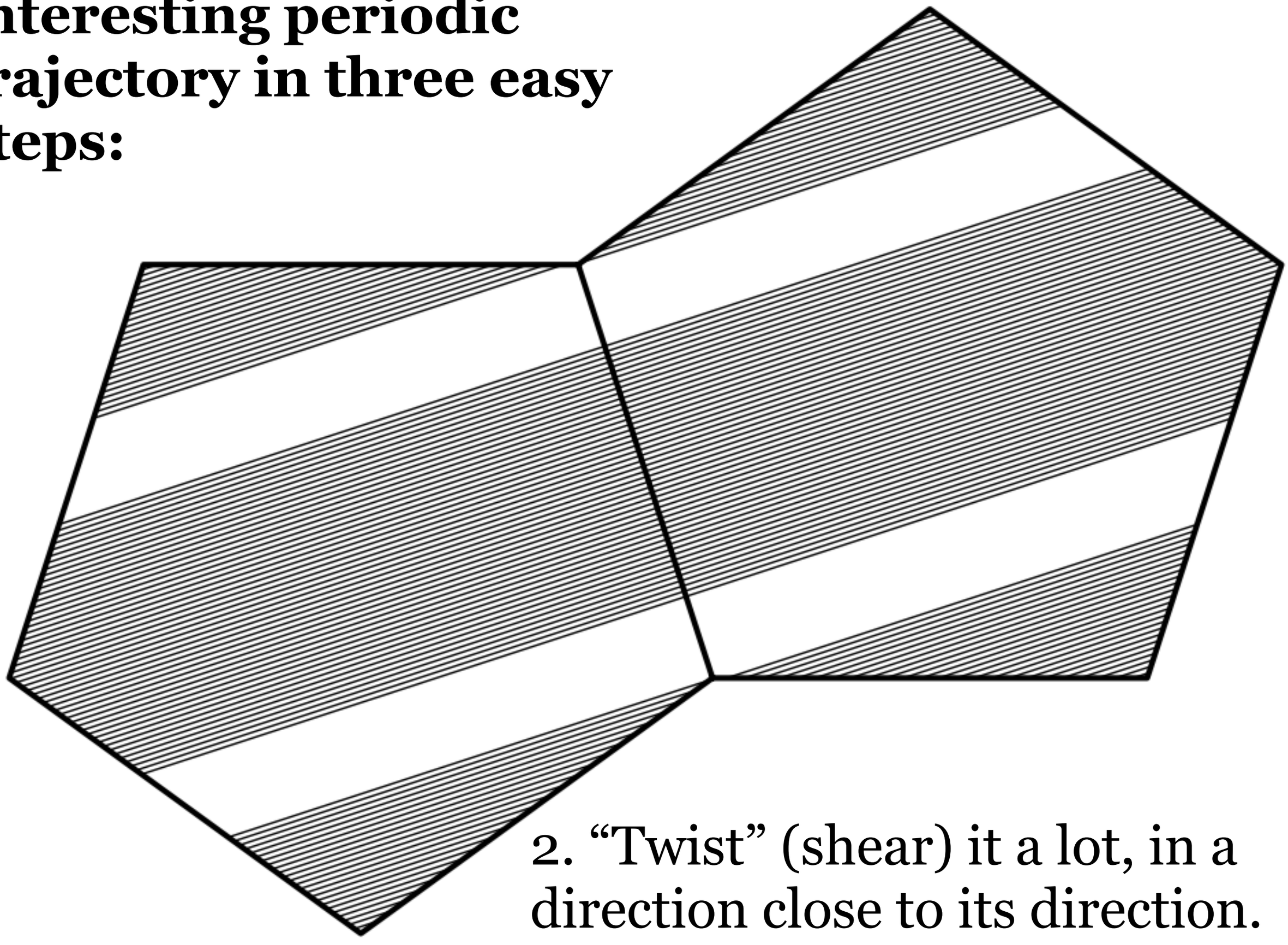

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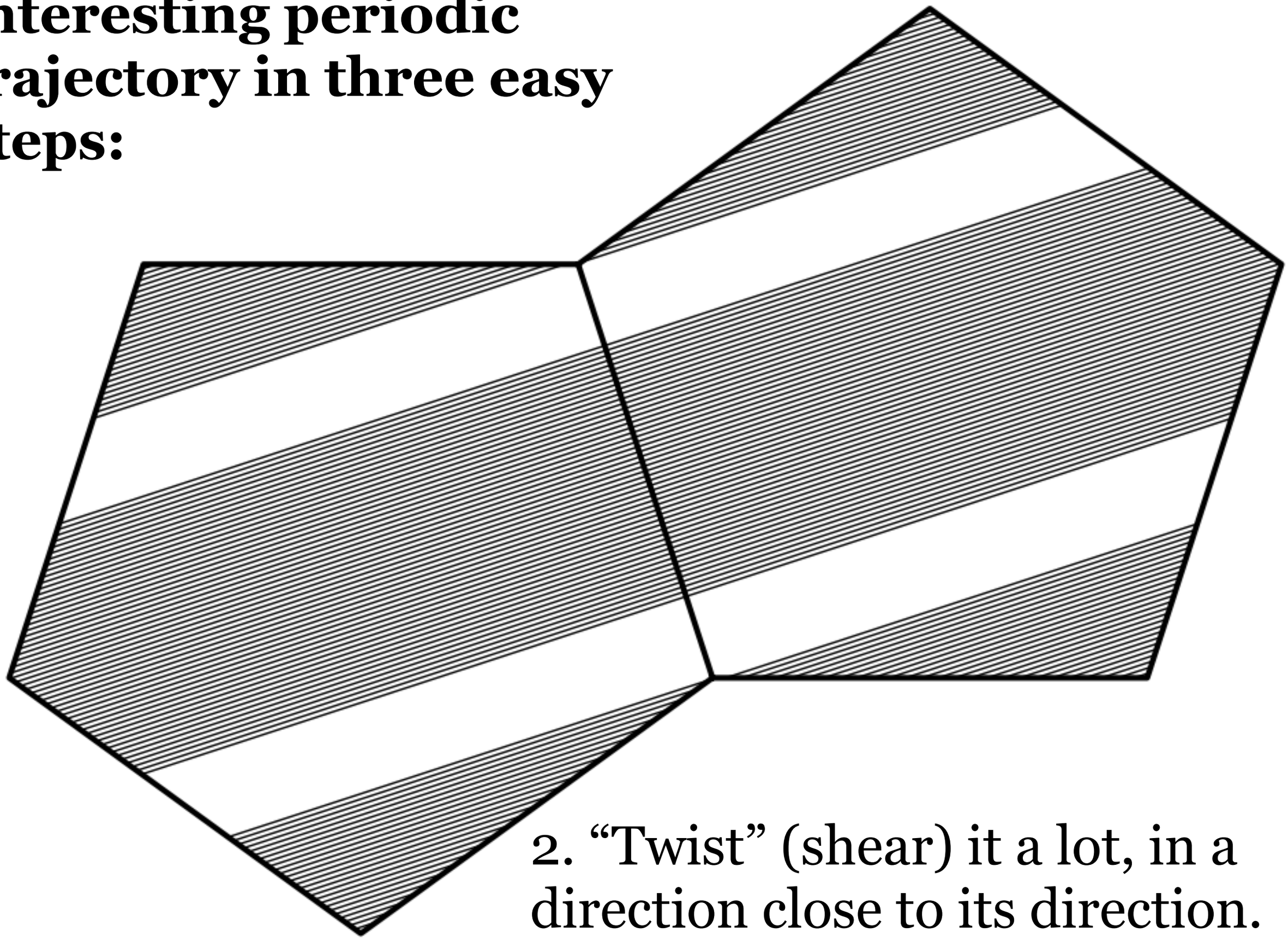

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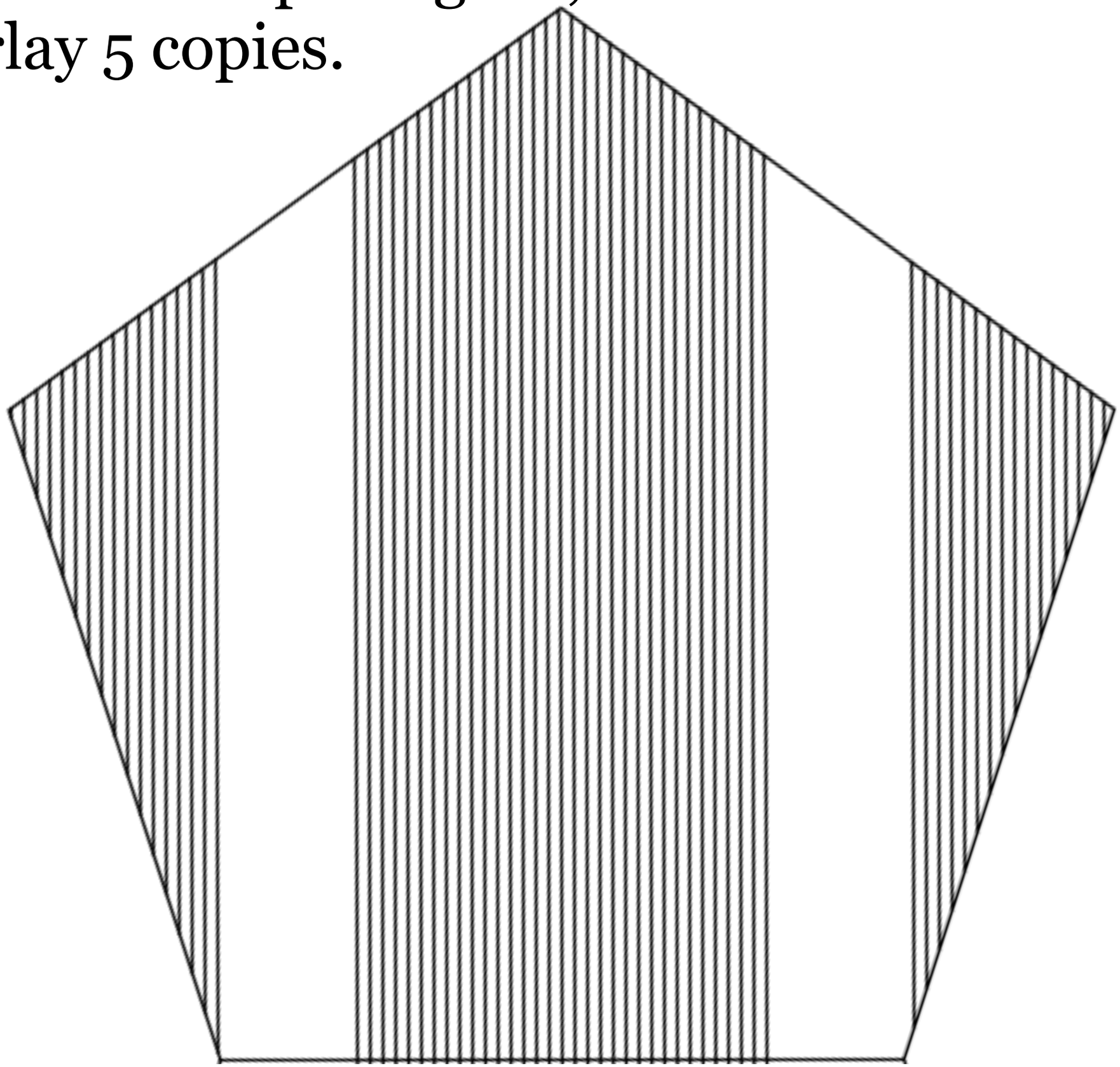
3. Take one of the pentagons,
and overlay 5 copies.



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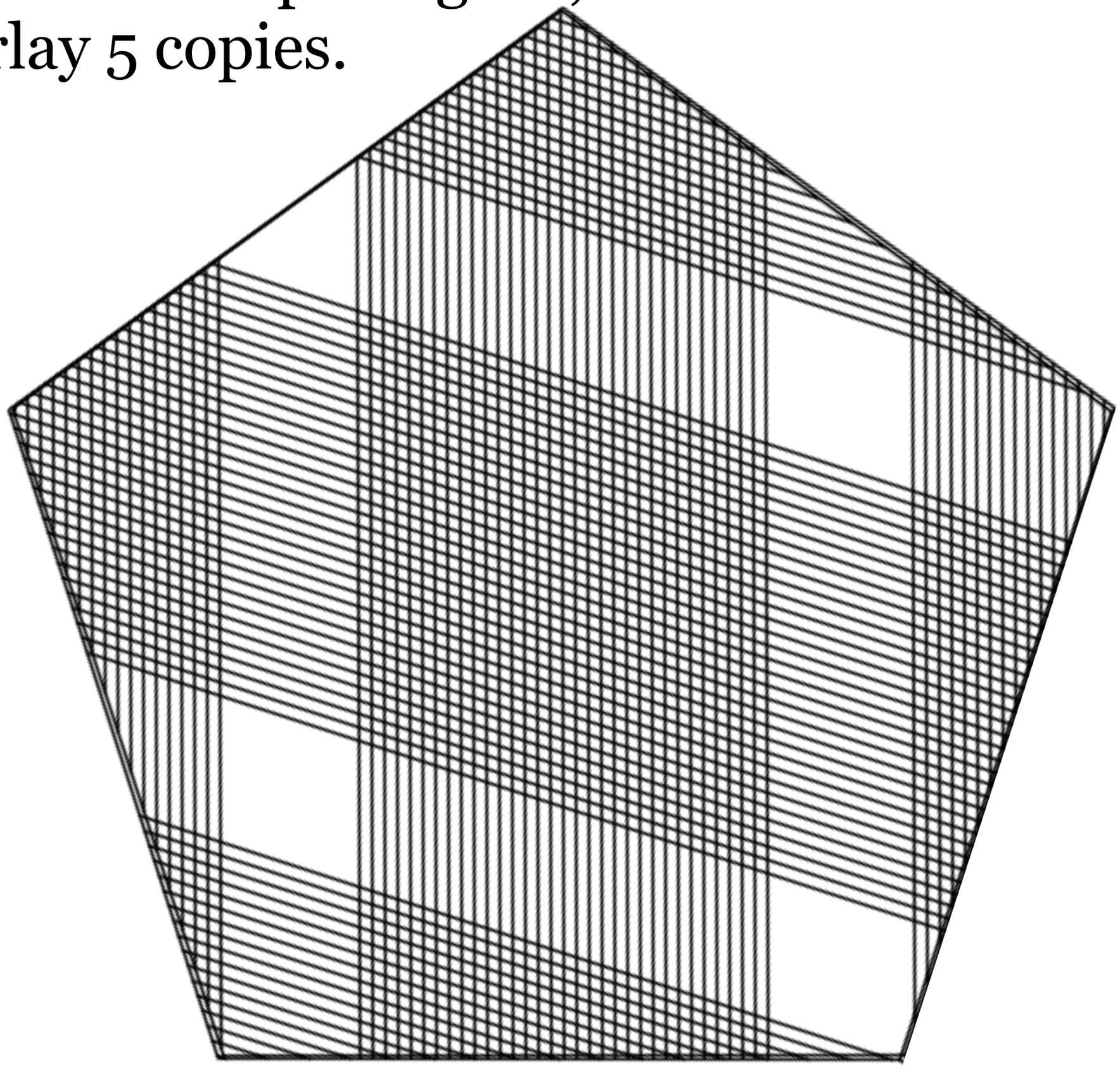

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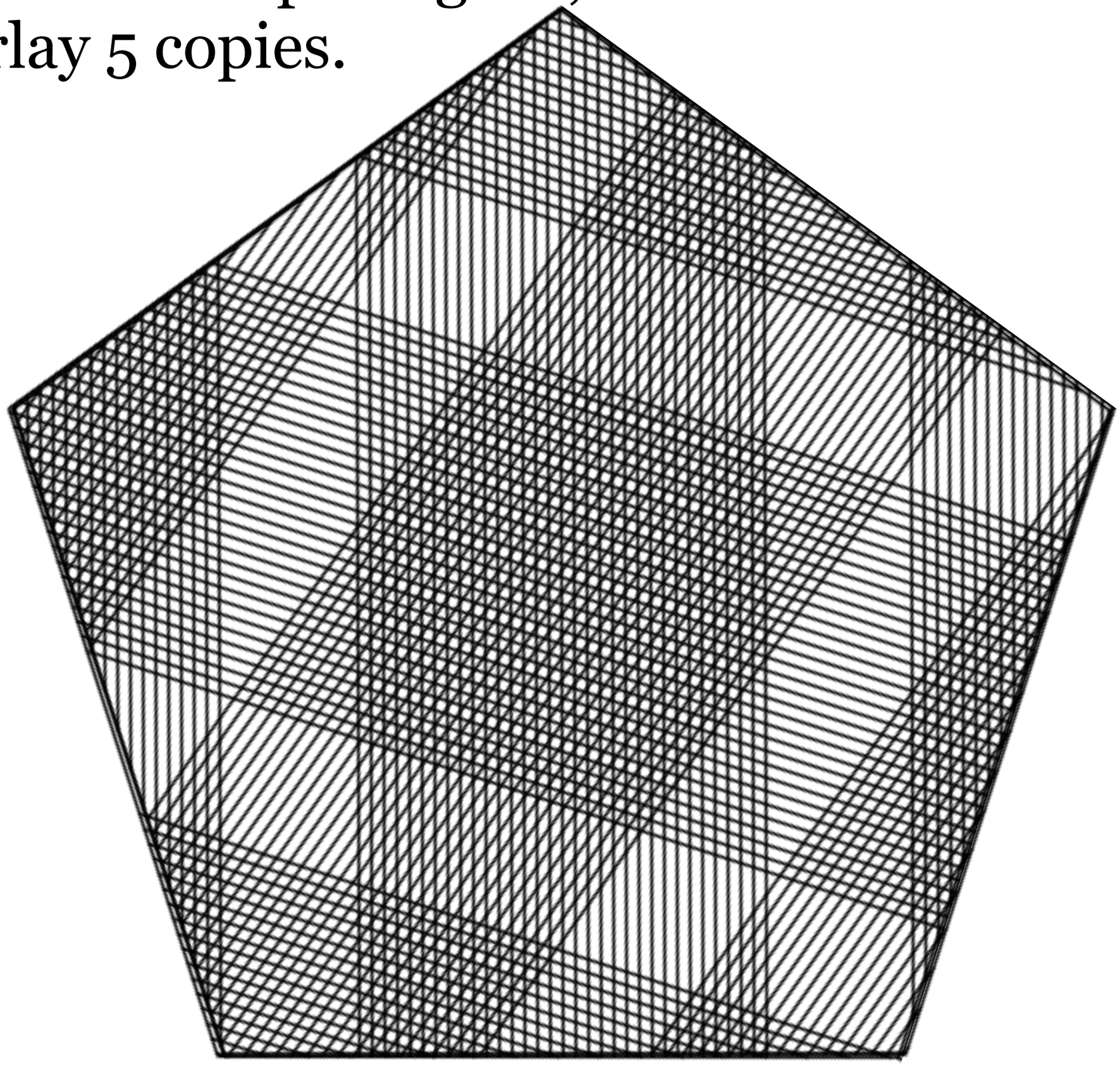

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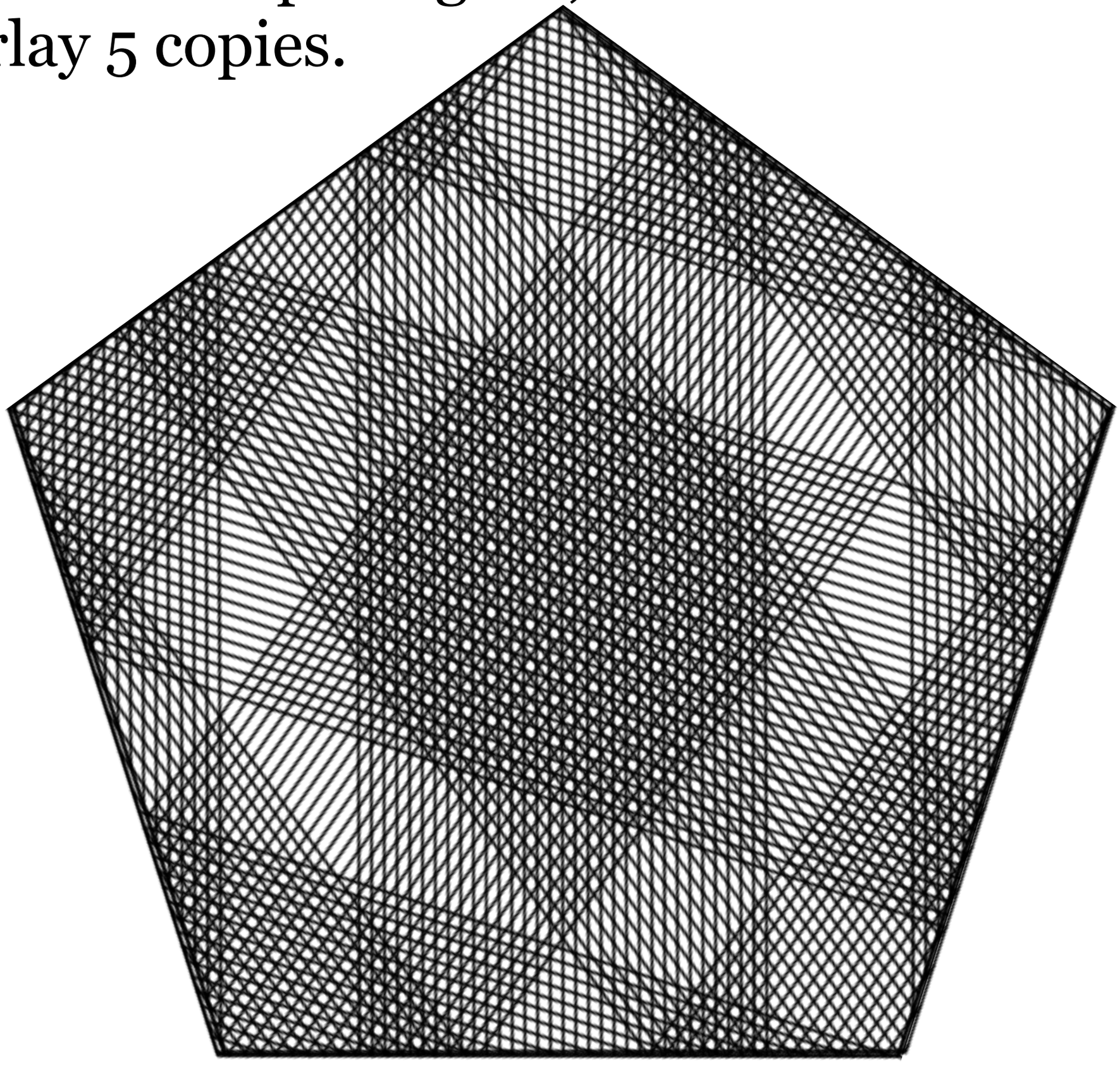
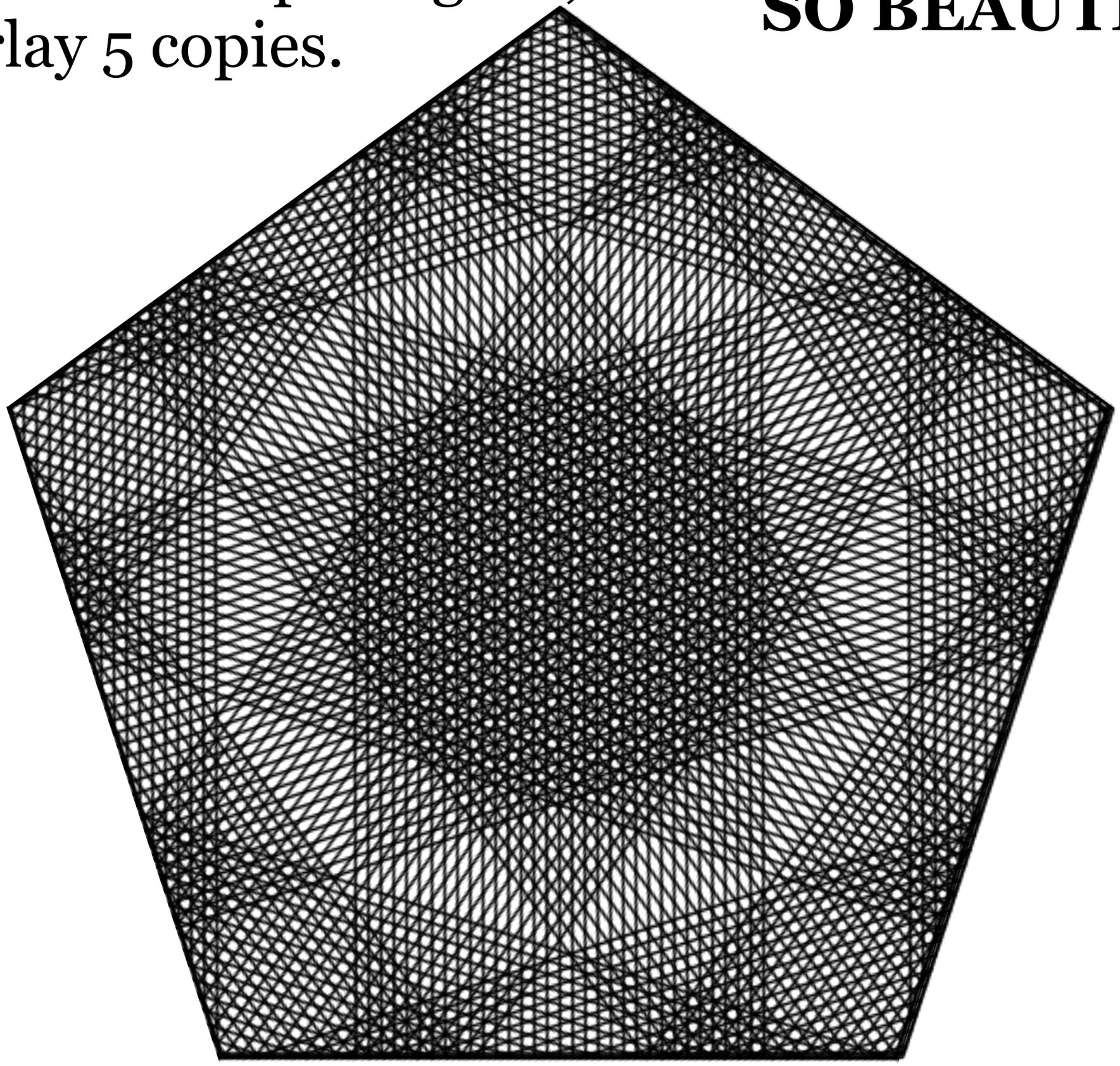
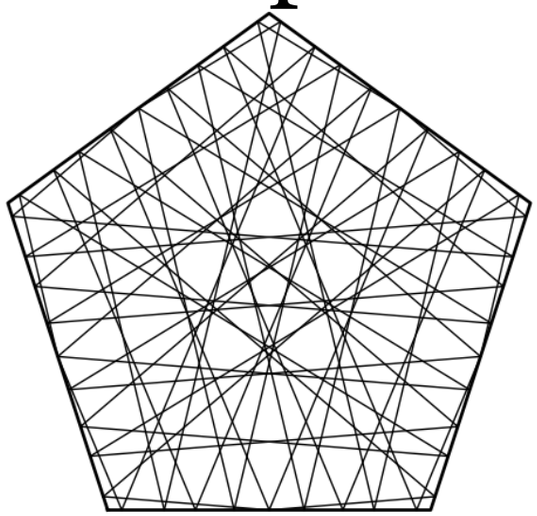


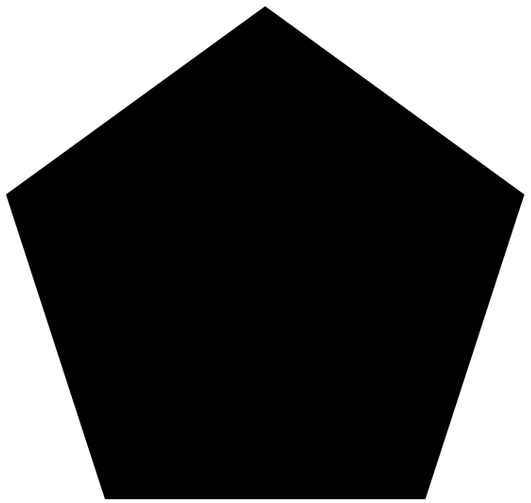
3. Take one of the pentagons, and overlay 5 copies.

