3D printing mathematical surfaces

Alba Málaga

November 28, 2022

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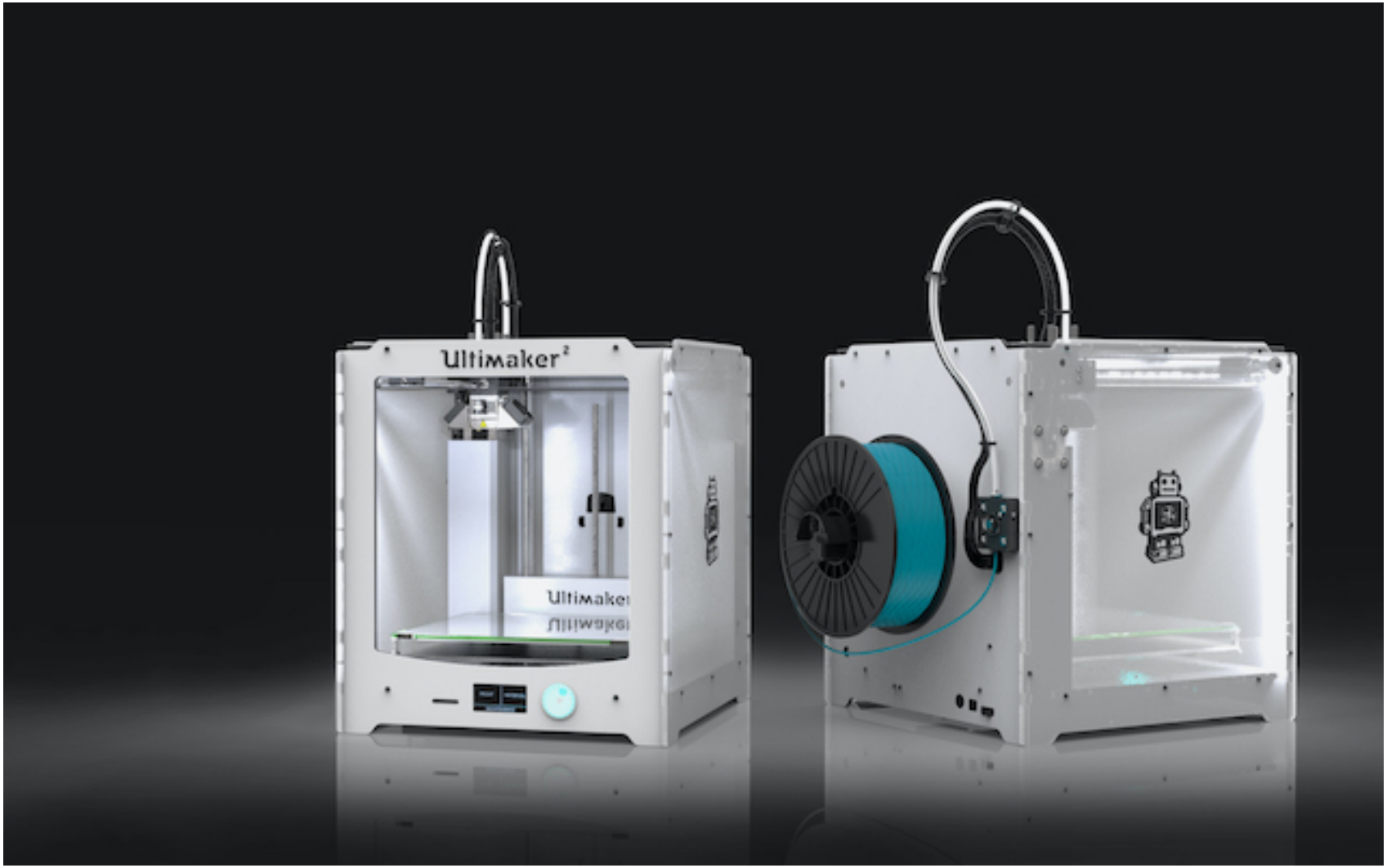
(other 3D printing technologies remain expensive)