SO BEAUTIFUL!



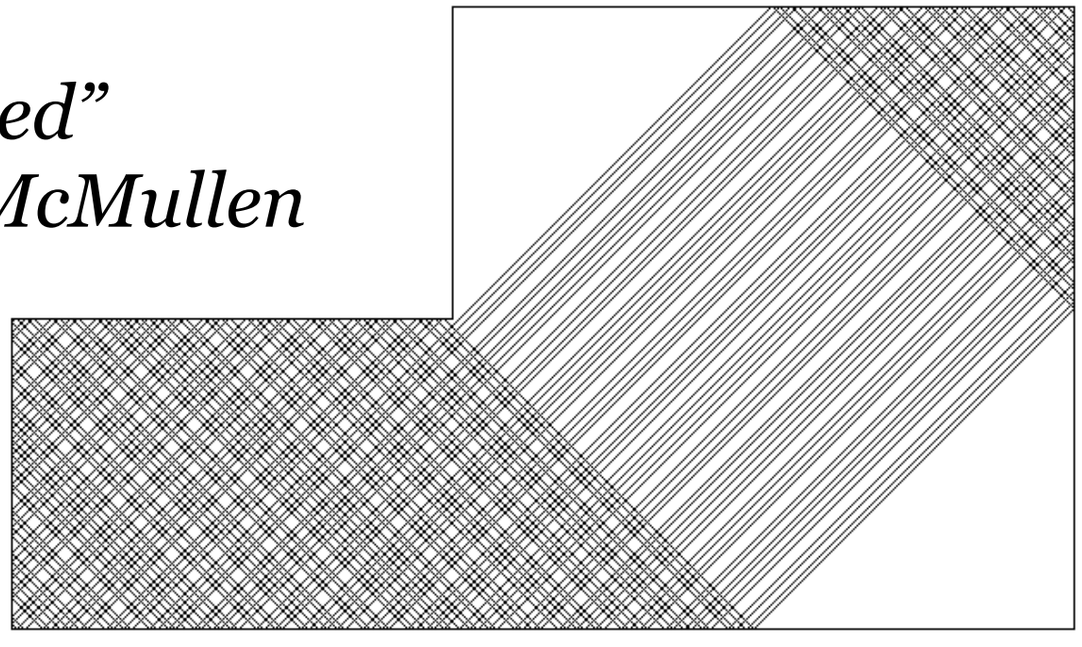
Regular polygons exhibit **optimal dynamics:**
Every path is either periodic or equidistributed.





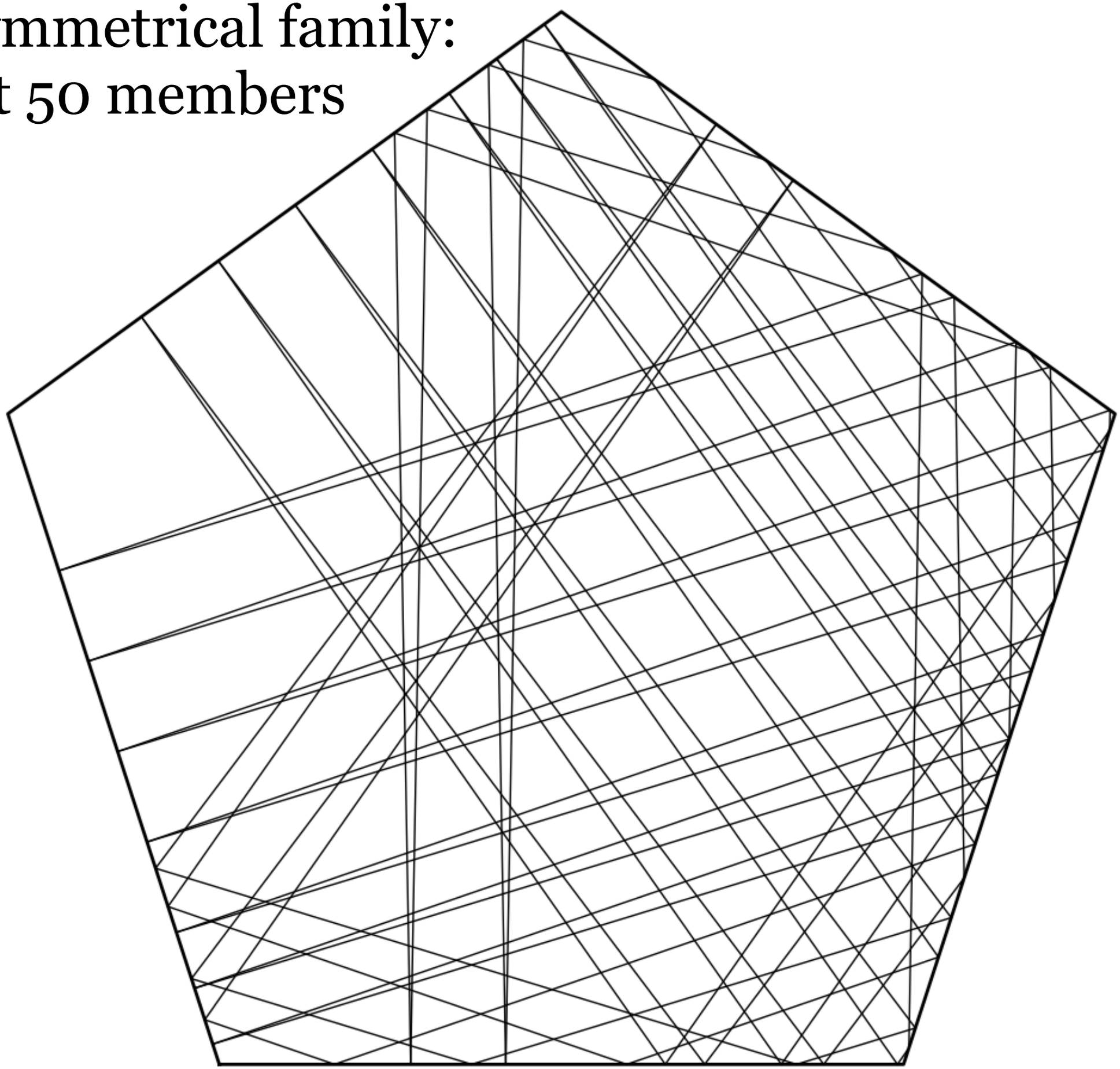
Other tables can have **non-optimal dynamics:**
For example, dense in one region, misses another.

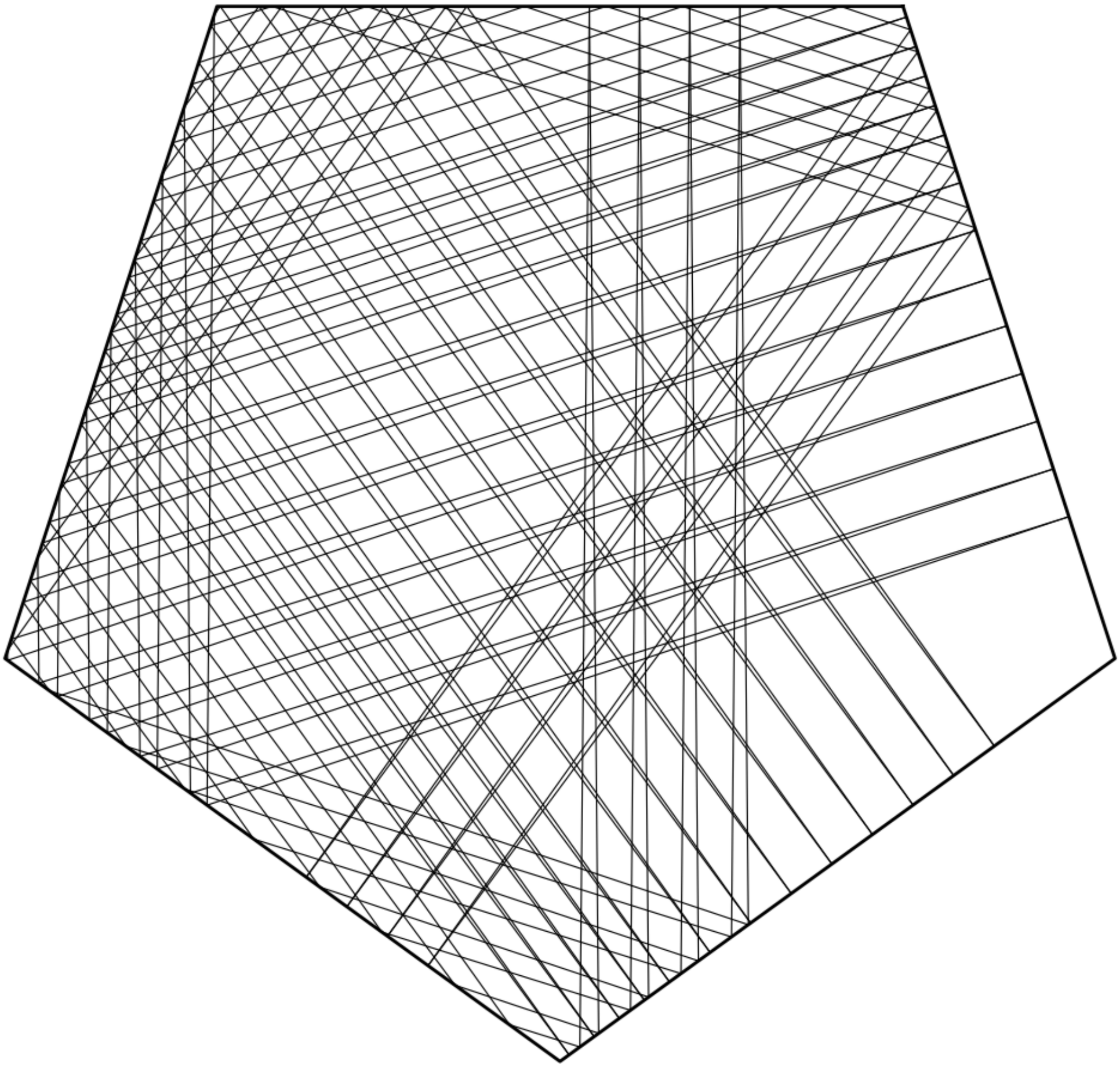
"Trapped"
by Curtis T. McMullen

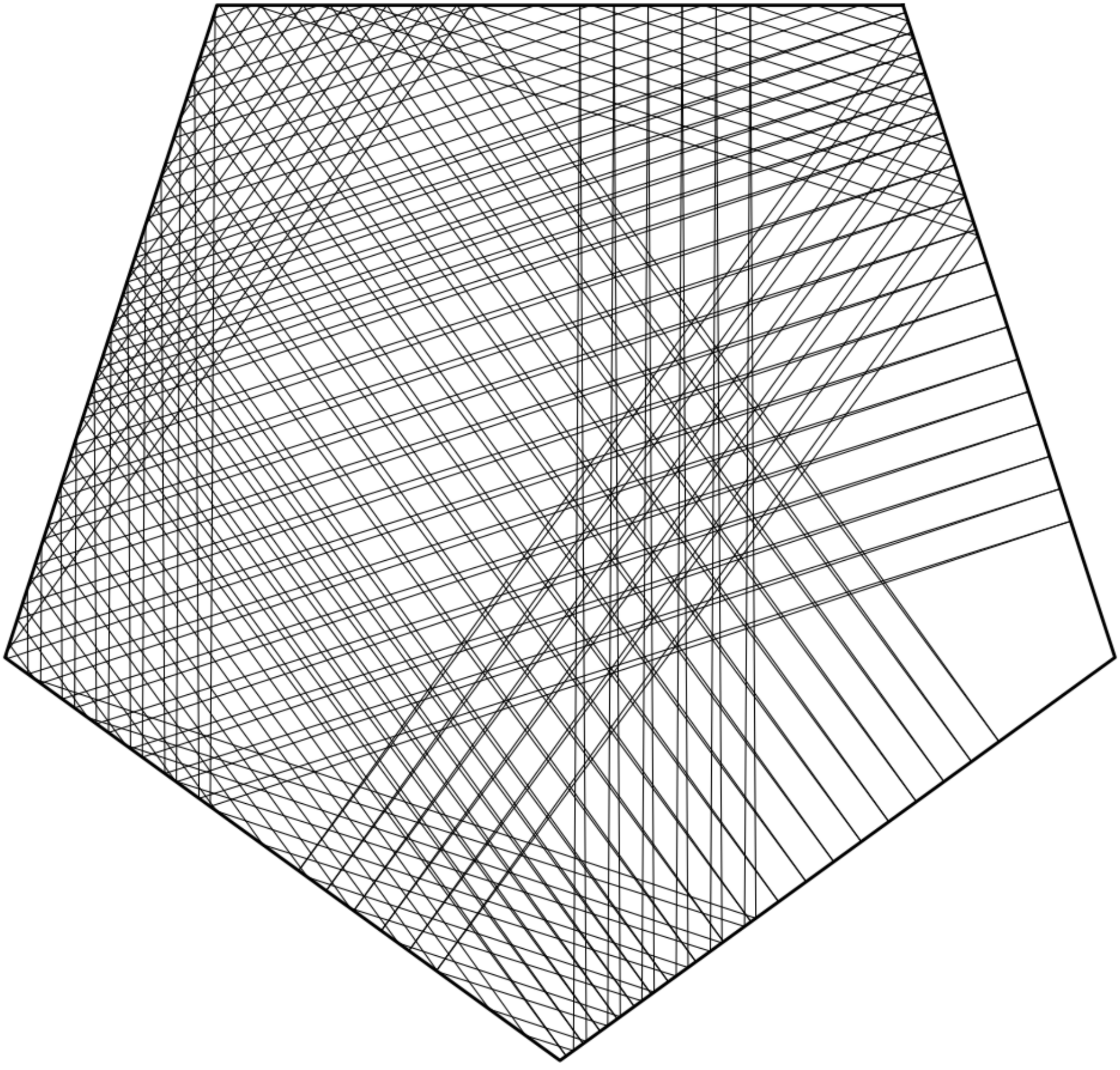


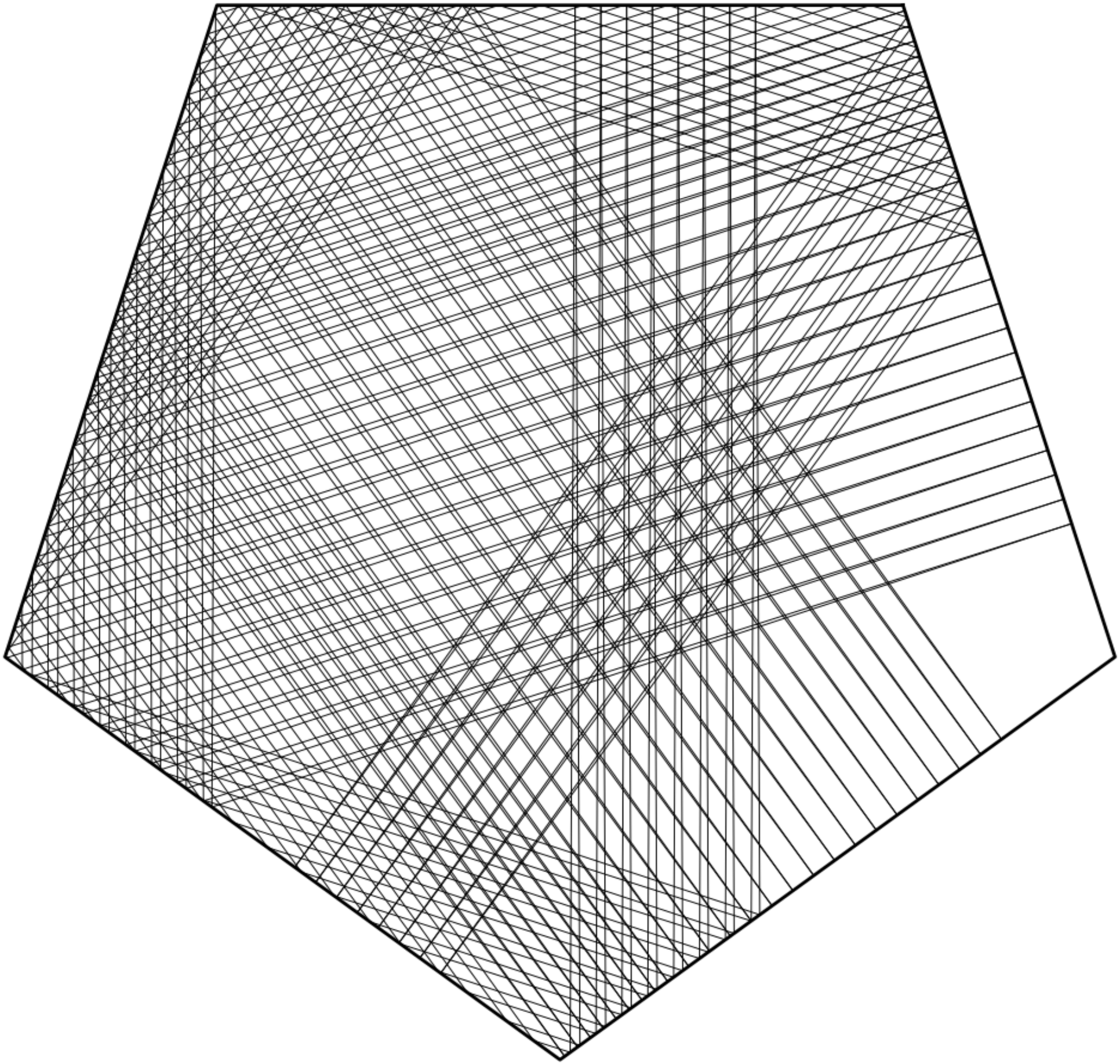
These long periodic trajectories simulate a violation.

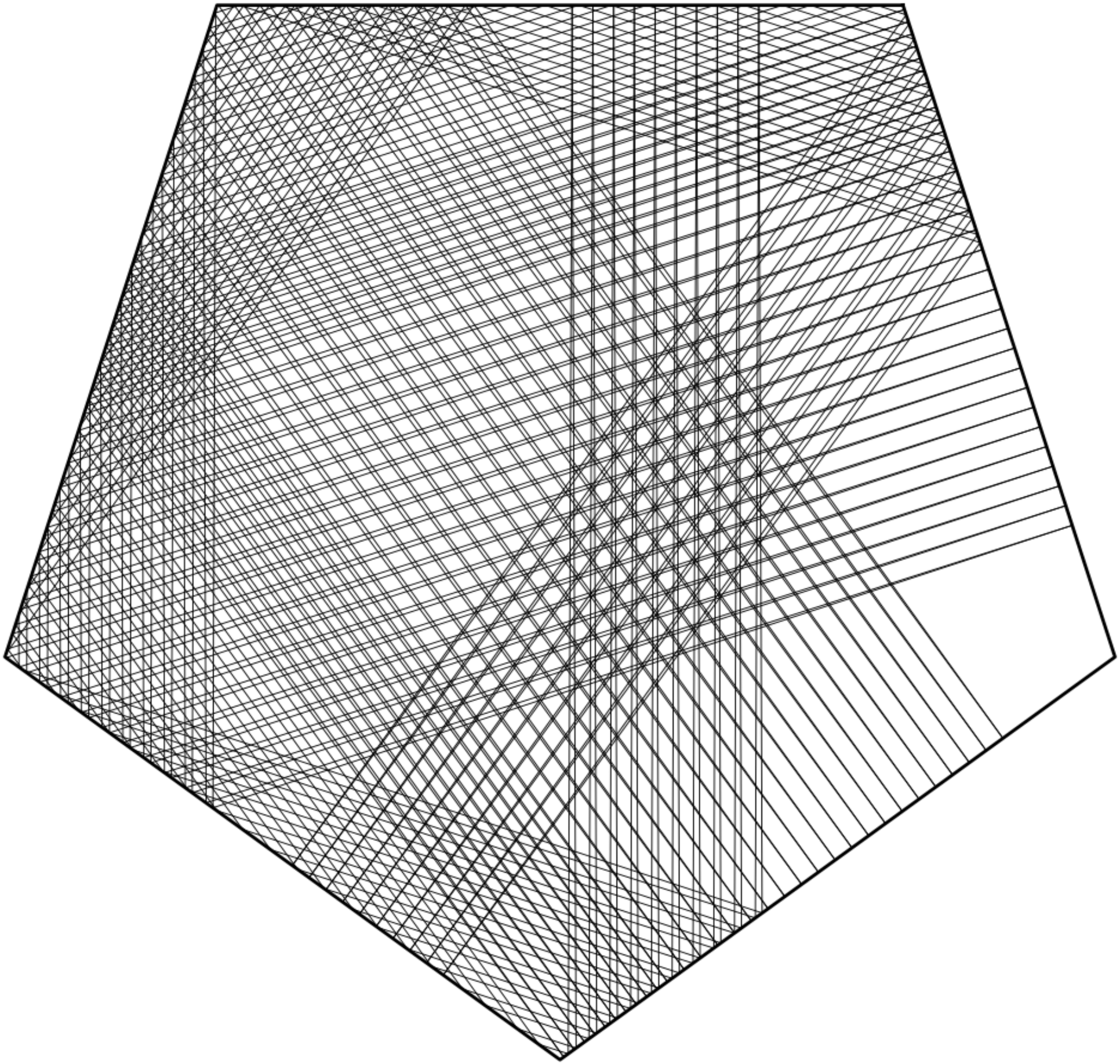
An asymmetrical family: its first 50 members

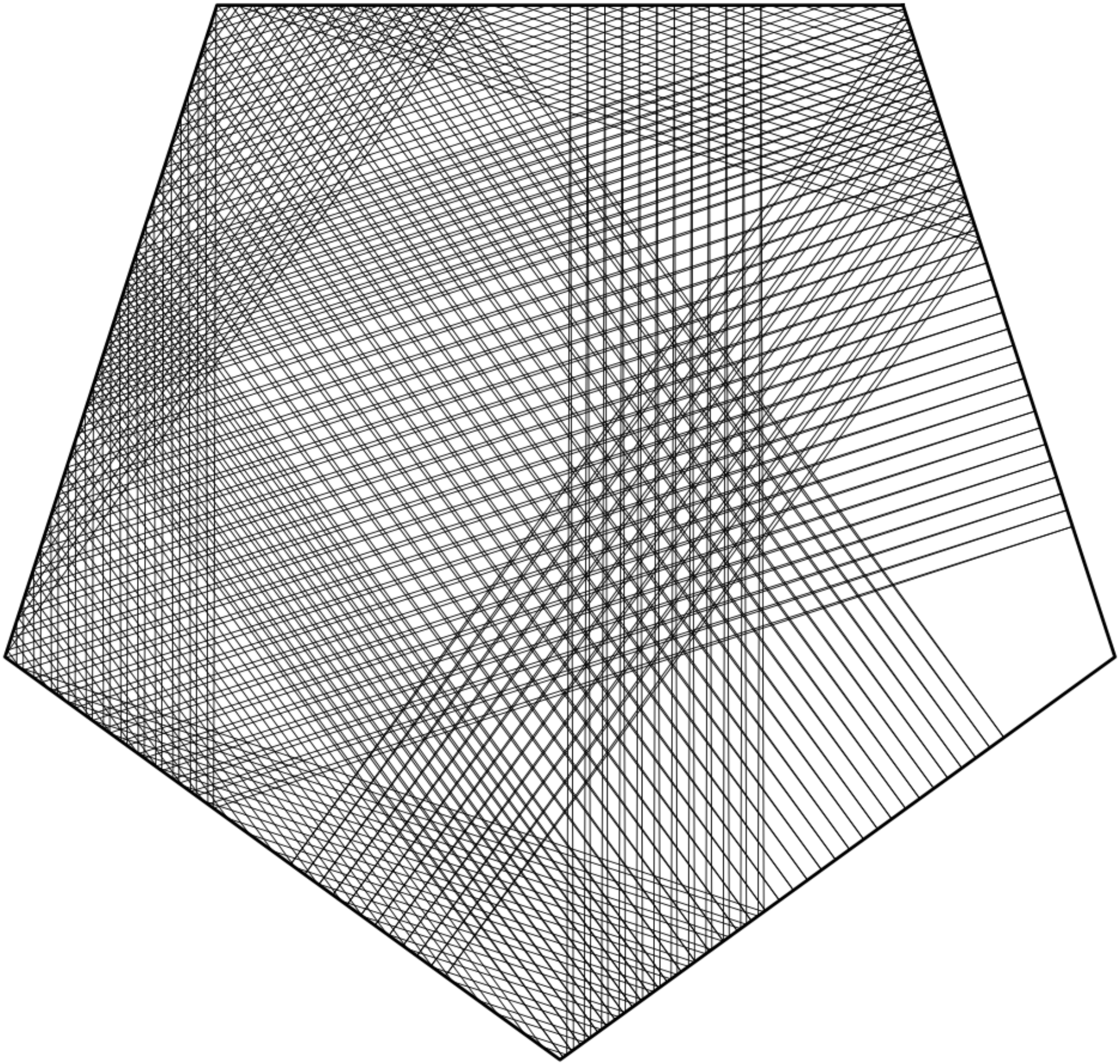


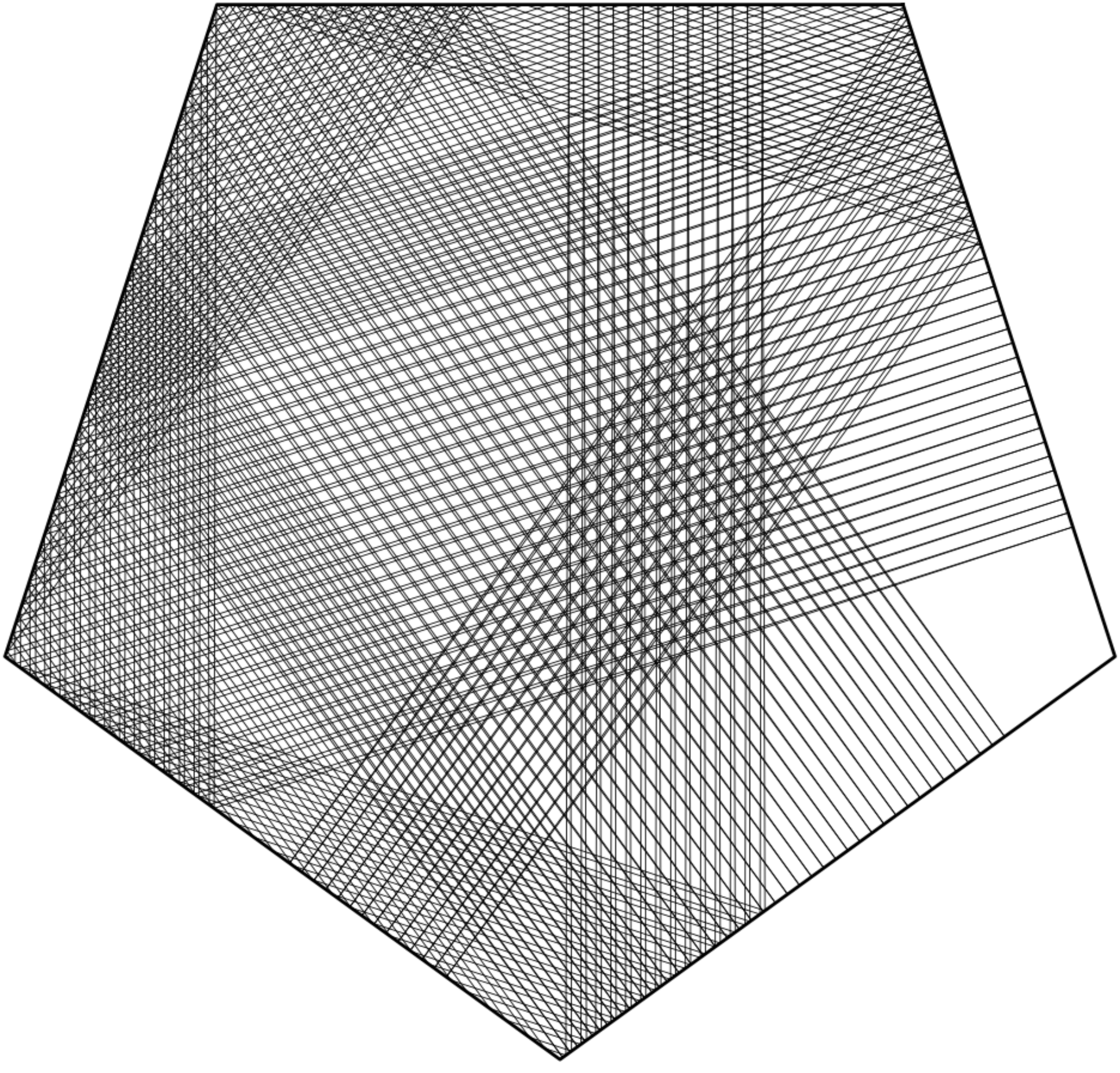


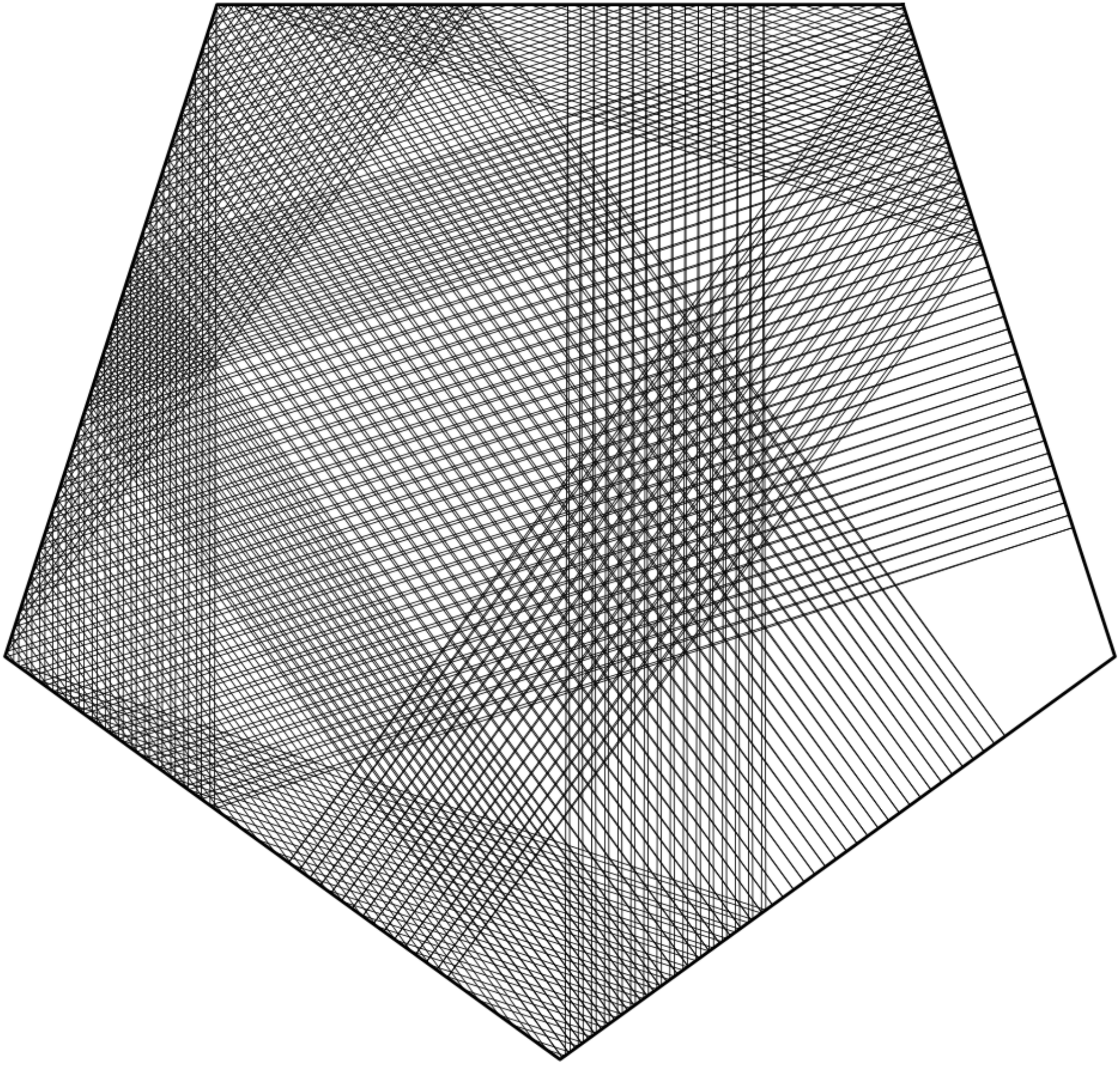


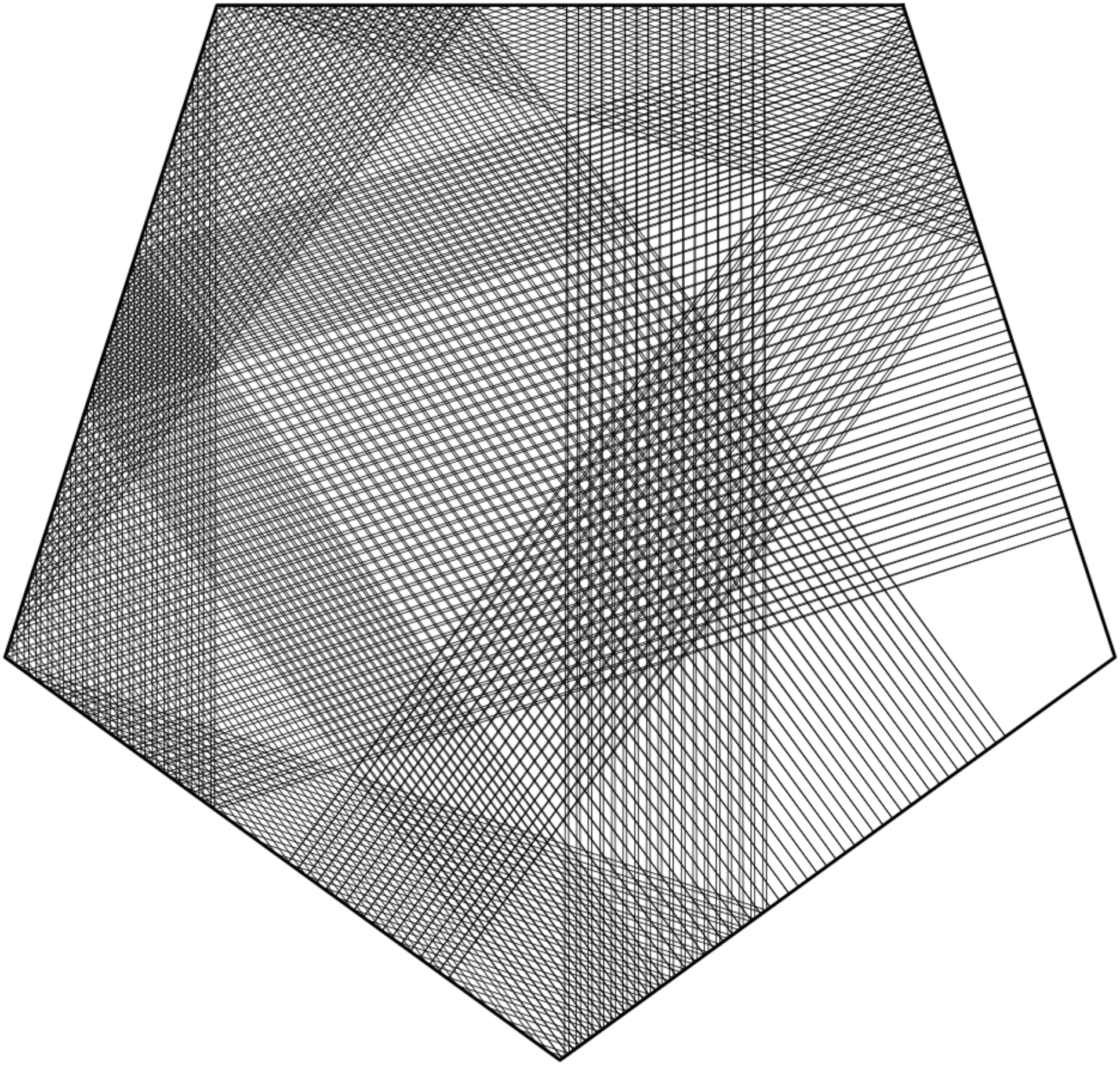


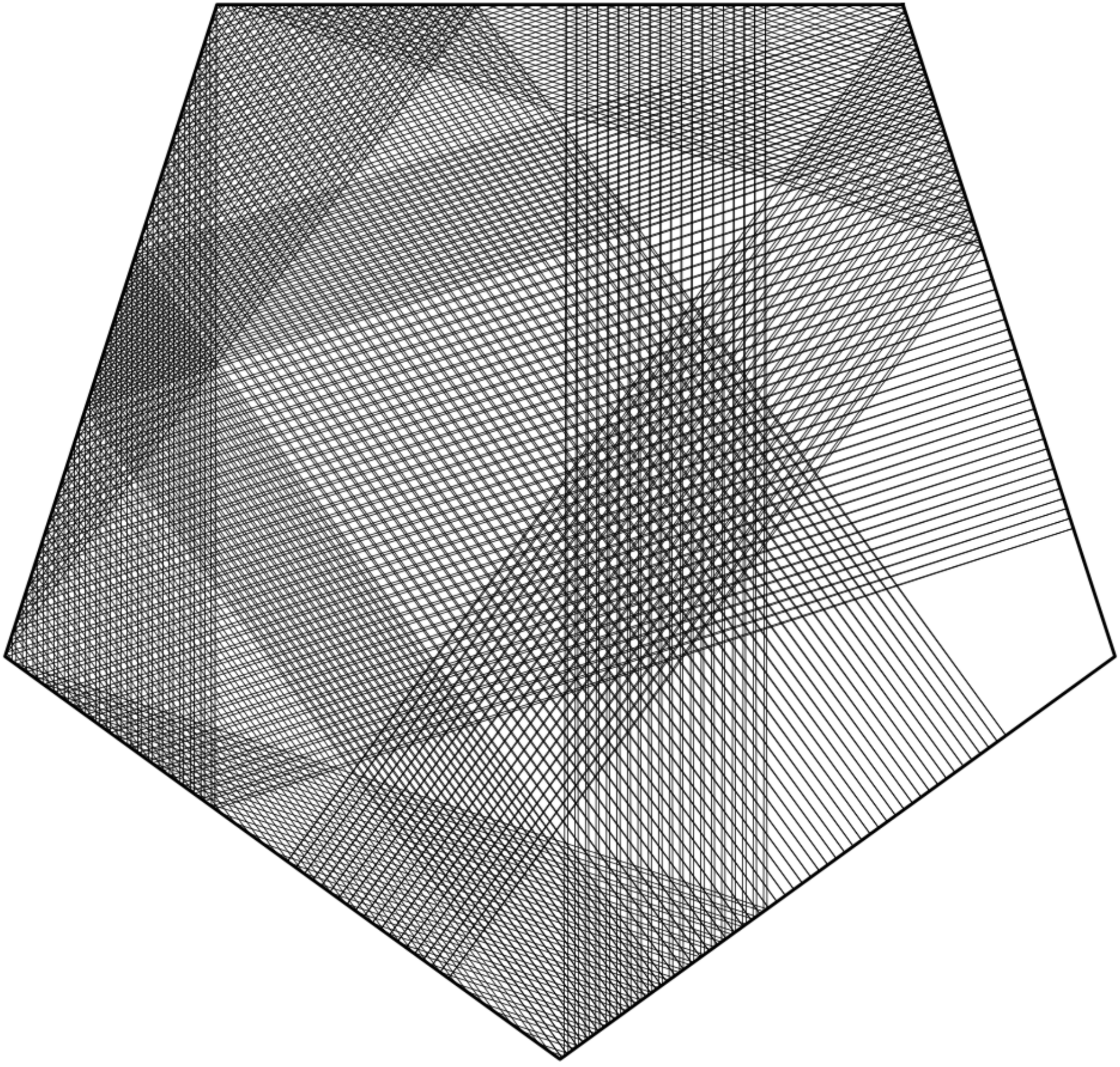


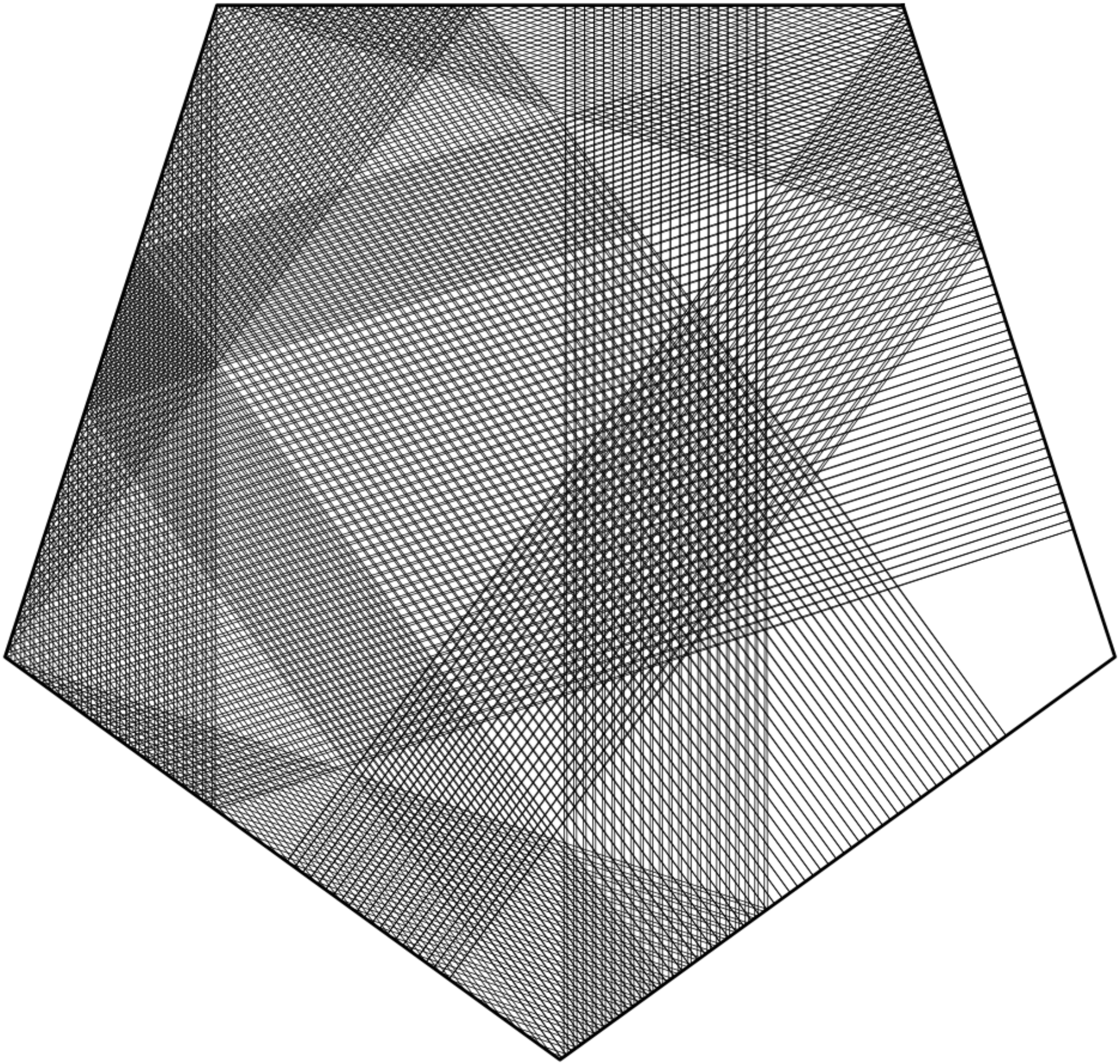


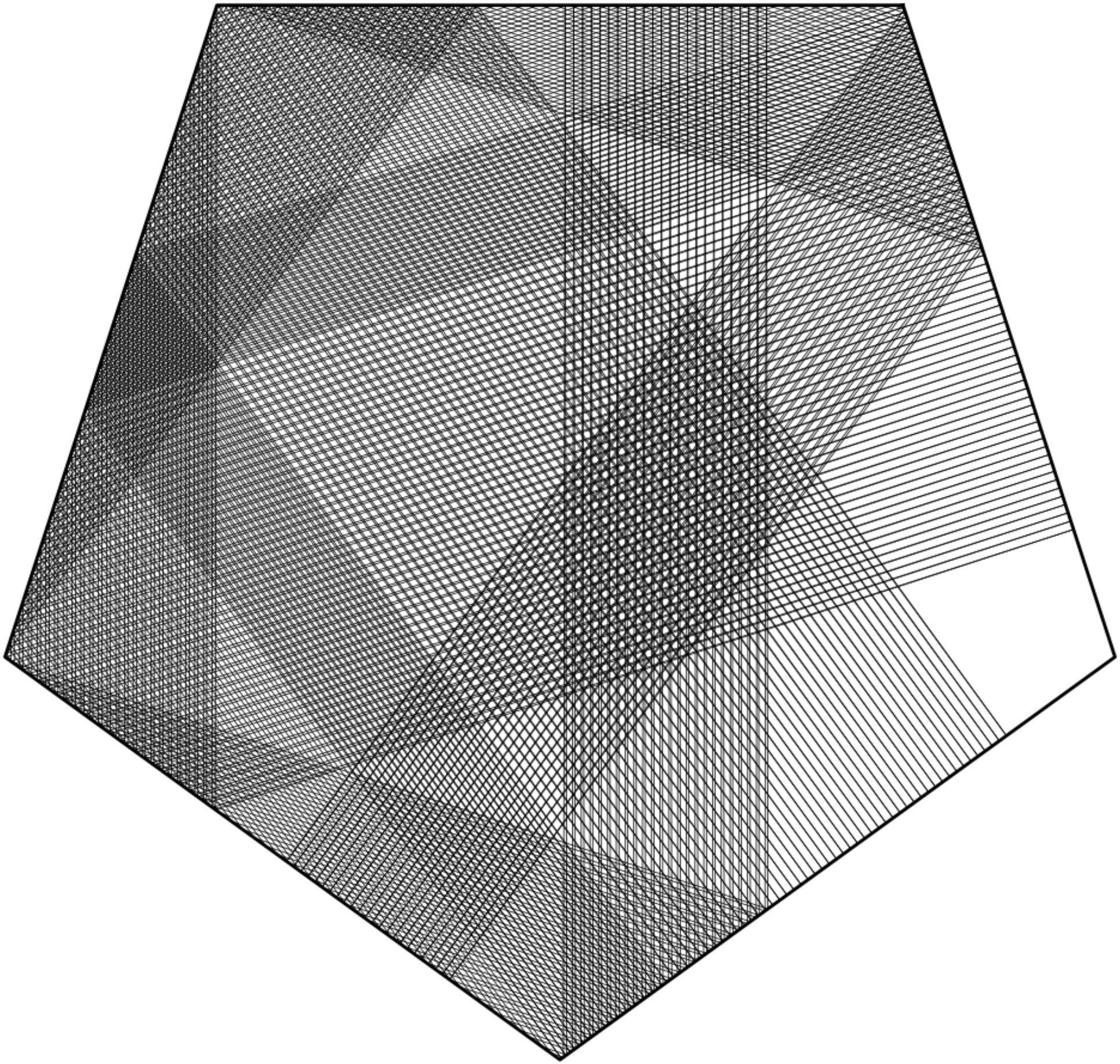


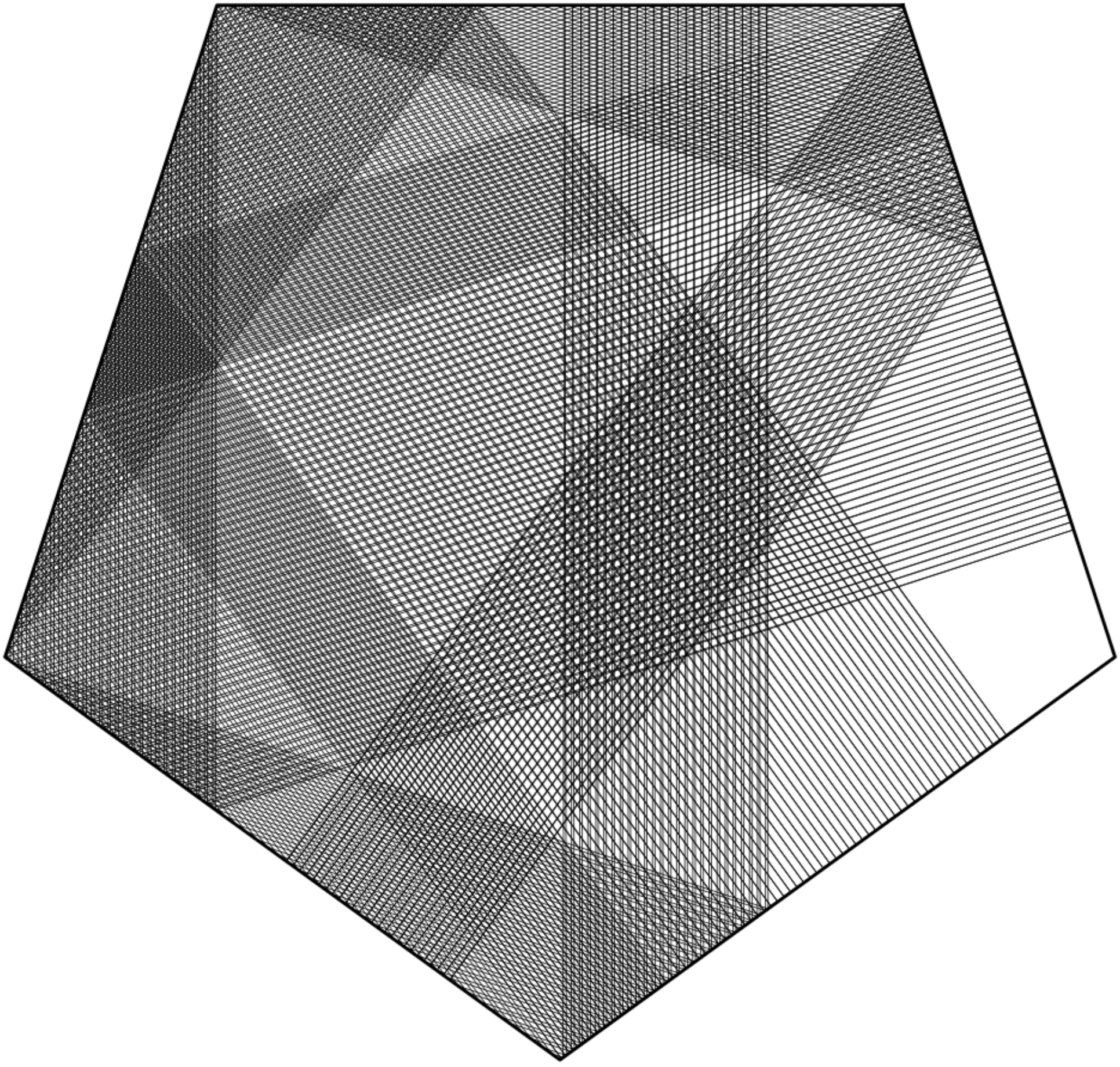


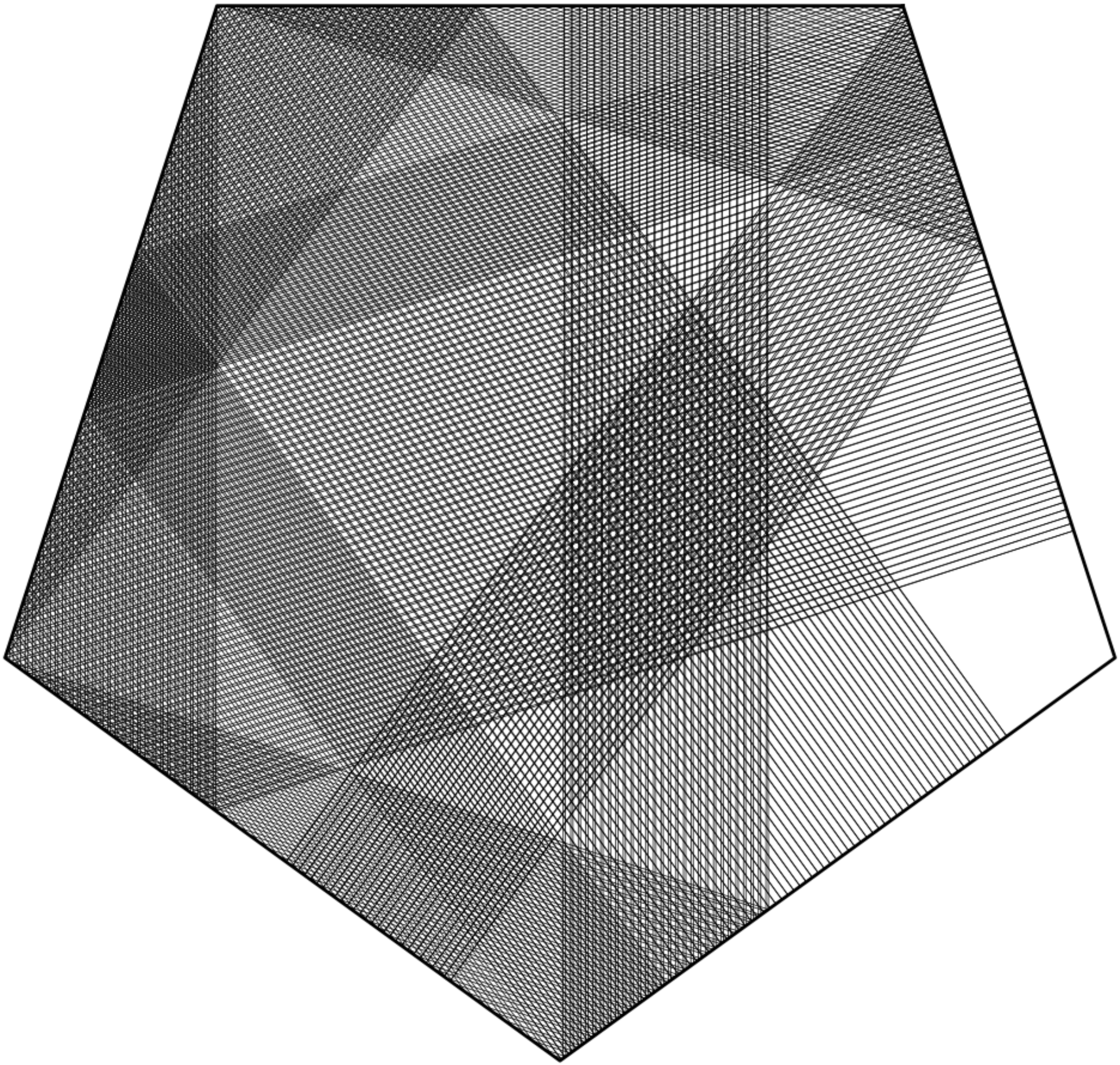


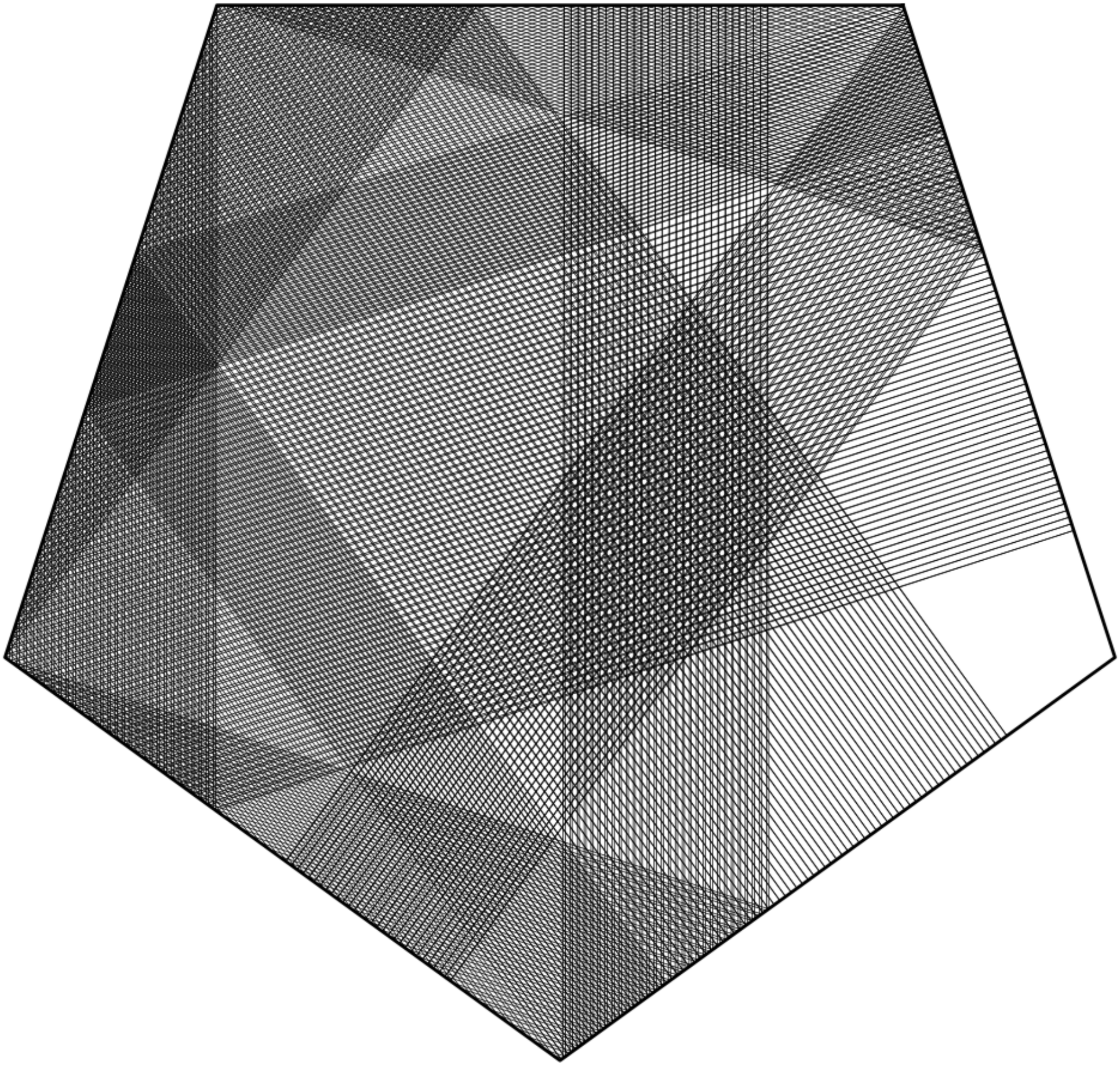


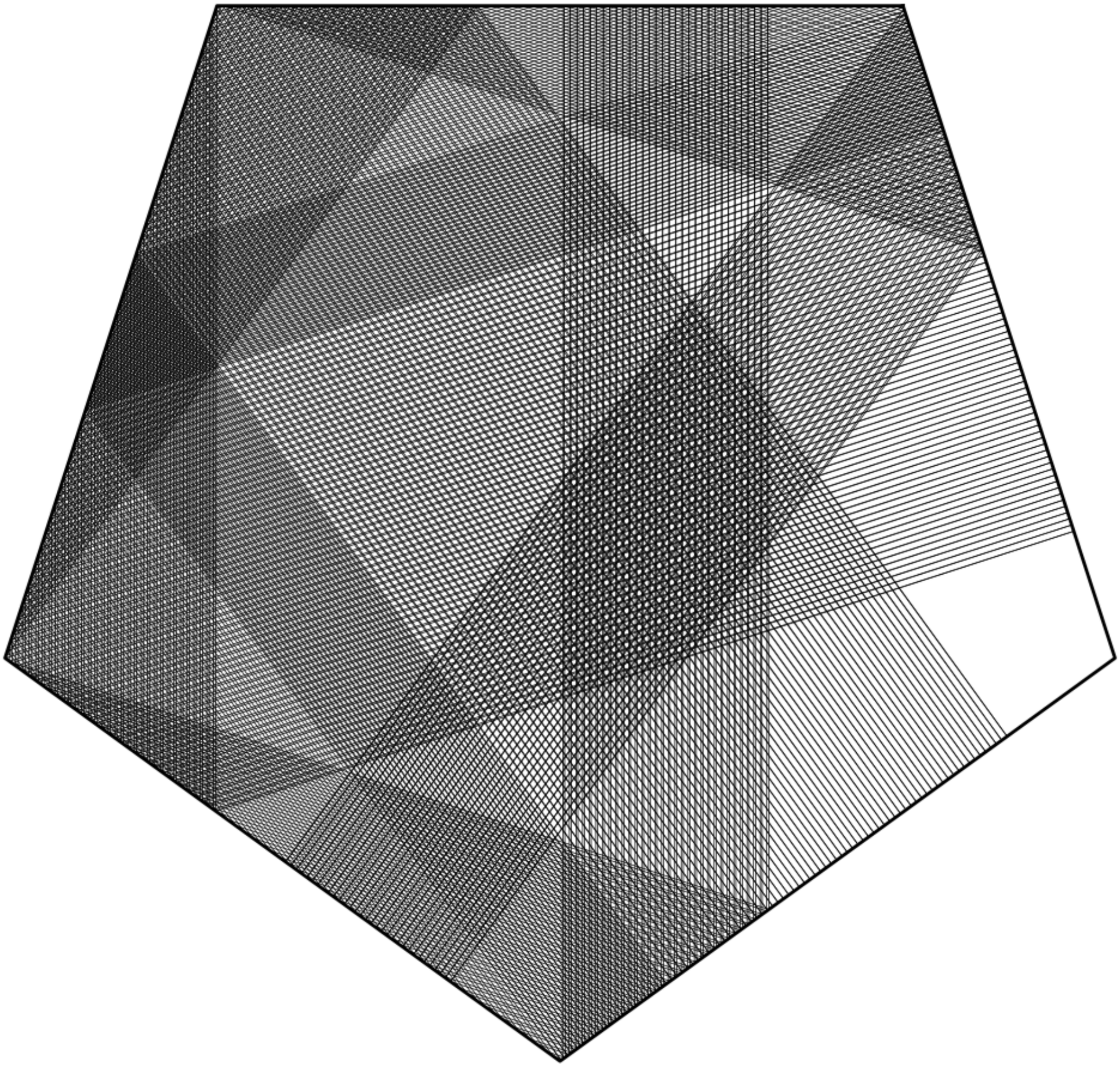


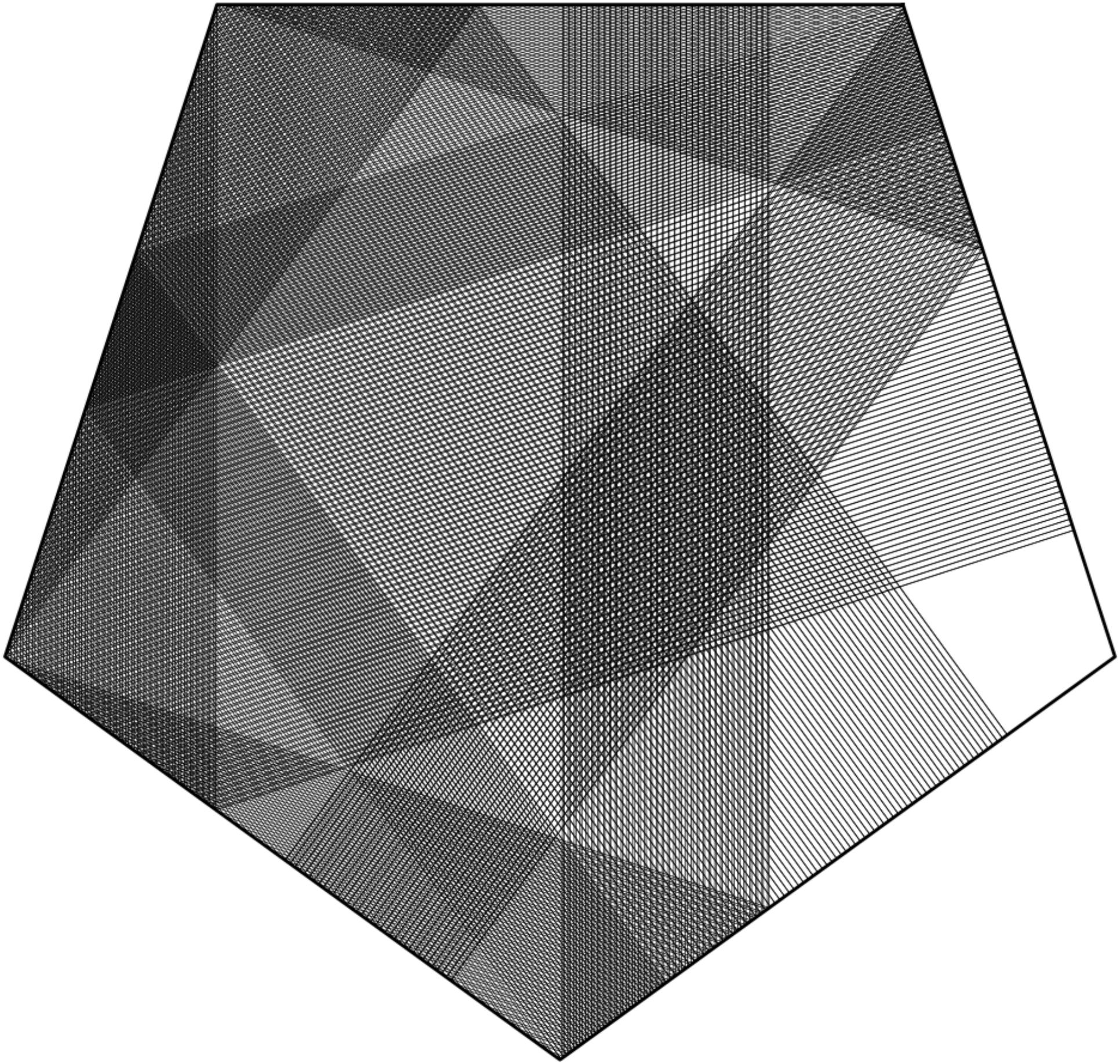


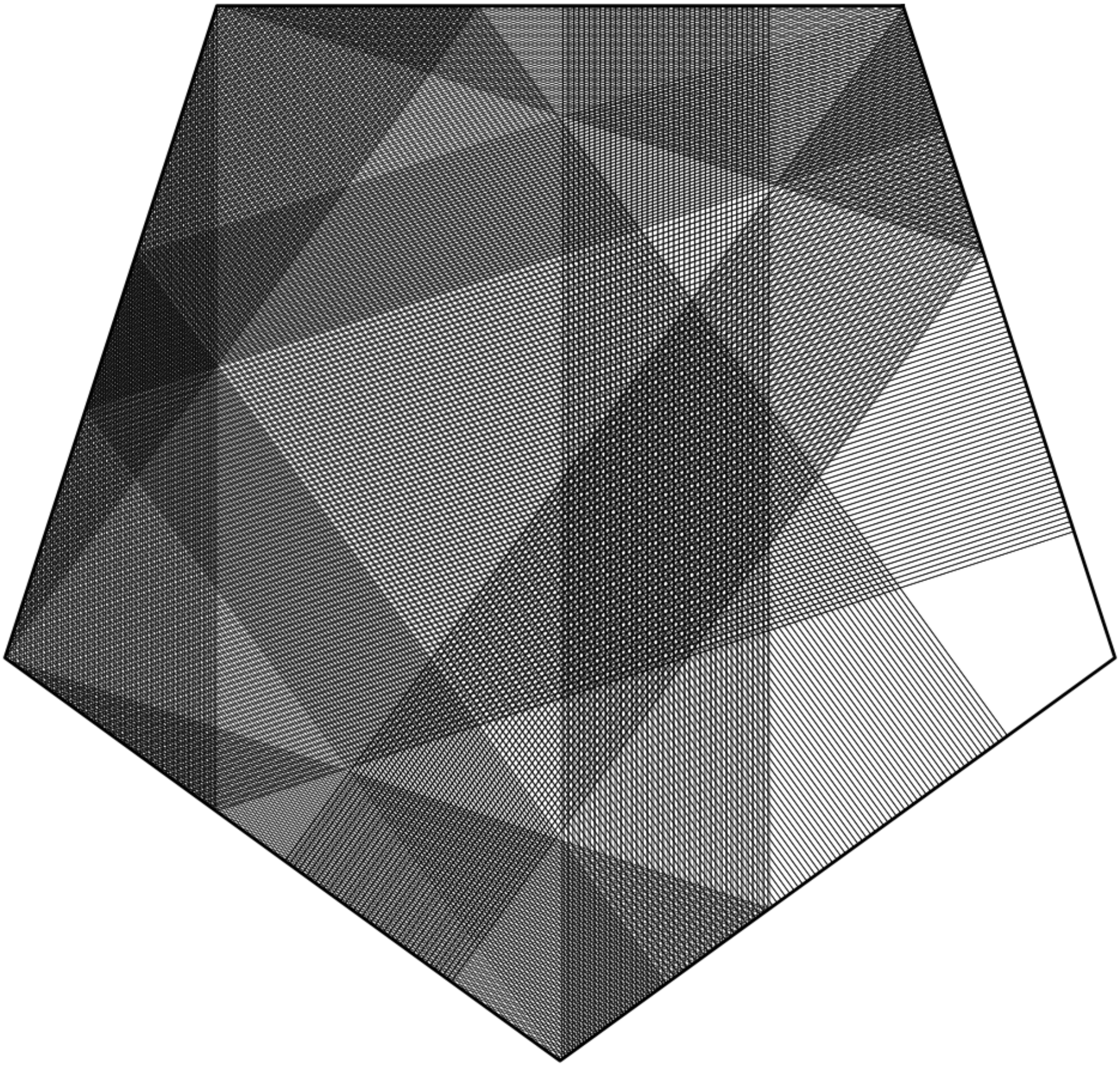


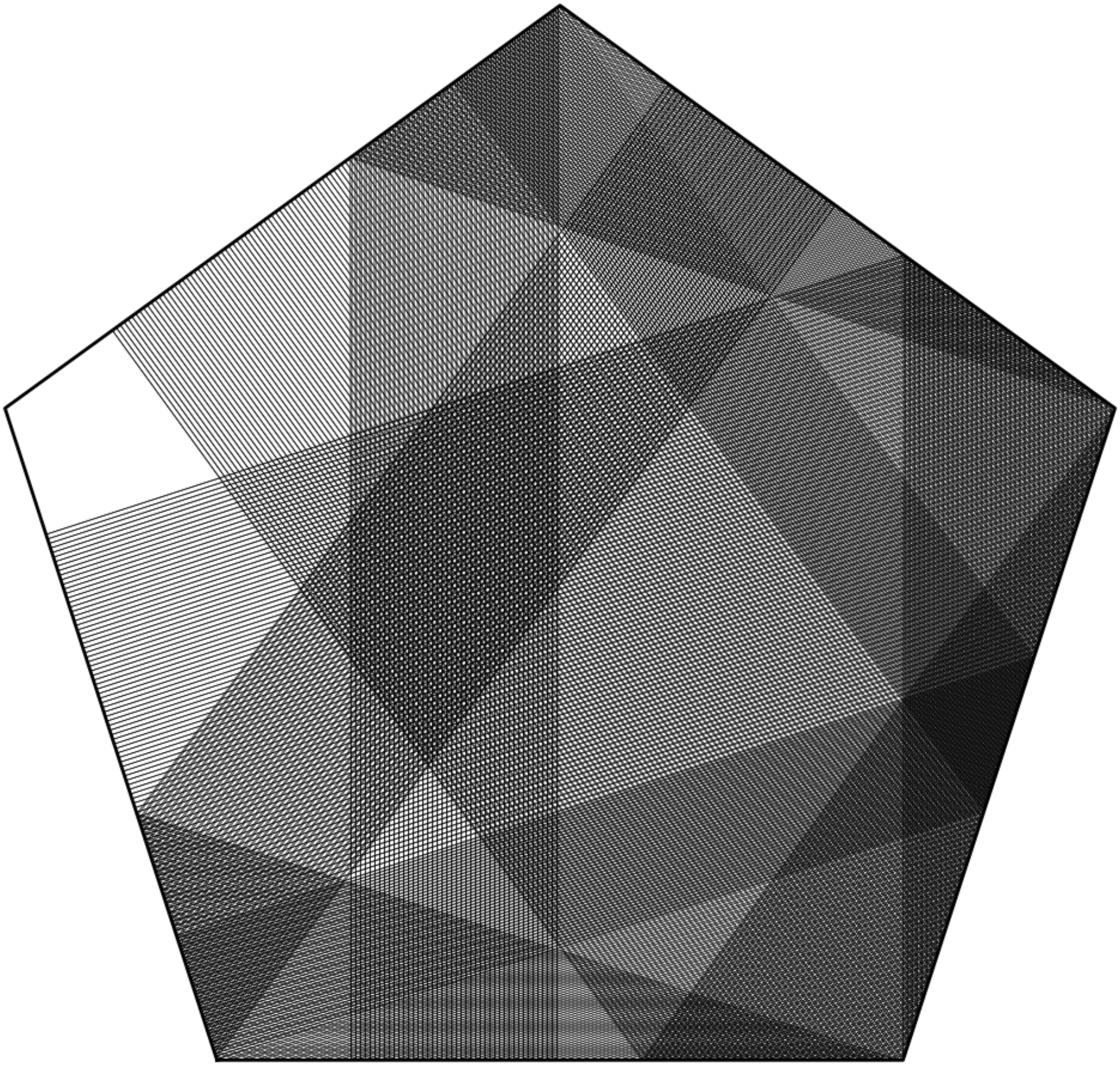


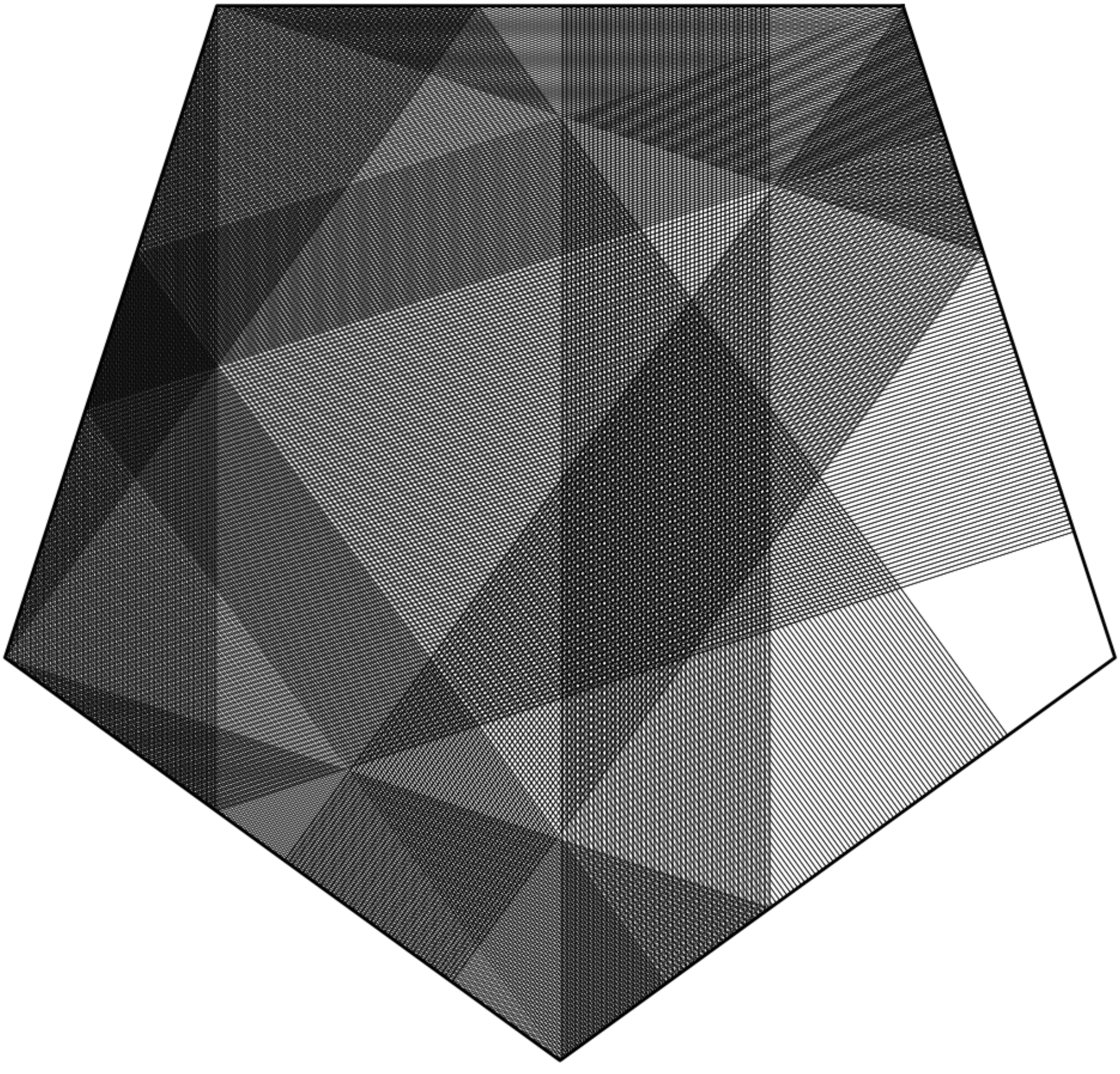






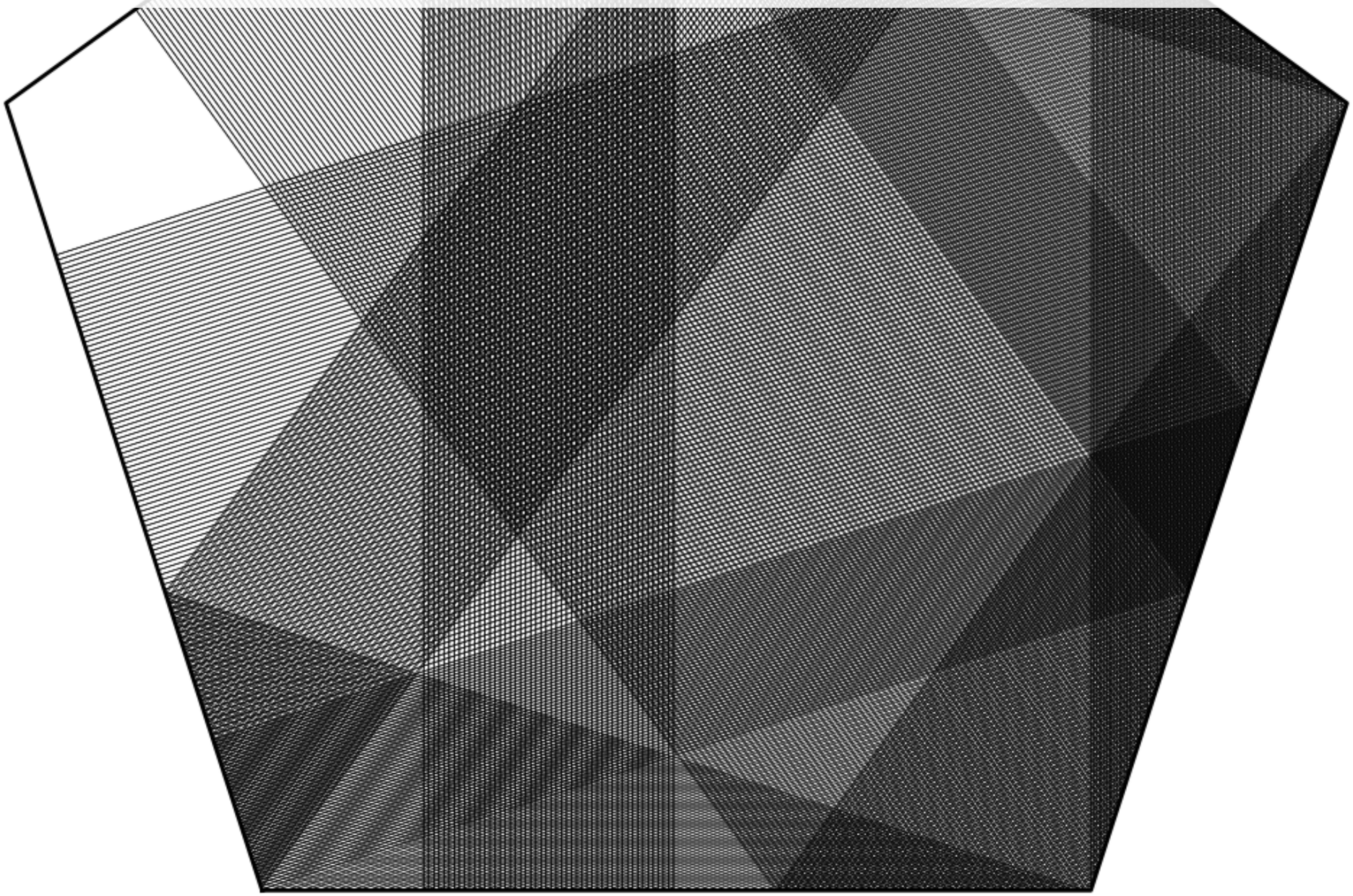






Question for this semester:

What is the mechanism — is there a similar method to“stamping around” that works for asymmetrical trajectories?



Question for this semester:
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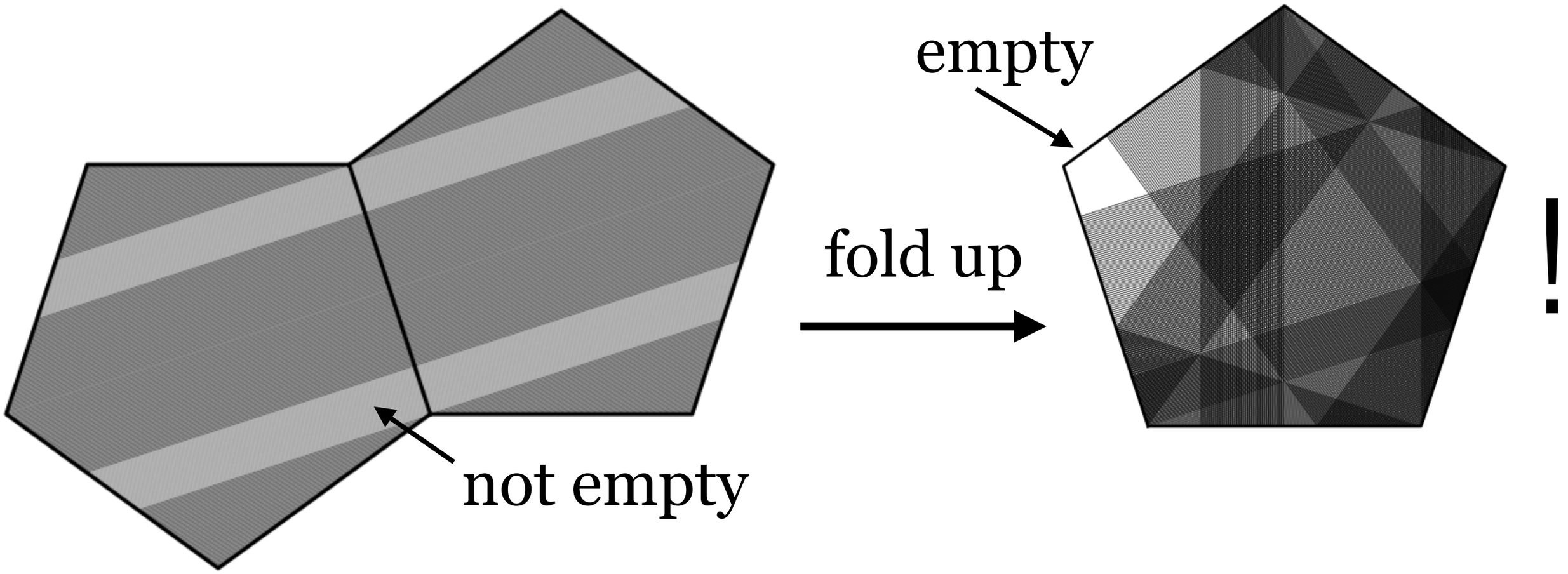
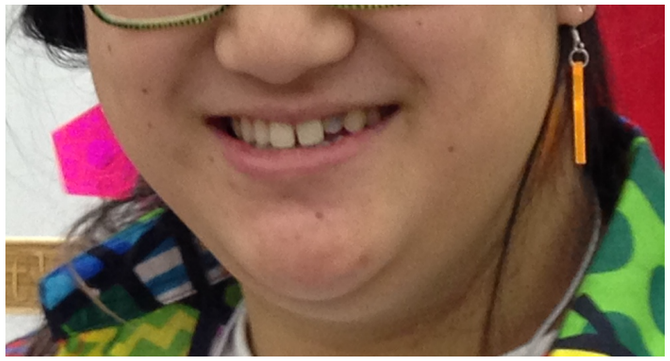


Question for this semester:

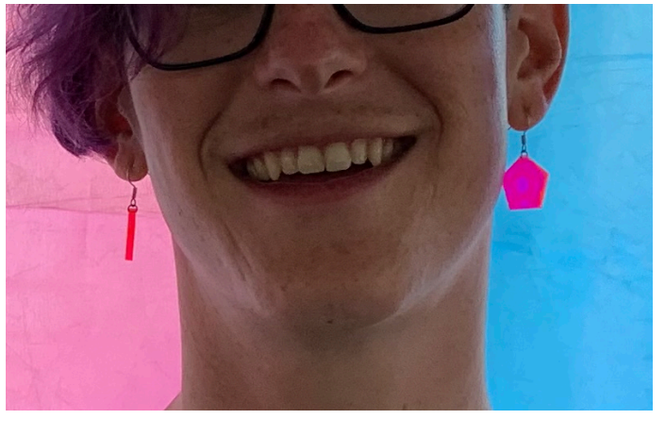
What kind of wicked awesome paraphernalia can we create, to get people excited about math?













Some visual interests in Number Theory and Arithmetic Geometry

Arthur Baragar

University of Nevada, Las Vegas

ICERM, September 6th, 2019

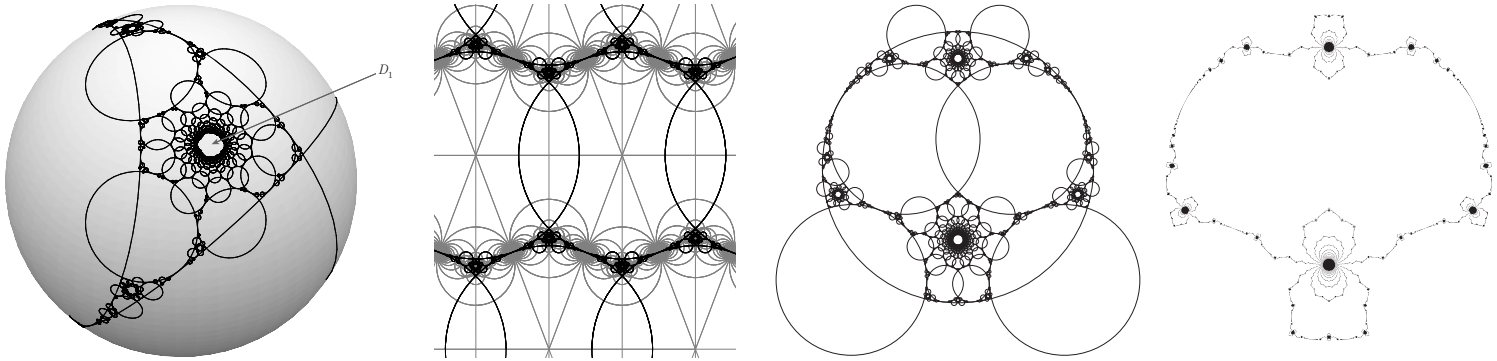
From [B., '94, '96]: The number of positive integer solutions to the Markoff-Hurwitz equation

$$w^2 + x^2 + y^2 + z^2 = 4wxyz$$

that are bounded by B is $\log(B)^{\beta+o(1)}$, where $2.43 < \beta < 2.48$.

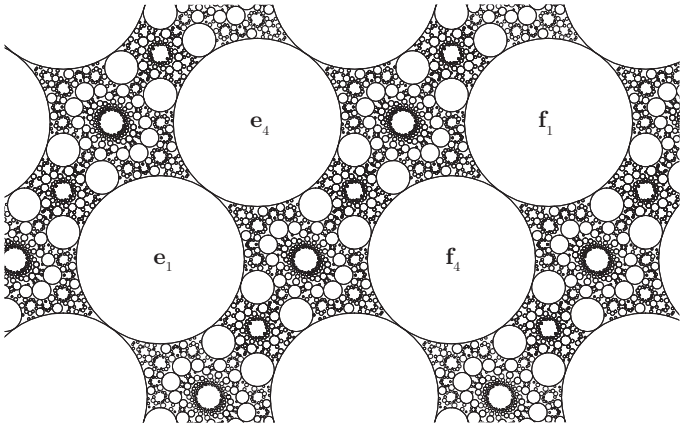
β looks like a fractal dimension. Does it have a picture?

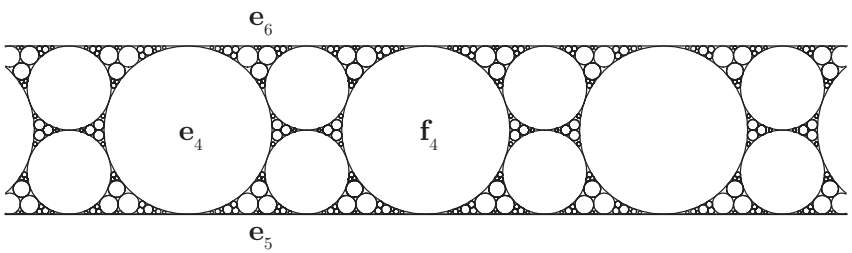
From [B., '11]: The ample cone for X in a particular class of K3 surfaces looks like:

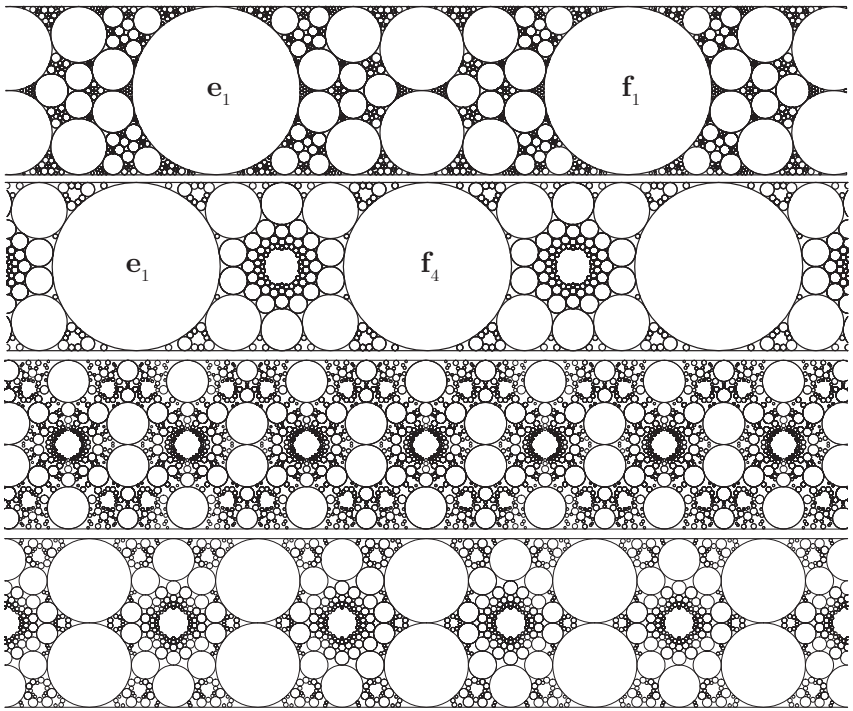


The residual set has dimension $\delta \approx 1.296$ (experimental). The number of smooth rational curves on X of degree bounded by B is $\sim cB^{\delta}$ (using recent work by Oh et al.).

In [B., '17 on ArXiv]: The Apollonian circle and sphere packings are ample cones for classes of K3 surfaces.
From [B., '18]: Contrary to popular belief, Apollonian packings exist in dimensions 4, 5 and 6. How do we 'see' them?







[B., '19?] The divisor class of a smooth rational curve on an Enriques surface X represents a plane in $\mathbb{H}^9$, so represents a hypersphere in $\mathbb{R}^8$, thought of as the boundary of the Poincaré upper half space model of $\mathbb{H}^9$. The set of all smooth rational curves on X gives a configuration of spheres in $\mathbb{R}^8$. If X is a generic nodal Enriques surface, then that configuration is an Apollonian packing in eight dimensions.

- An appropriate cross section gives us an Apollonian packing in seven dimensions.
- Using ideas in [B., '18], we can build an Apollonian packing in nine dimensions.
- All these packings were described by Maxwell ('81), who identified them as sphere packings, but seems to have been unaware that they are Apollonian sphere packings.

[B., McKinnon, Roth(?), '20?] We are studying a rational elliptic surface whose ample cone in $\mathbb{R}^{1,9}$, when modeled in the Poincaré upper half space model $\mathbb{H}^9$ with the elliptic divisor at infinity, has walls that are all spheres of radius 1 with centers in the E8 lattice.

Skills and expertise:

- Hyperbolic Geometry
  - Vector model (the pseudosphere in Lorentz space)
  - Spheres in $\mathbb{R}^{n-1} \cong \partial\mathbb{H}^n_E$.
- Coxeter graphs
- Maple V ... :-(

Hopes for the semester:

- Collaborations? Others have pictures similar to mine. What is the connection between our fields?
- Computing skills. Can we 'fly through' a three-dimensional object?
- Visualization. Are there better ways of seeing and understanding objects in high dimensions?

Mikael
Vejdemo-Johansson

CUNY College of Staten Island
CUNY Graduate Center

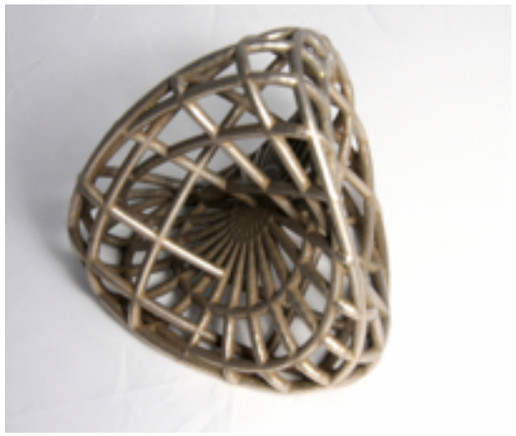
Primary Research Focus

- Applied Topology - in particular *weird ways to use Homology*
- MSc / PhD: computational homological algebra
- After that: Topological Data Analysis, persistent homology, Mapper
- Never been able to properly focus though…

Everything else…

- Counting necktie knots with formal languages
- Lasercutting
- 3d-printing
- Programming (everything all the time, since I was 11)
    - Twitter bots
    - d3.js
    - …









Goals for this semester

- Cool collaborations on fun, interesting and spectacular projects.

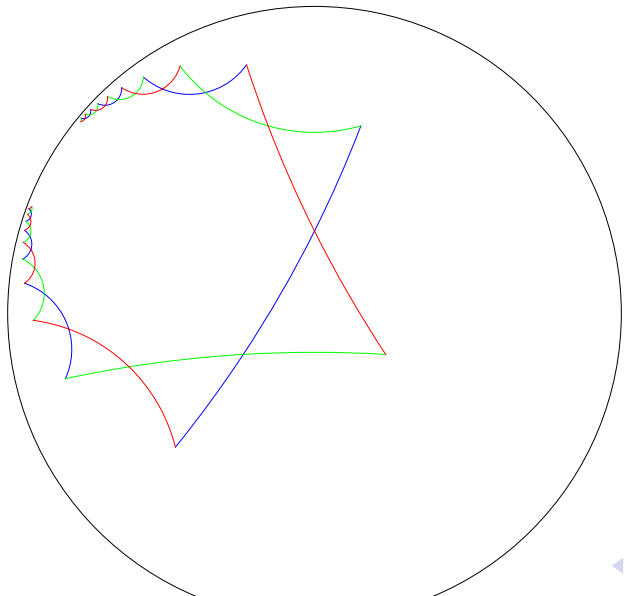
- Will be here sporadically:
  Illustrating Geometry and Topology
  Early October (3.5 days)
  Early November (4 days)

Illustrating and visualizing geometries: Groups, moduli spaces, and dynamics

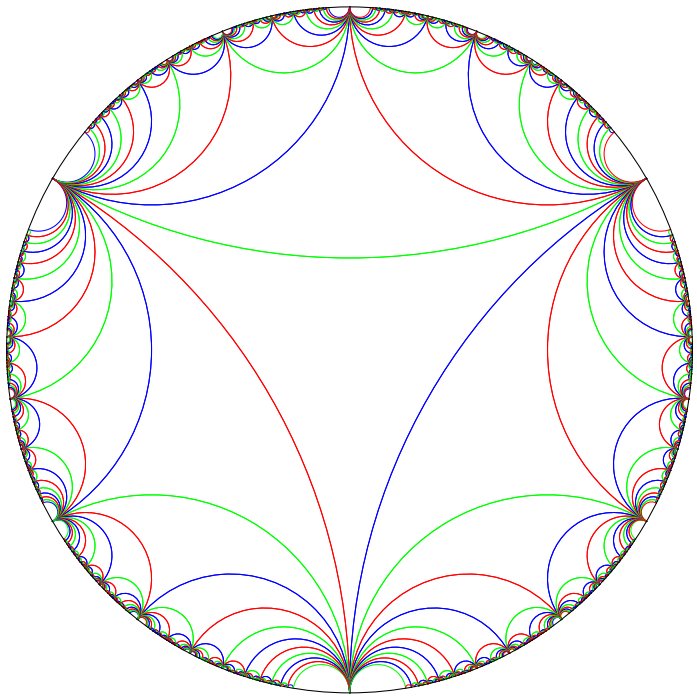
Bill Goldman

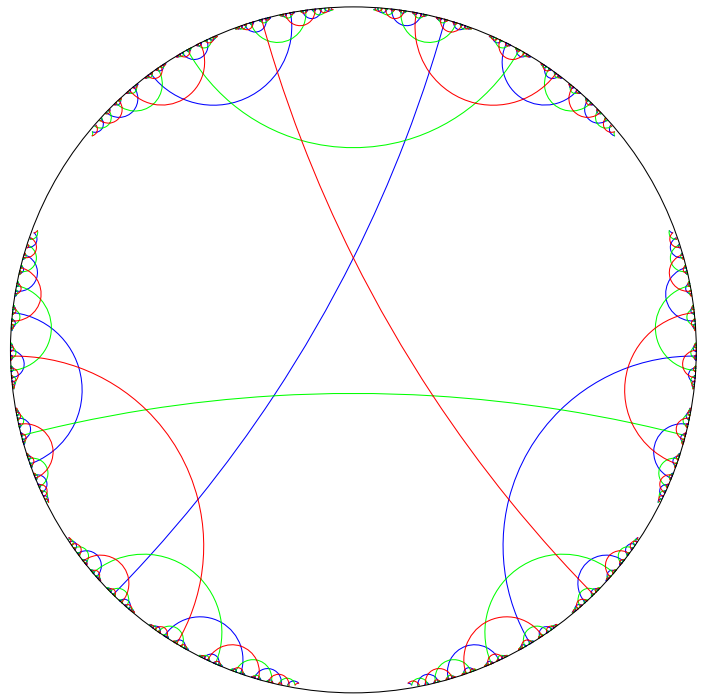
University of Maryland

4-5 September 2019



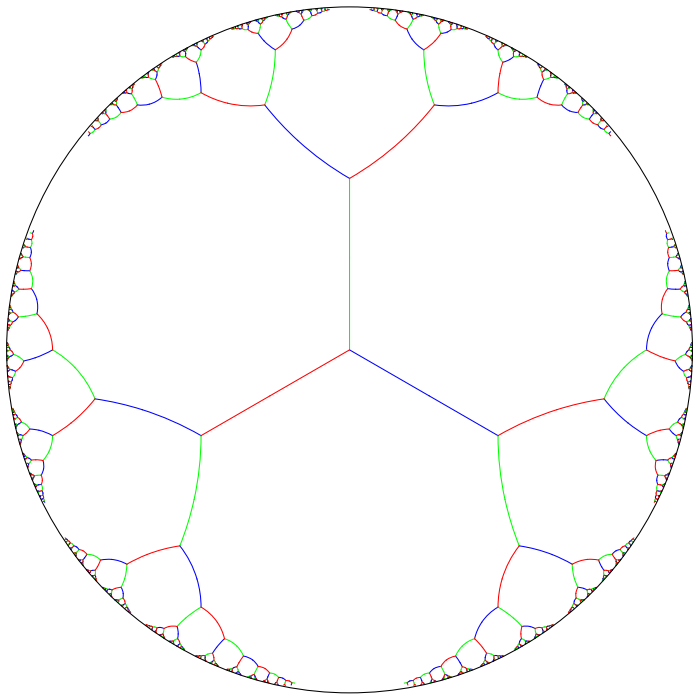
Hyperbolic geometry on a punctured torus

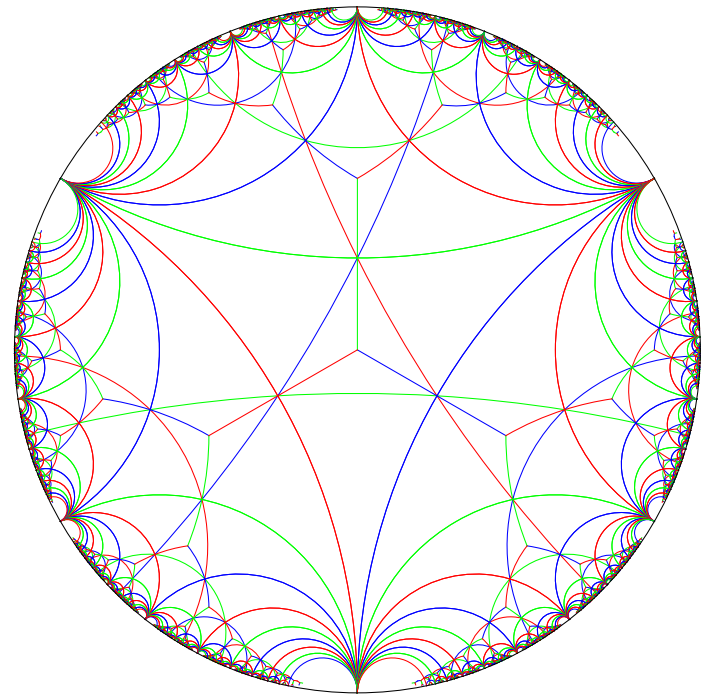




Ideal triangles and lifts of simple closed geodesics

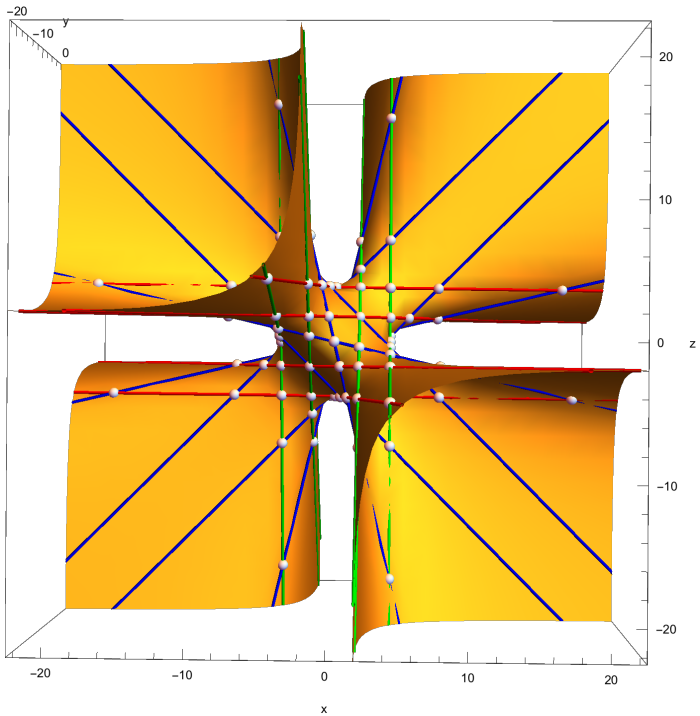
Geodesics on universal covering

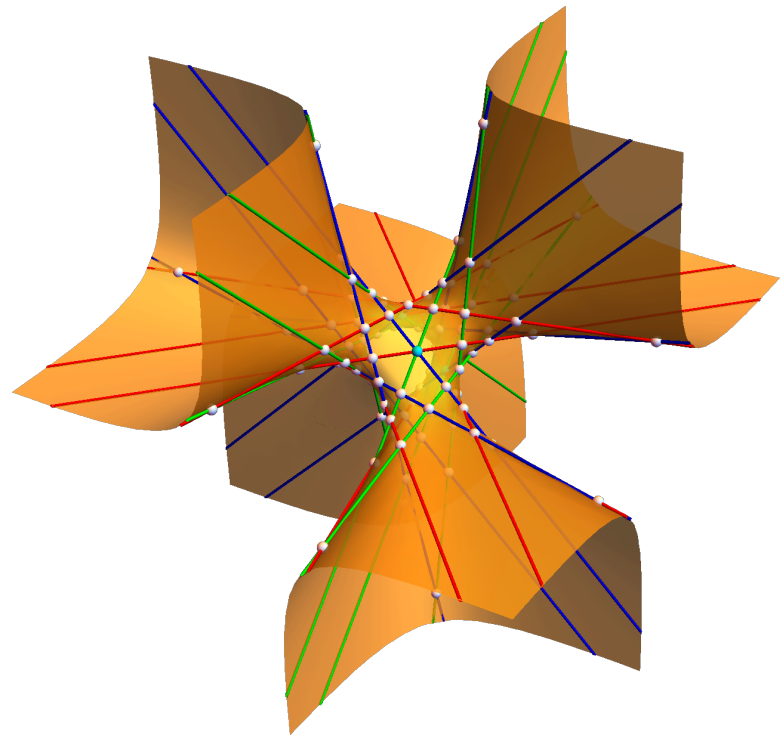




Dual tree to ideal triangles, together with the closed geodesics

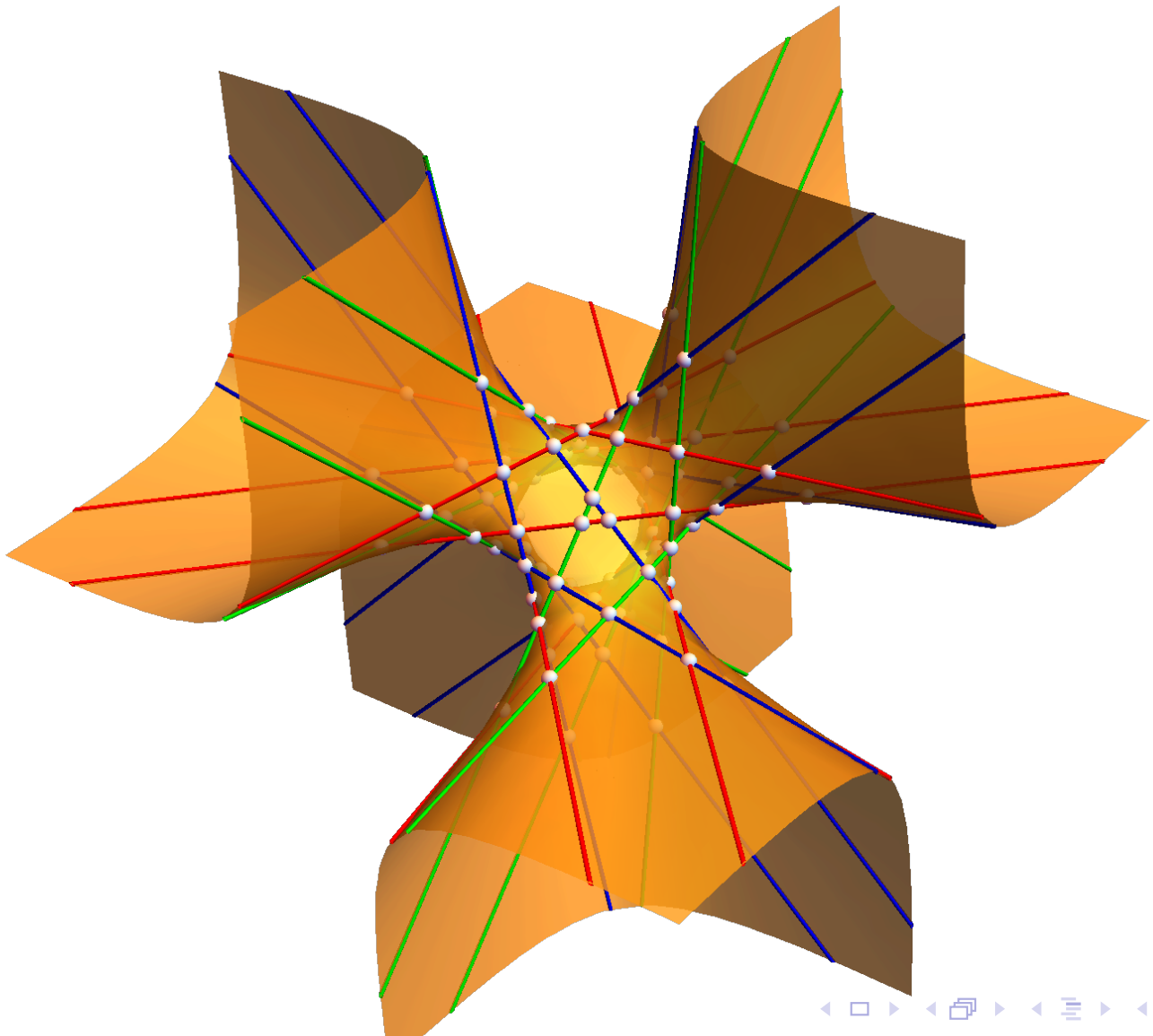
Moduli spaces of geometric structures on surface





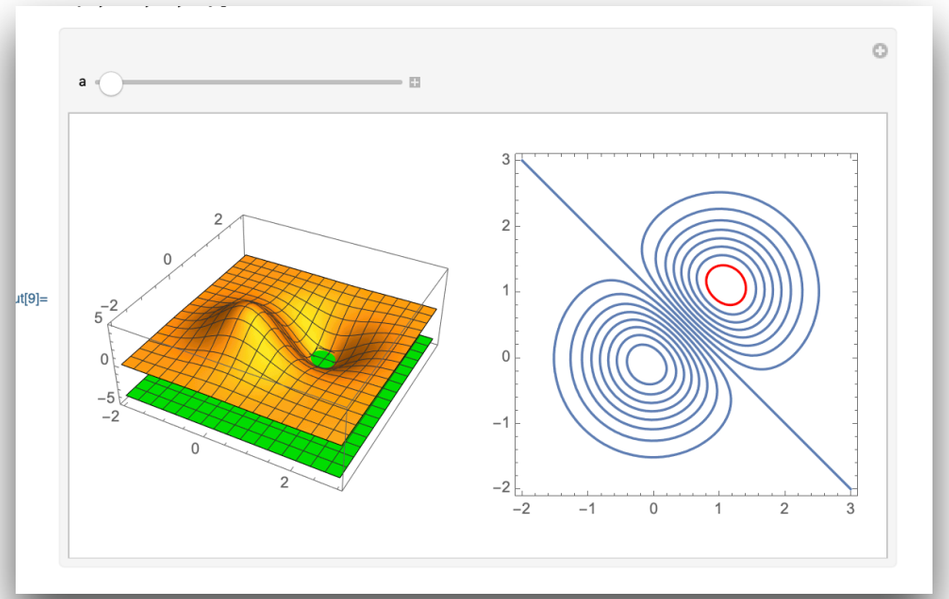
Lines on the cubic surface $x^2 + y^2 + z^2 - xyz = 20$

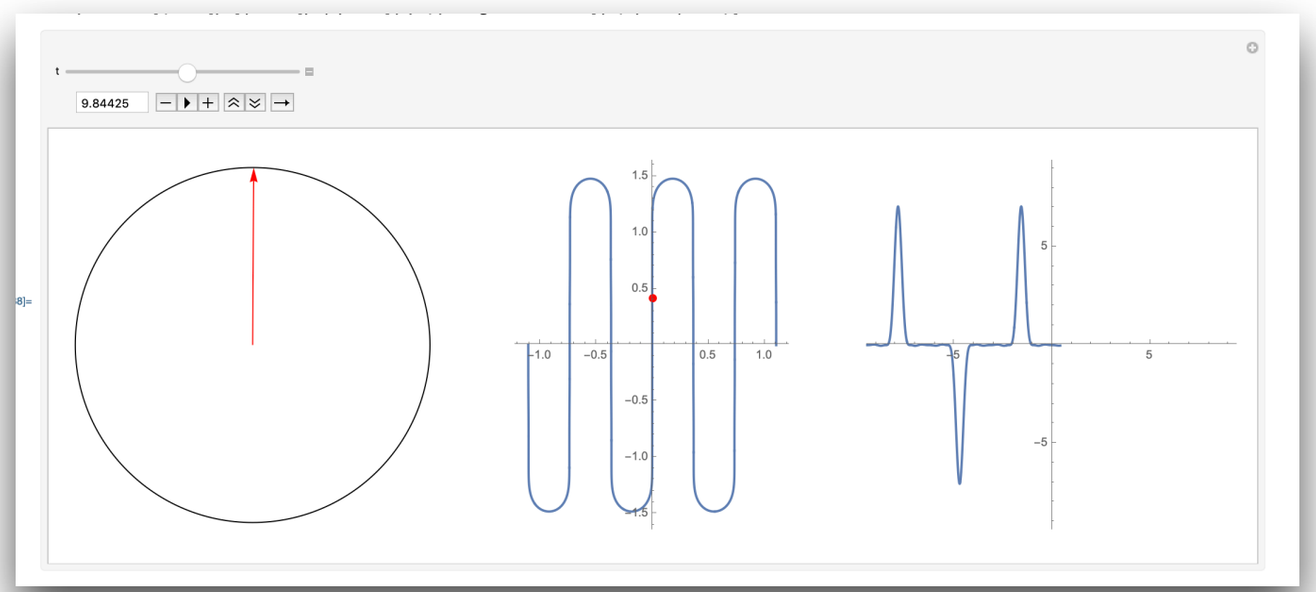
Dynamical change: $x^2 + y^2 + z^2 - xyz = 32$



Kelly Delp

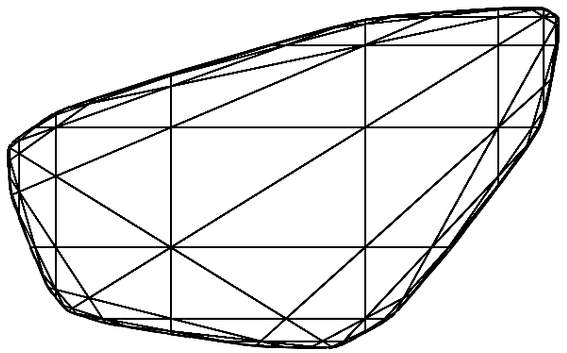
Cornell University
Senior Lecturer, Director of TA programs

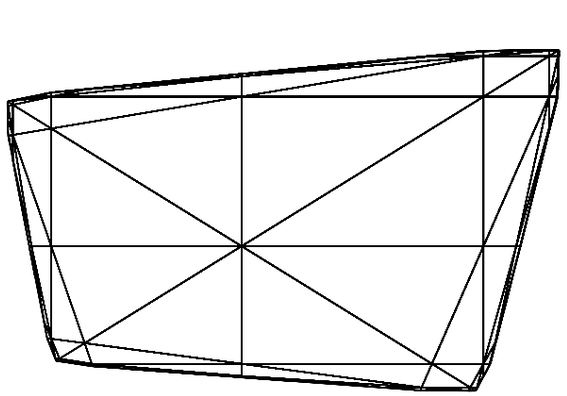


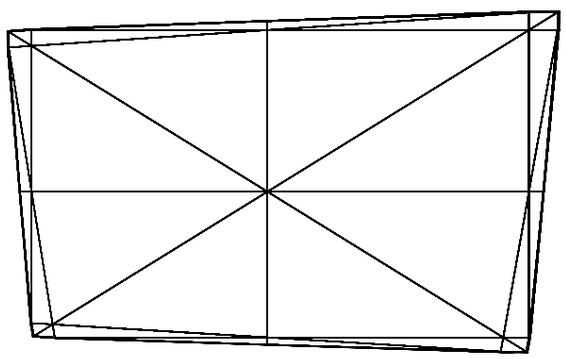


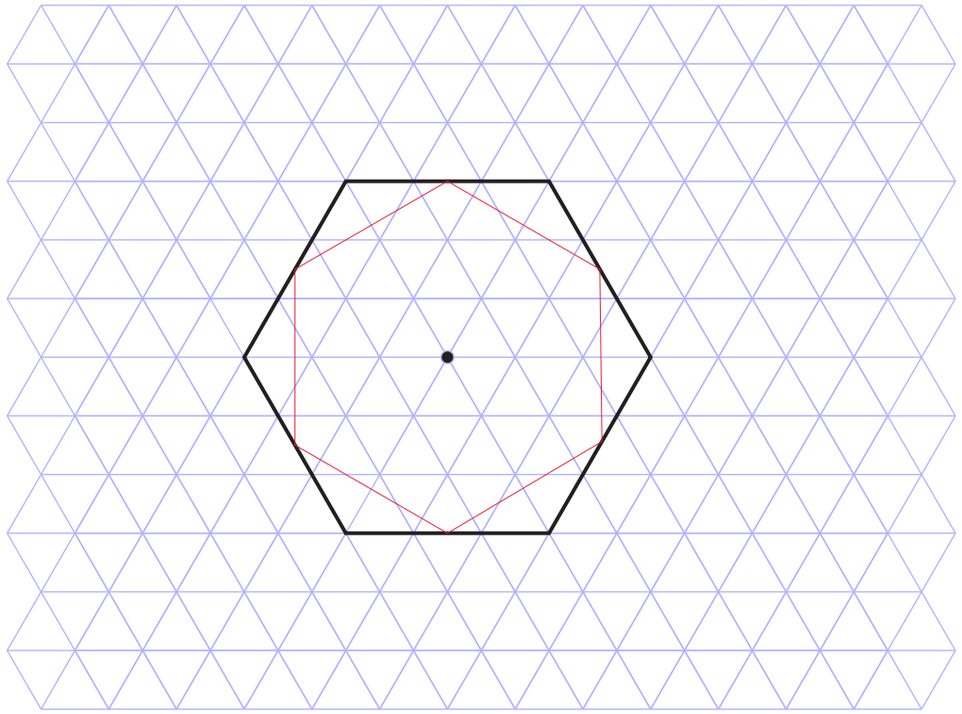
Mathematical Interests: Geometric Topology

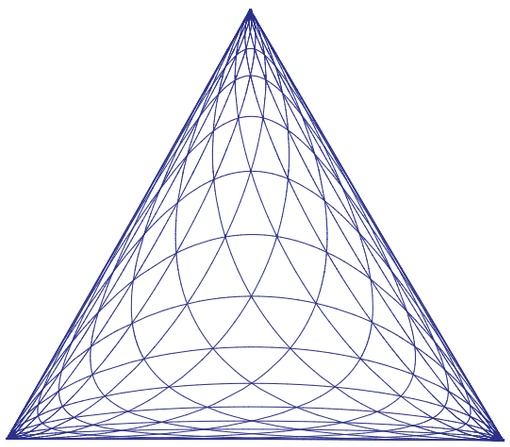
Strictly Convex Real Projective Manifolds

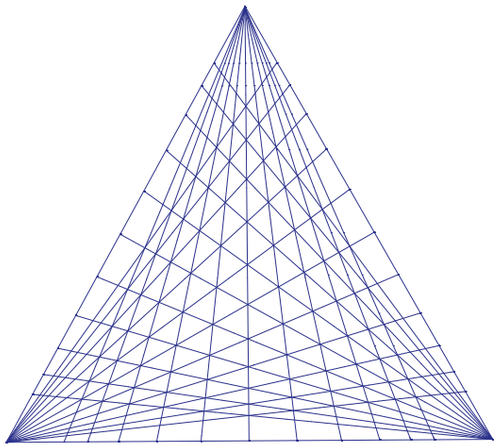




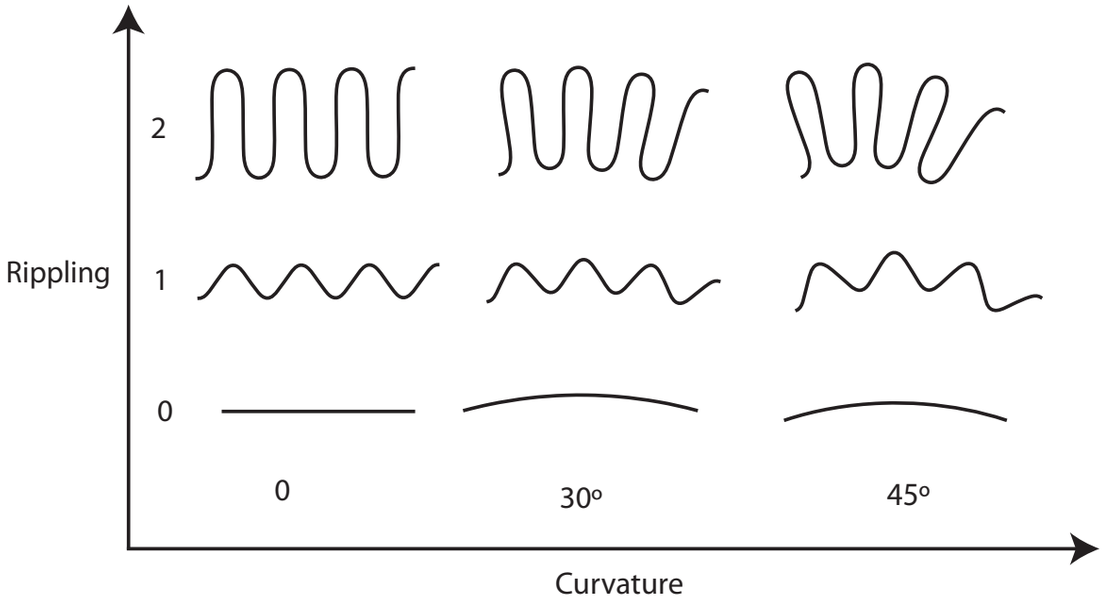








Playing with Surfaces

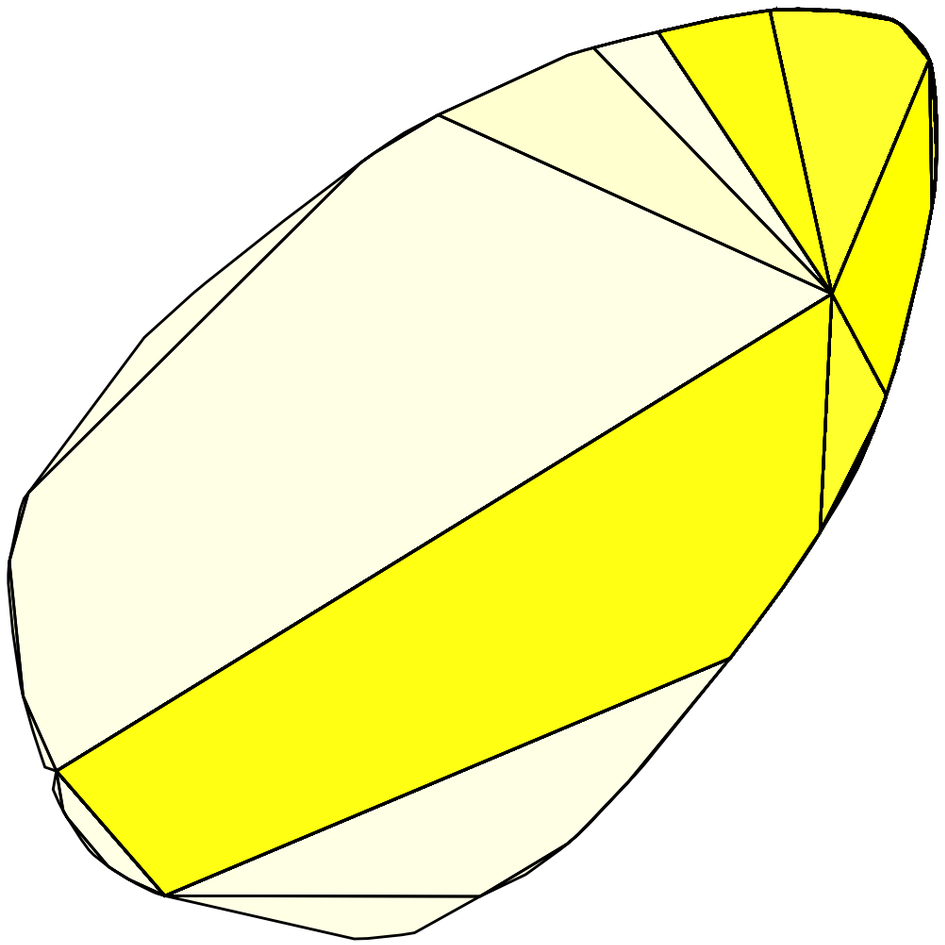








Deformation of Closed RP^2 Surface



TEL AVIV MUSEUM OF ART
מוזיאון תל אביב לאמנות
HERTA & PAUL AMIR BUILDING
הבנייין ע"ש שמואל והרטה עמיר

Mark J Stock

“Greatest Hits”

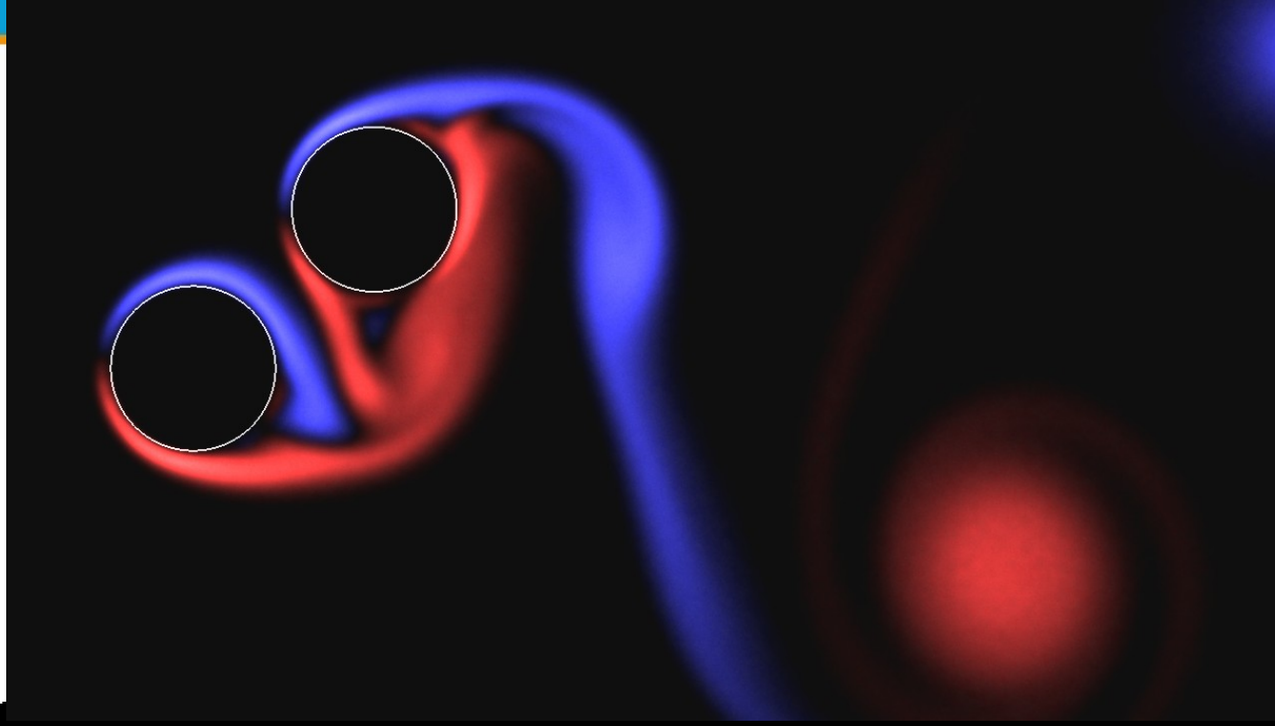
ICERM – Illustrating Mathematics
me@markjstock.com -or- @markjstock

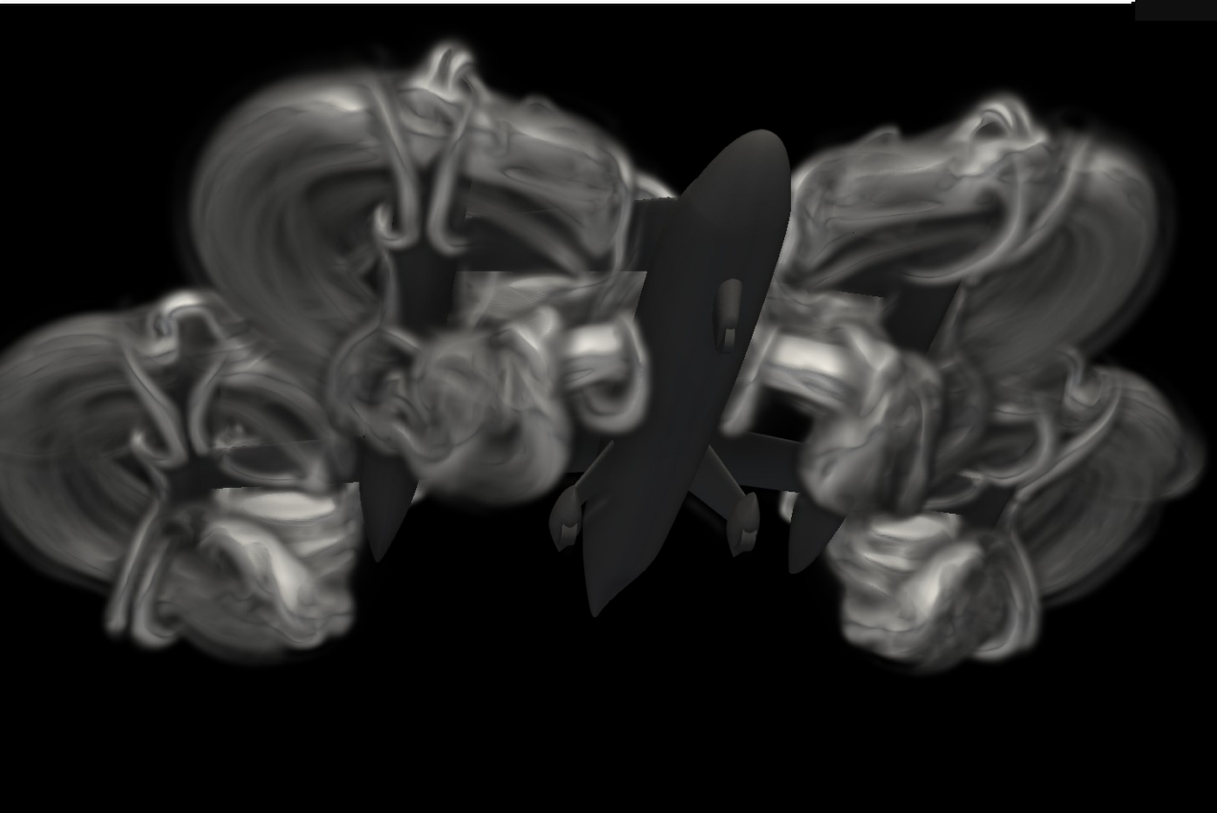
“Tell me about yourself”

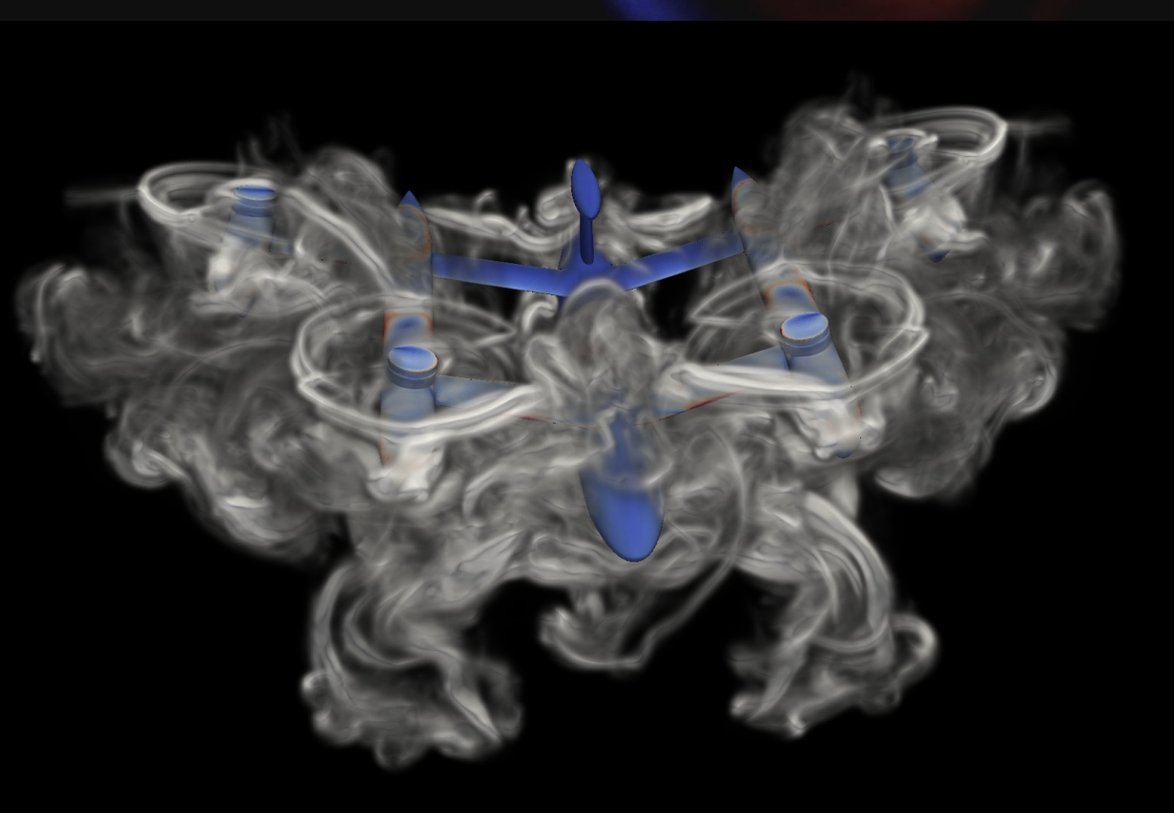
- PhD Aerospace Engineering 2006 (not a Mathematician)
- Part-time at Applied Scientific Research, Santa Ana, CA
- Part-time visual artist (prints, video, sculpture, VR)
- Part-time business owner (TinyMtn and MiniCty)
- Part-time sleeper

Fluids









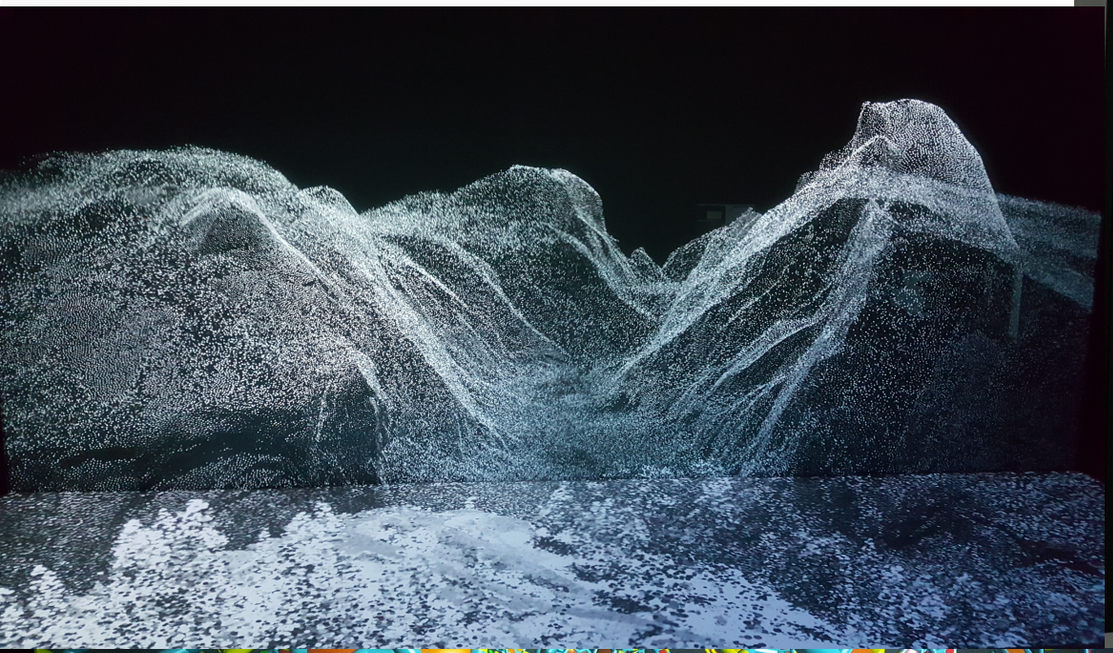
Fractals

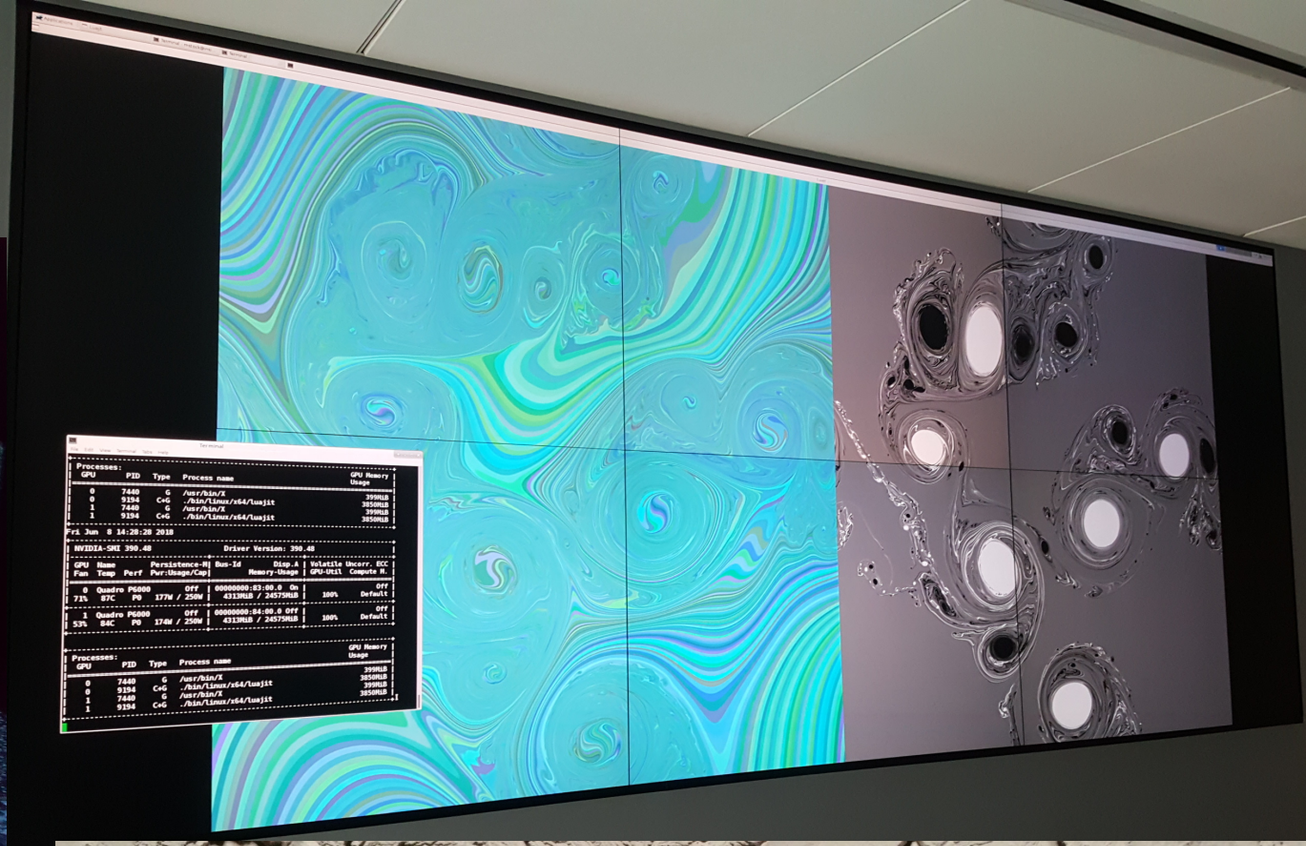






CG/VR/GPU

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0 9194 C+G ./bin/linux/x64/luajit 385MiB
1 7440 G /usr/bin/X 359MiB
1 9194 C+G ./bin/linux/x64/luajit 385MiB
Fri Jun 8 14:28:28 2018
NVIDIA-SMI 390.48 Driver Version: 390.48
GPU Name Persistence-M Bus-Id Disp.A Volatile Uncorr. ECC
Fan Temp Perf Pwr:Usage/Cap Memory-Usage GPU-Util Compute M.
0 Quadro P6000 Off 00000000:03:00.0 On Off
71% 87C P0 177W / 250W 4313MiB / 24575MiB 100% Default
1 Quadro P6000 Off 00000000:04:00.0 Off Off
53% 84C P0 174W / 250W 4313MiB / 24575MiB 100% Default
Processes:
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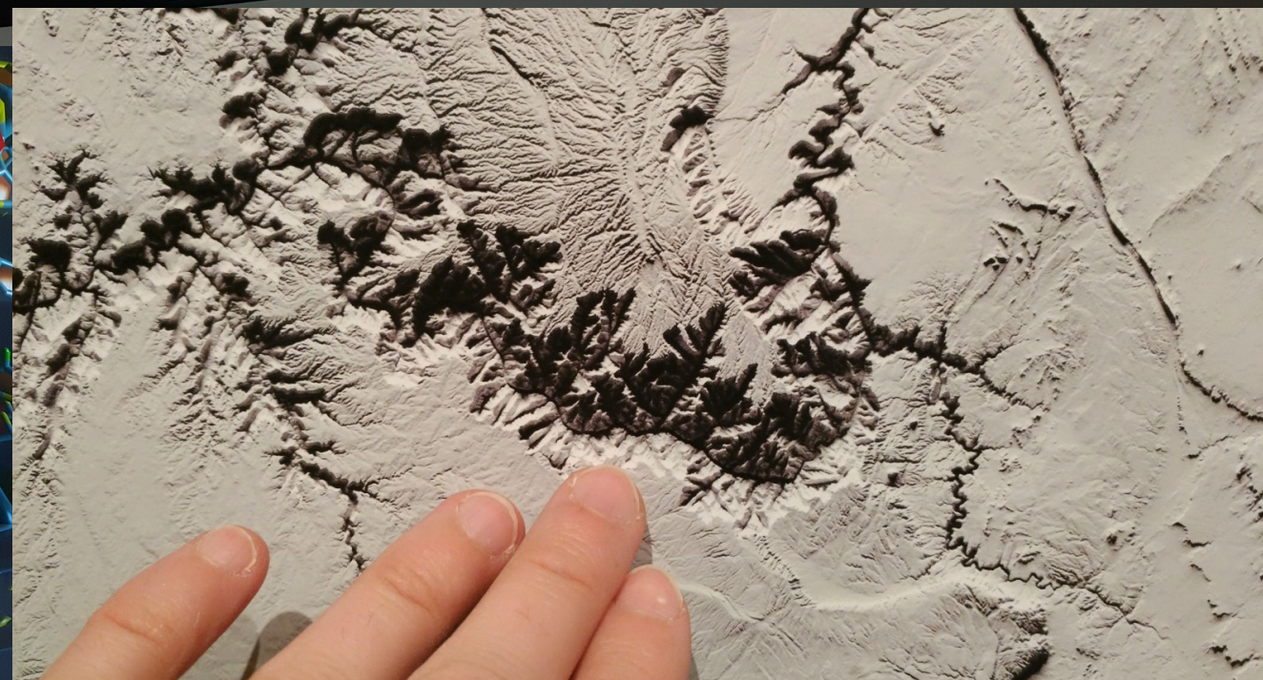
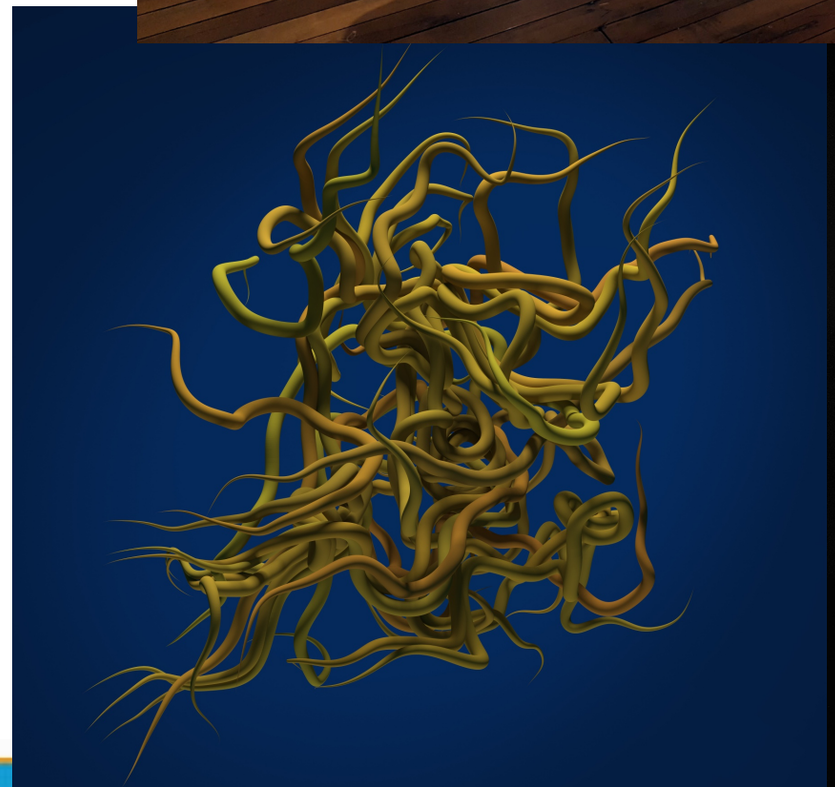


Artwork

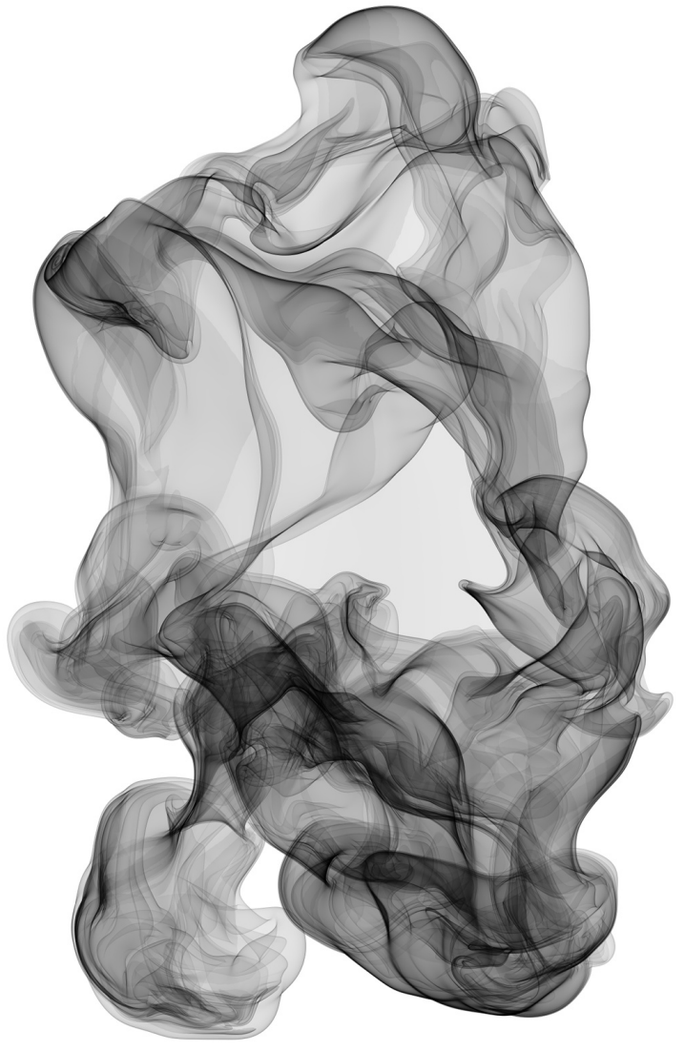








Artwork







TinyMtn & MiniCty







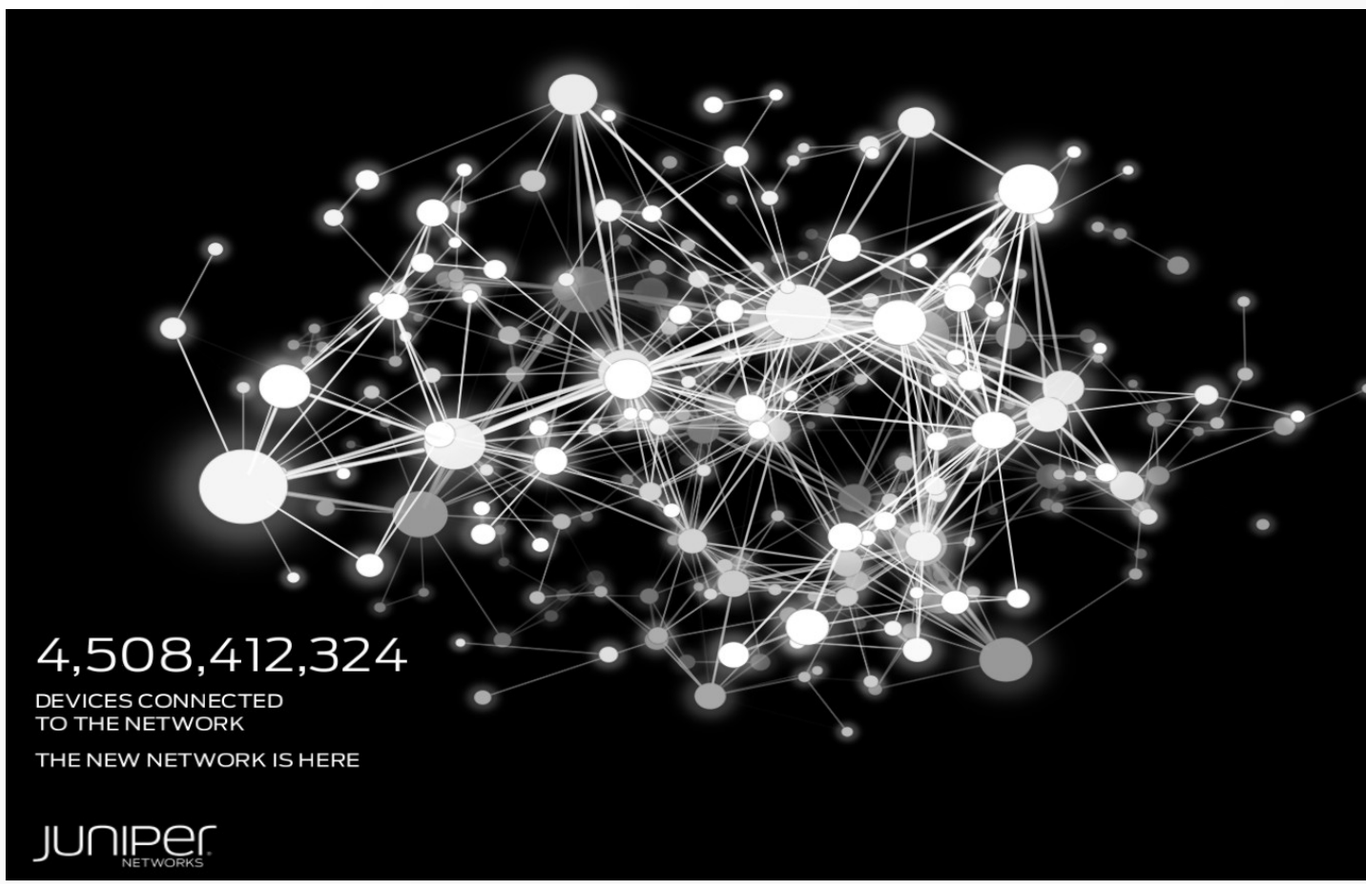


Skills & Experience

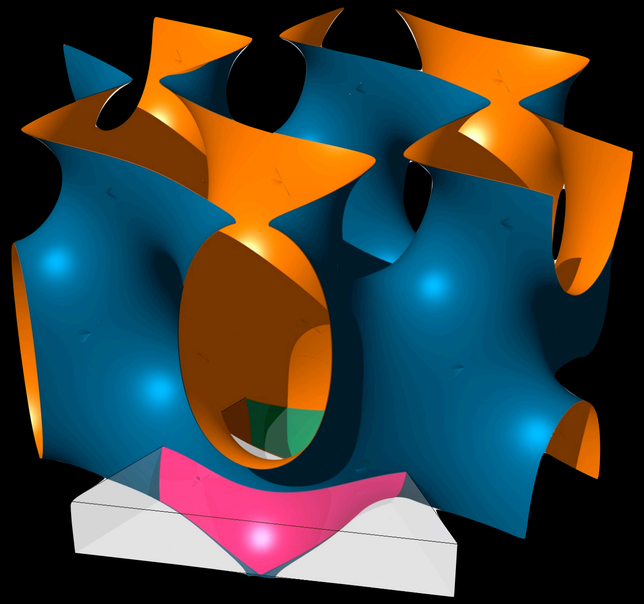
- High-performance computing (MPI, OpenMP, CUDA, C++)
- Computational physics, numerical methods
- Computer graphics (OpenGL, compute shaders, VR)
- Radiosity rendering (Radiance because Blender scares me)
- 3D printing (online and living room)
- NOT: slow anything, CAD, other peoples' software

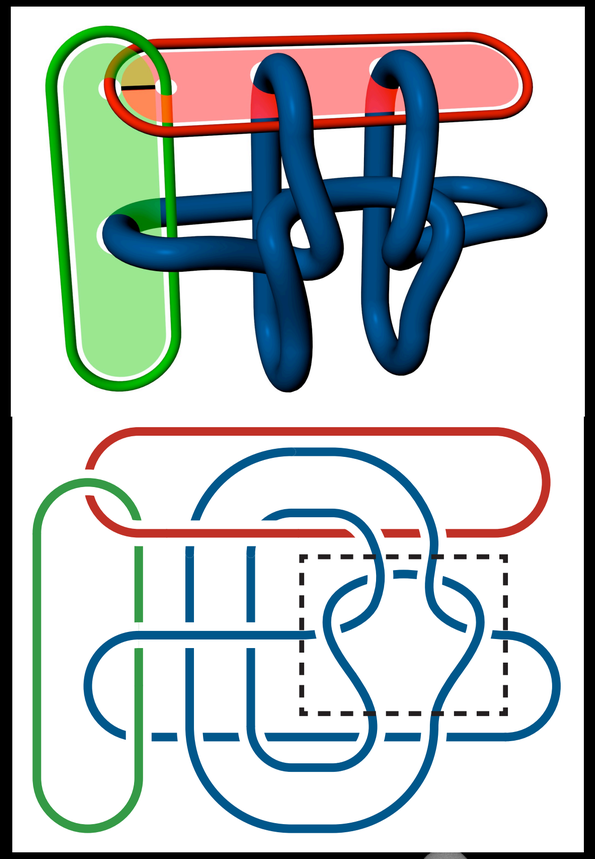
Semester Interests / Projects

- Viz or print paths in dynamical systems (chaotic, n-body)
- Viz and/or print graphs and networks
- Make an interactive installation from work done here

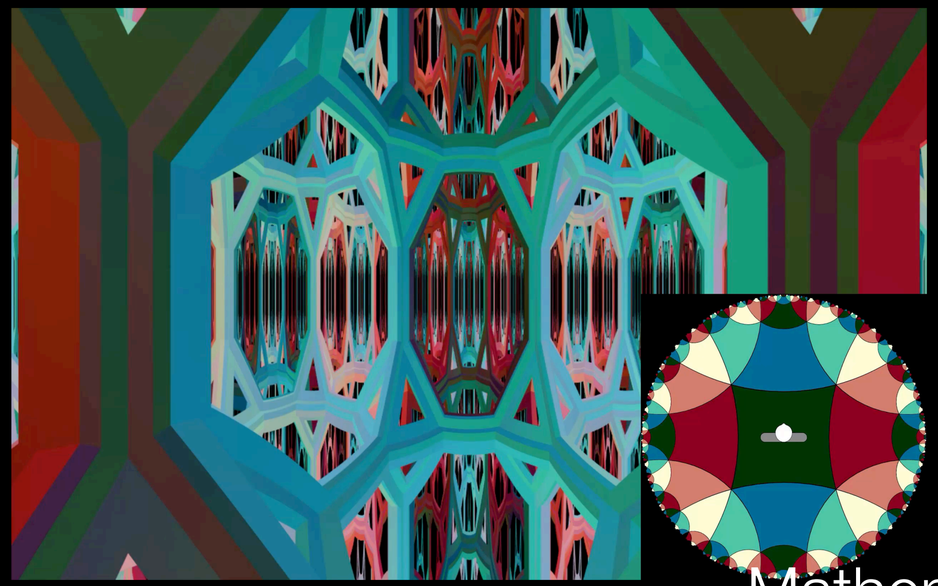


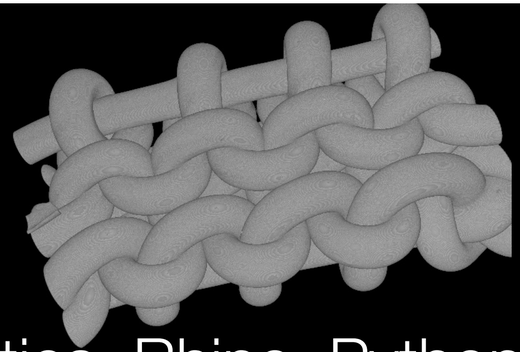
Sabetta Matsumoto (she/her)

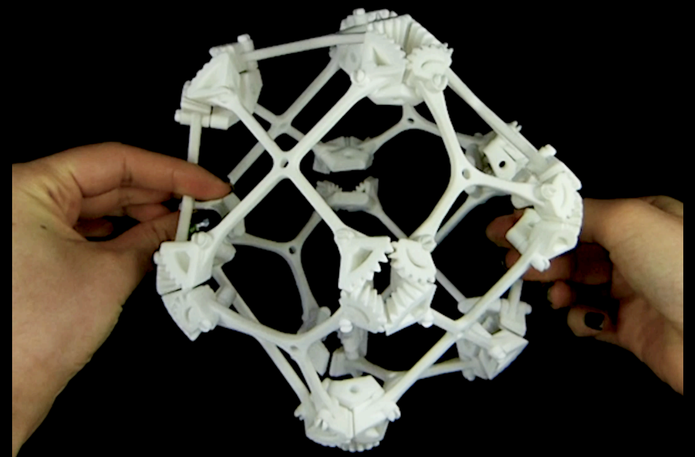










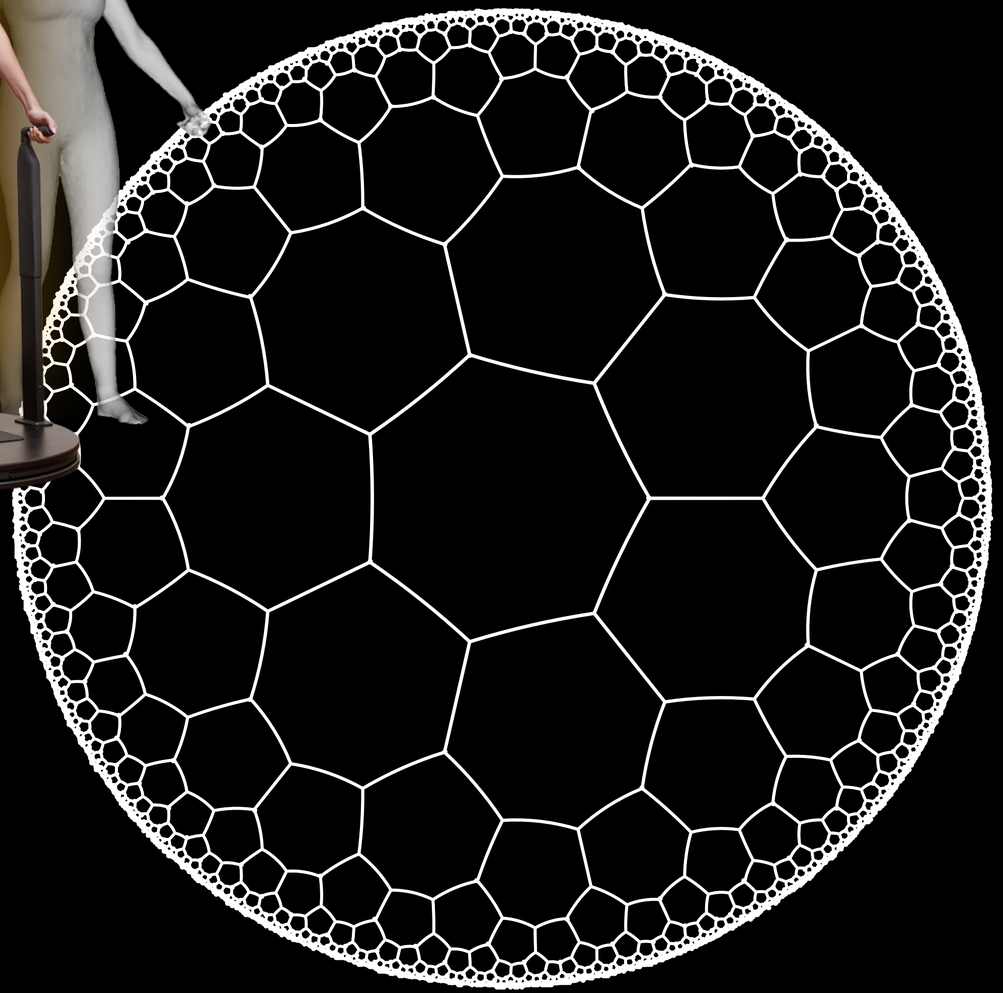


Mathematica, Rhino, Python, Gcode

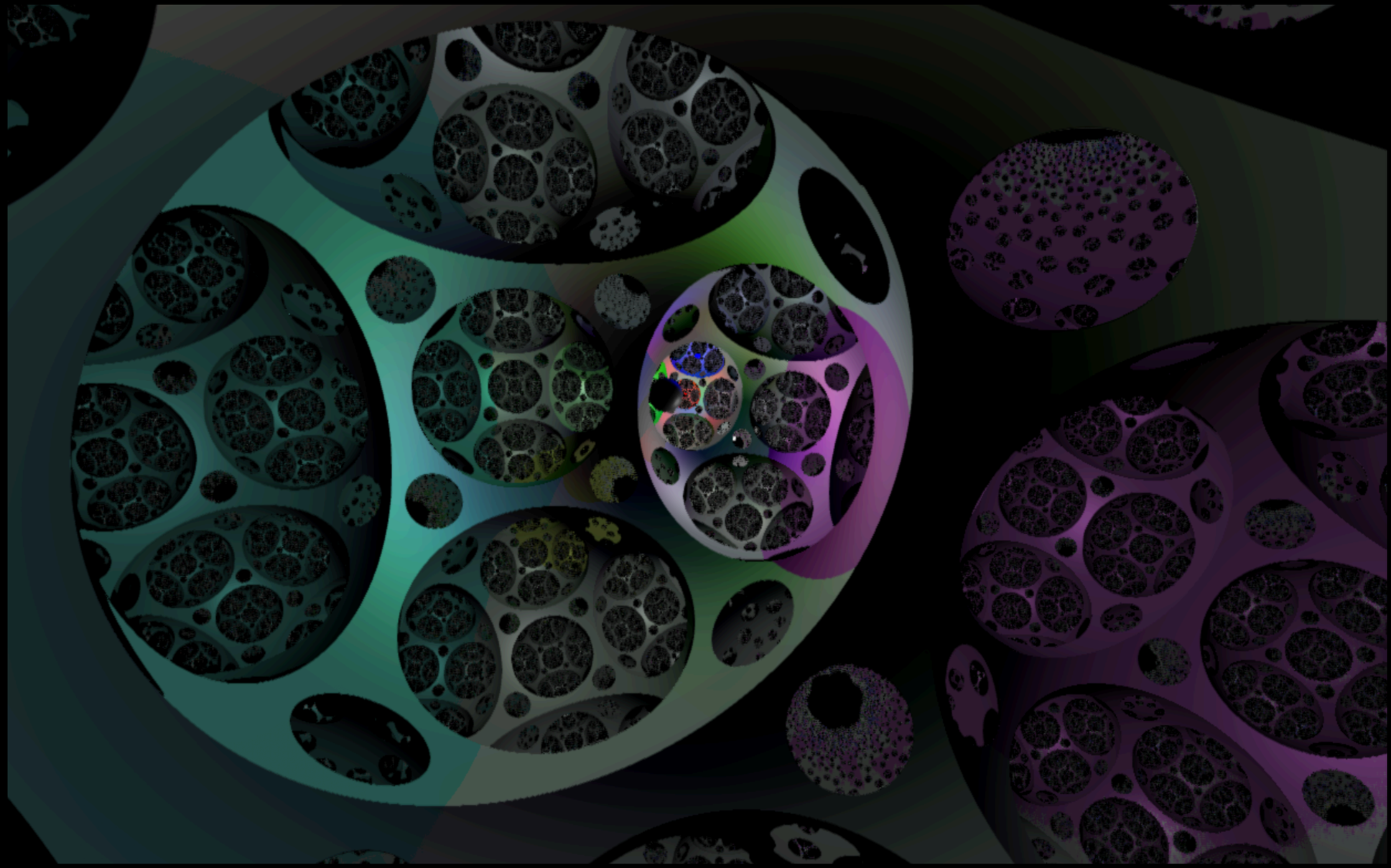
Help me make my new tattoo!







VR Thurston geometries with ray marching



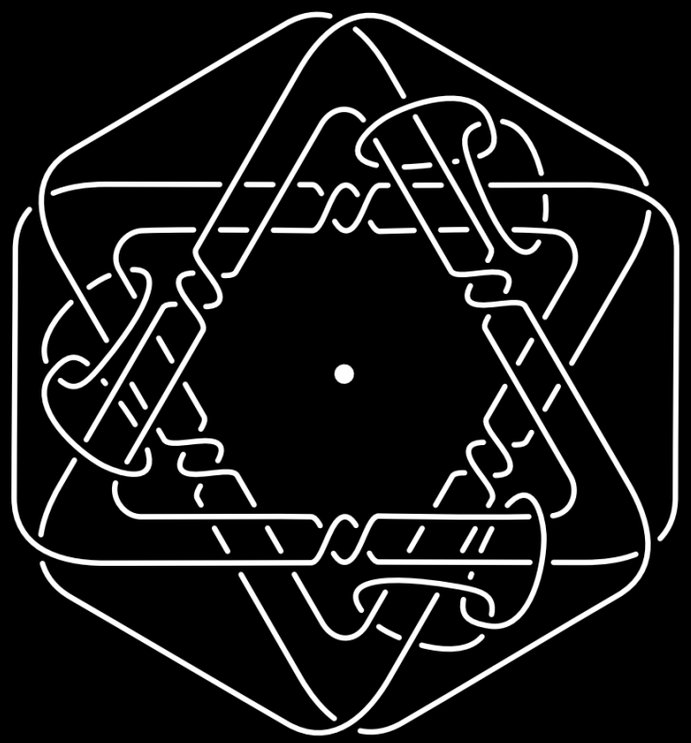
Inside view of a hyperbolic 3-manifold in SnapPy

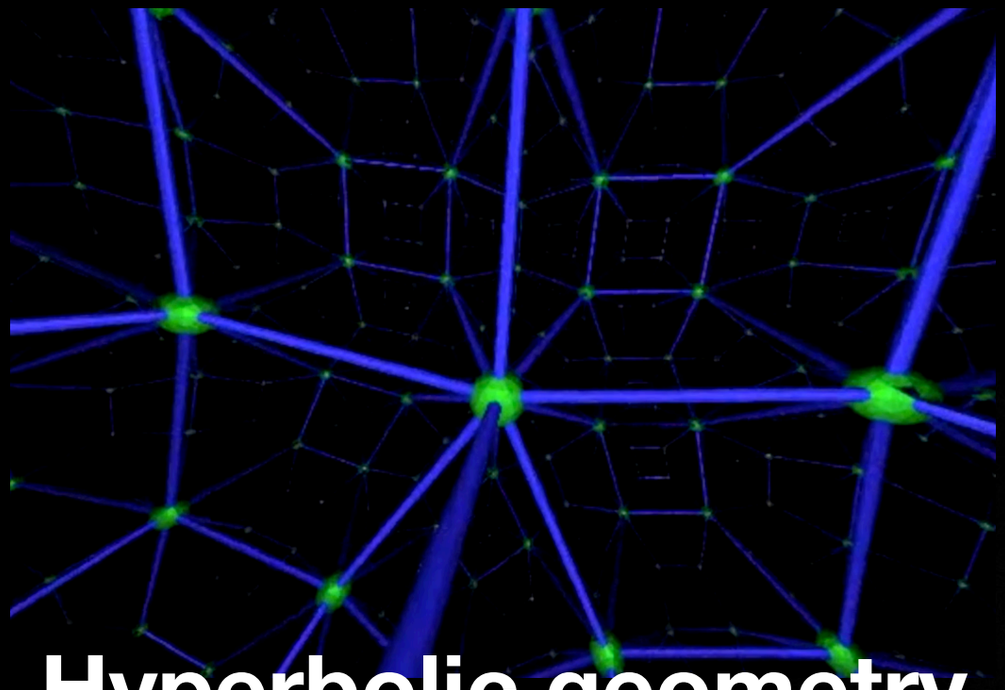
Matthias Goerner

(by day: Senior Software Engineer
at Pixar Animation Studios,
by night: Low-dimensional Topologist)

Previous work and interests

Knots and Links

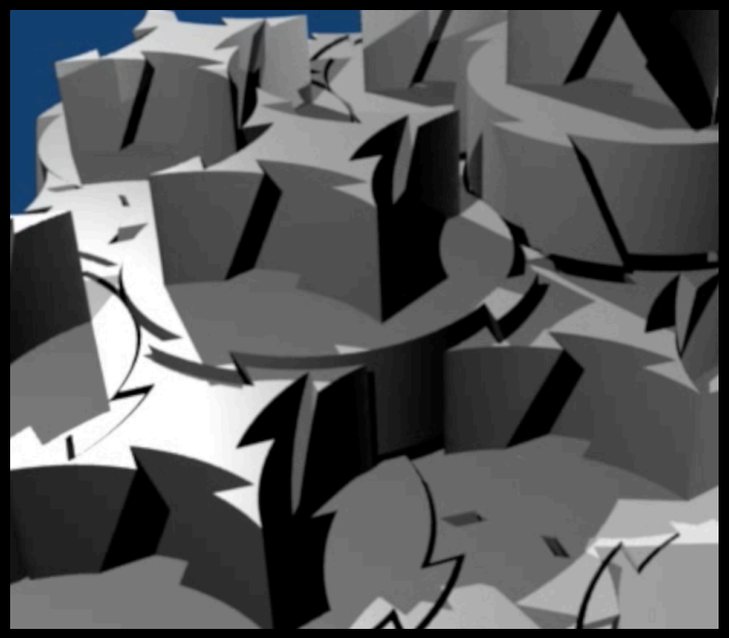




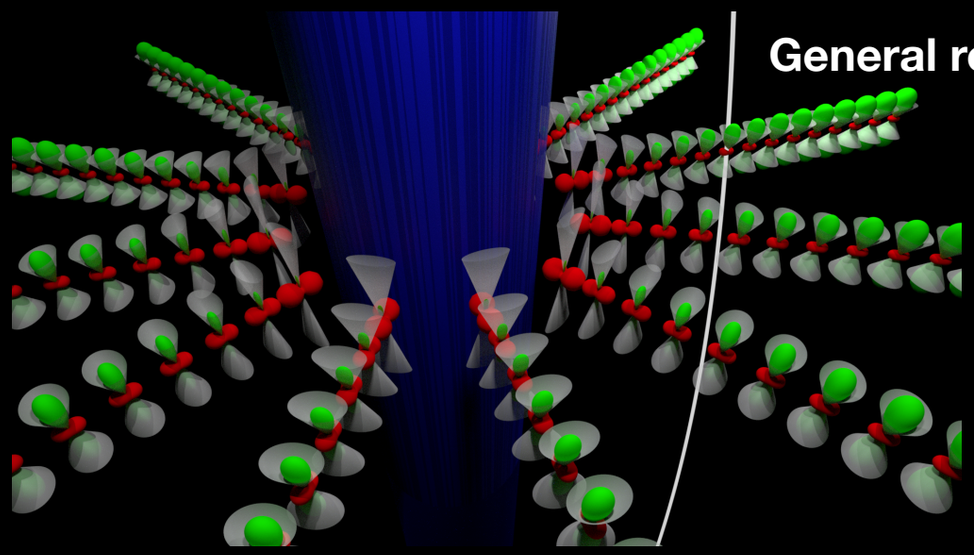
Hyperbolic geometry

Hilbert's 3rd problem (scissors congruence)

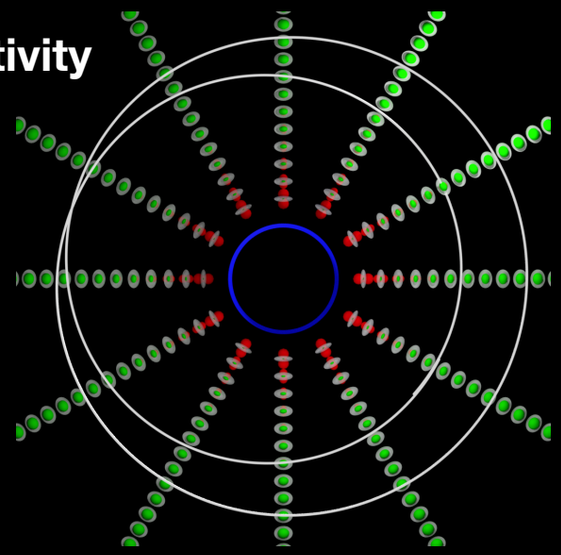




Misc



General relativity

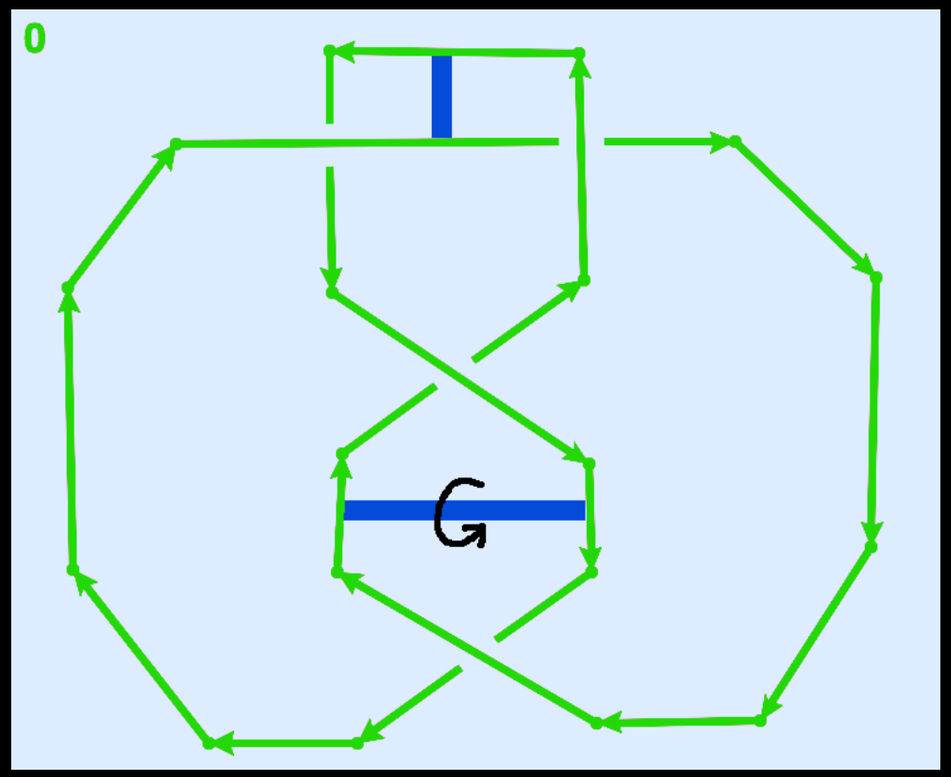


Computational Skills

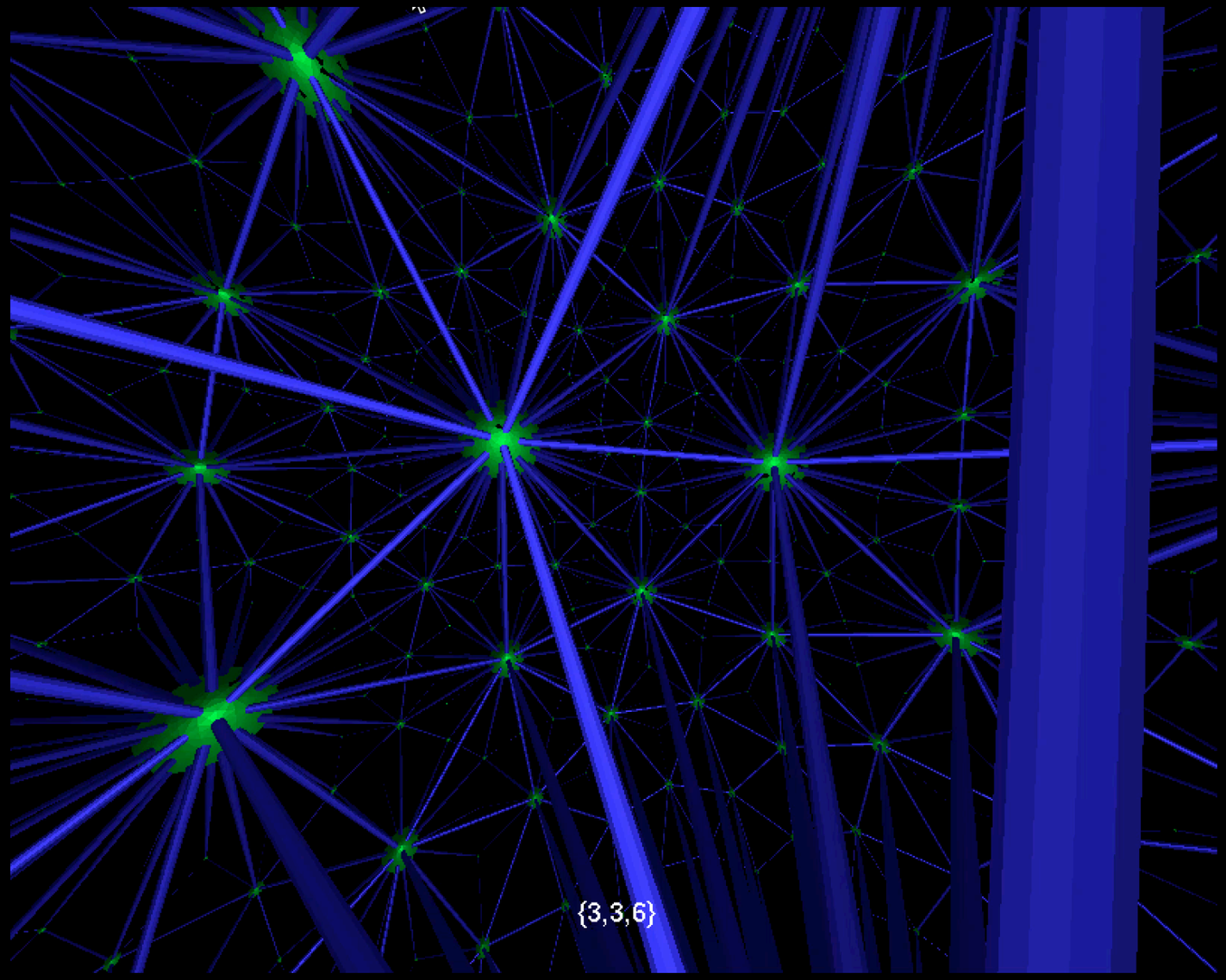
- Computations in hyperbolic space/3-manifolds
- 3-manifold software: SnapPy, Regina, Orb
- Graphics: OpenGL, Blender
- Math software: SageMath
- Languages: C++, Python

Goal: Inside view of hyp. 3-mfd

Knot diagram view



Inside view of complement

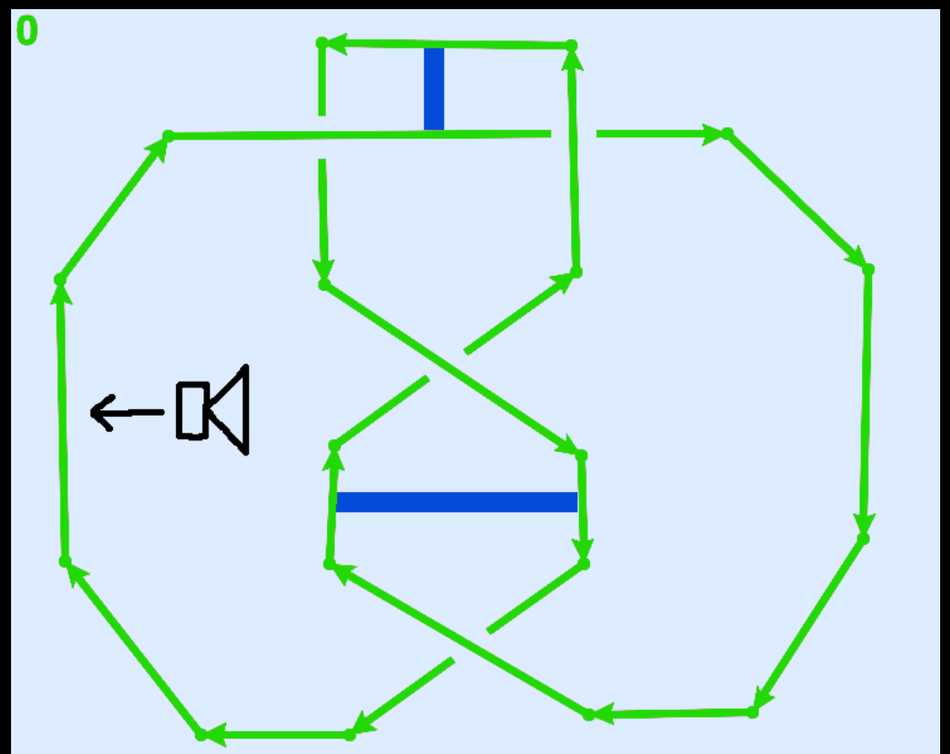


Notes:

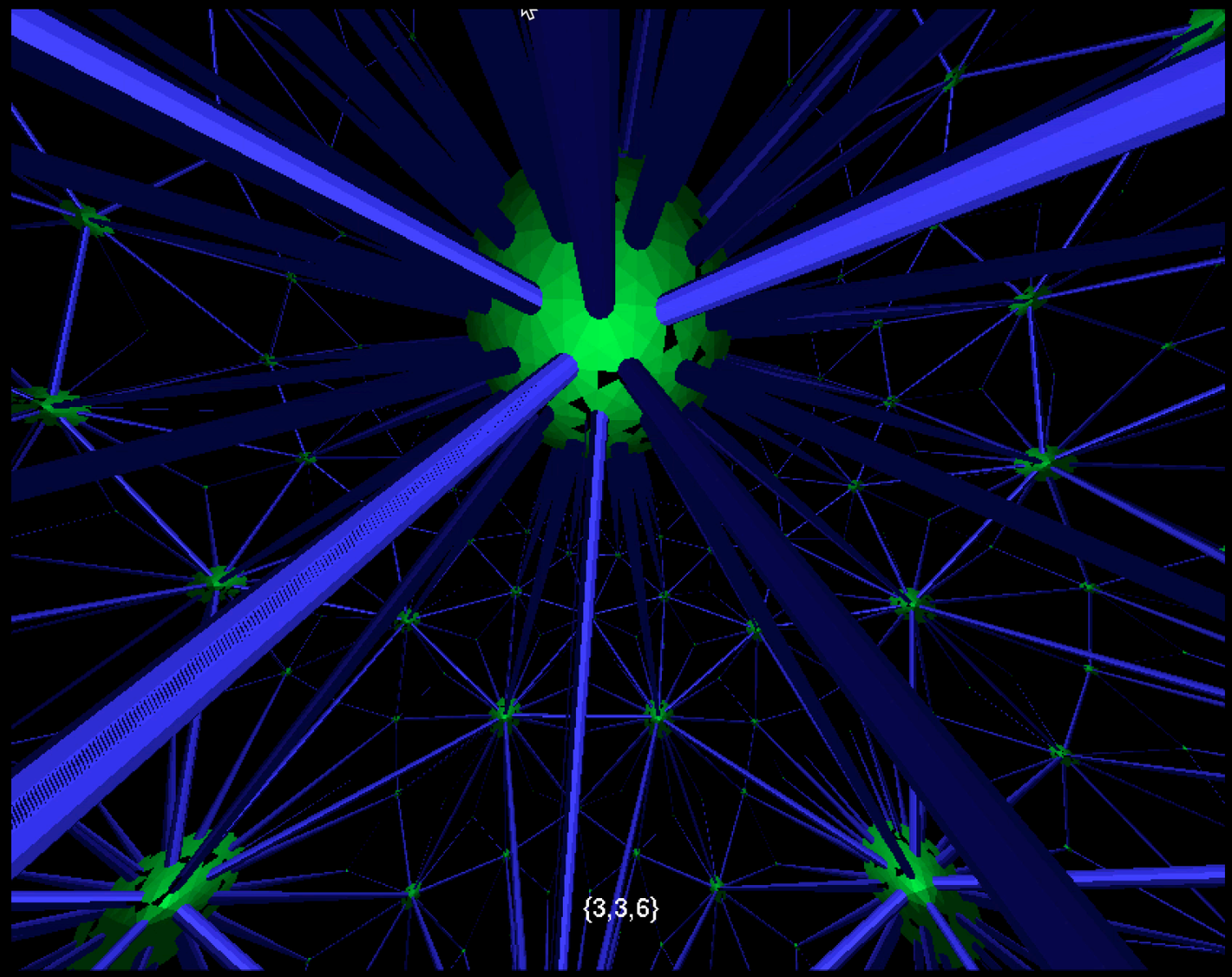
- **Two blue edges would be colored differently**
- **Would see your own space ship in every other tetrahedron**

Goal: Inside view of hyp. 3-mfd

Knot diagram view



Inside view of complement



Challenge:

- **Draw your trajectory in the knot diagram**

What to draw?

Intrinsic:

- **Cusp neighborhoods/Ford domains**
- **Shortest geodesics**
- **Longitude and meridian**
- **Canonical cell decomposition**
- **Avatar (little space ship) at your position**

Extrinsic:

- **Triangulation**
- **Generators of fundamental group**

Other:

- **Animation of a deformation of a hyperbolic structure from cusped to closed manifold**

ICERM: Illustrating mathematics

Jonathan Wise

University of Colorado / Brown

September, 2019

Research Interests

Moduli spaces of ...

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- algebraic curves

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- line bundles on curves (Picard group)

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... particularly their degenerations (encoded by tropical geometry).

Visualization Interests

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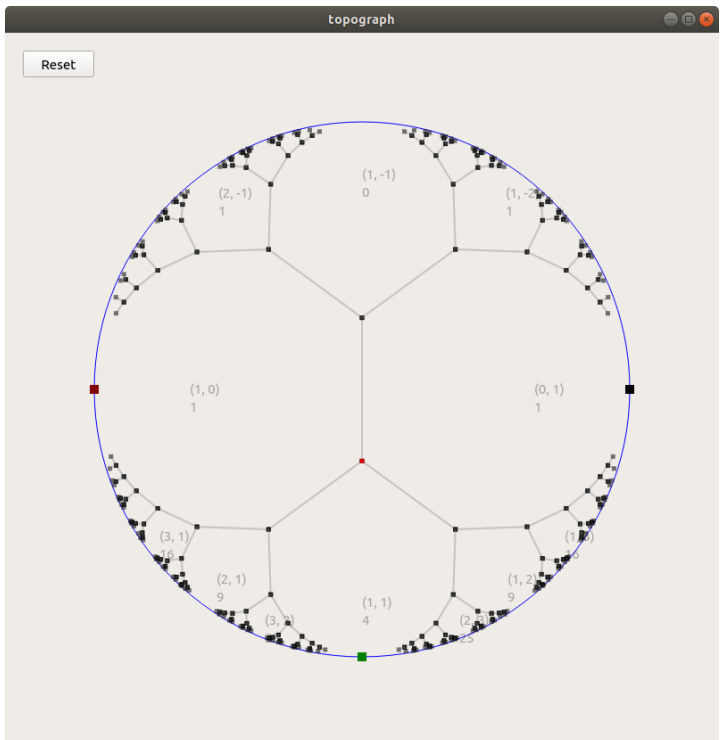
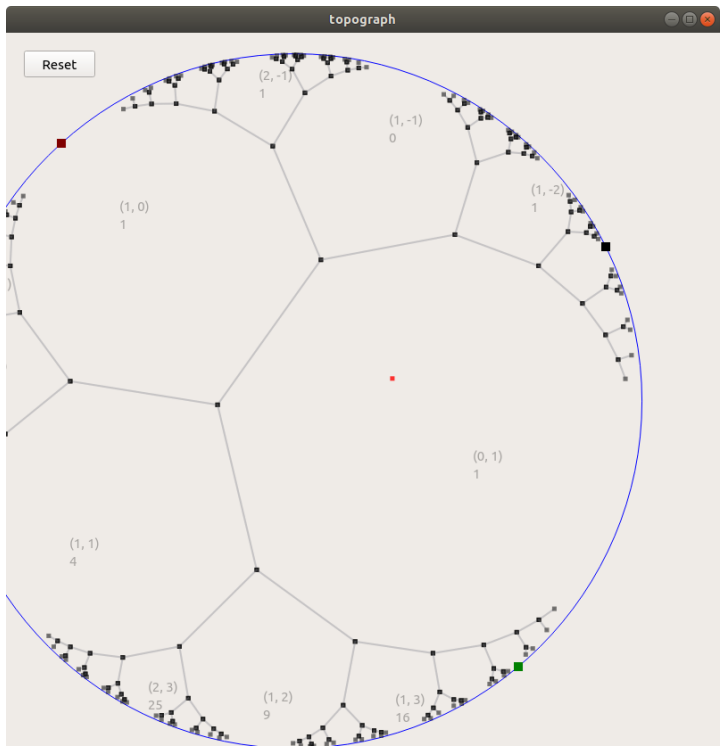
Moduli spaces of ...

- pairwise disjoint triples of integer points of $\mathbf{P}^1$ (Conway's topograph)

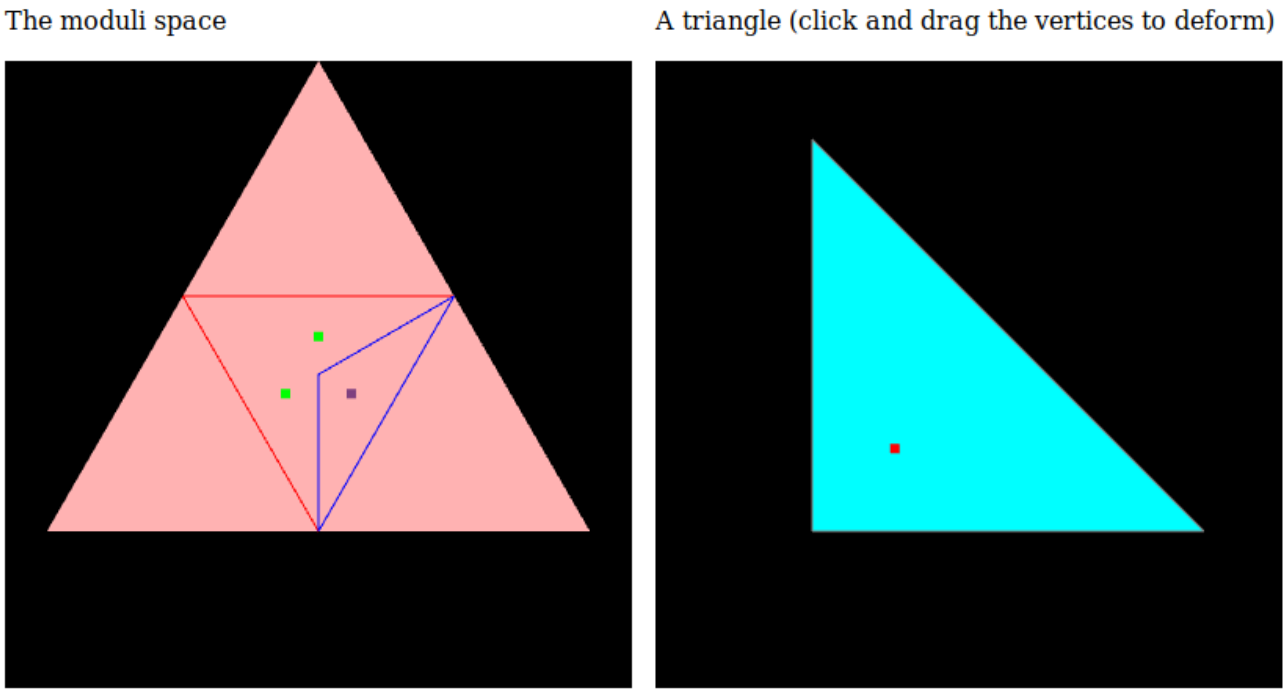




Visualization Interests

Moduli spaces of ...

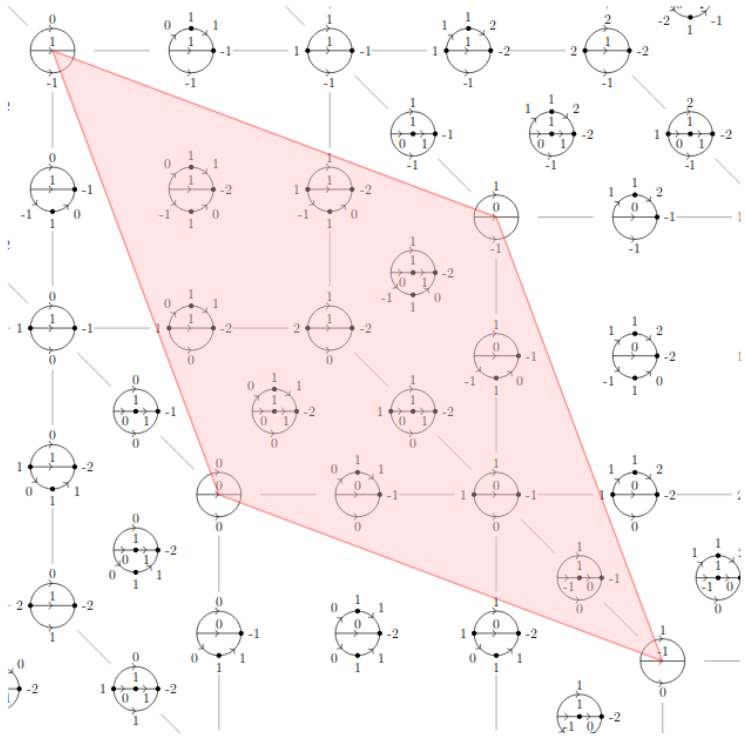
- pairwise disjoint triples of integer points of $\mathbf{P}^1$ (Conway's topograph)
- oriented metric triangles (illustrating stacks)



Visualization Interests

Moduli spaces of ...

- pairwise disjoint triples of integer points of $\mathbf{P}^1$ (Conway's topograph)
- oriented metric triangles (illustrating stacks)
- tropical Picard group



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Construct some new (interactive) visualizations of ...

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Make past projects prettier, more interactive, etc.

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Construct some new (interactive) visualizations of ...

- tropical K3 surfaces (and their deformations)
- tropical Picard groups of curves

Make past projects prettier, more interactive, etc.

Use visualizations to get intuition about moduli spaces (especially of K3 surfaces)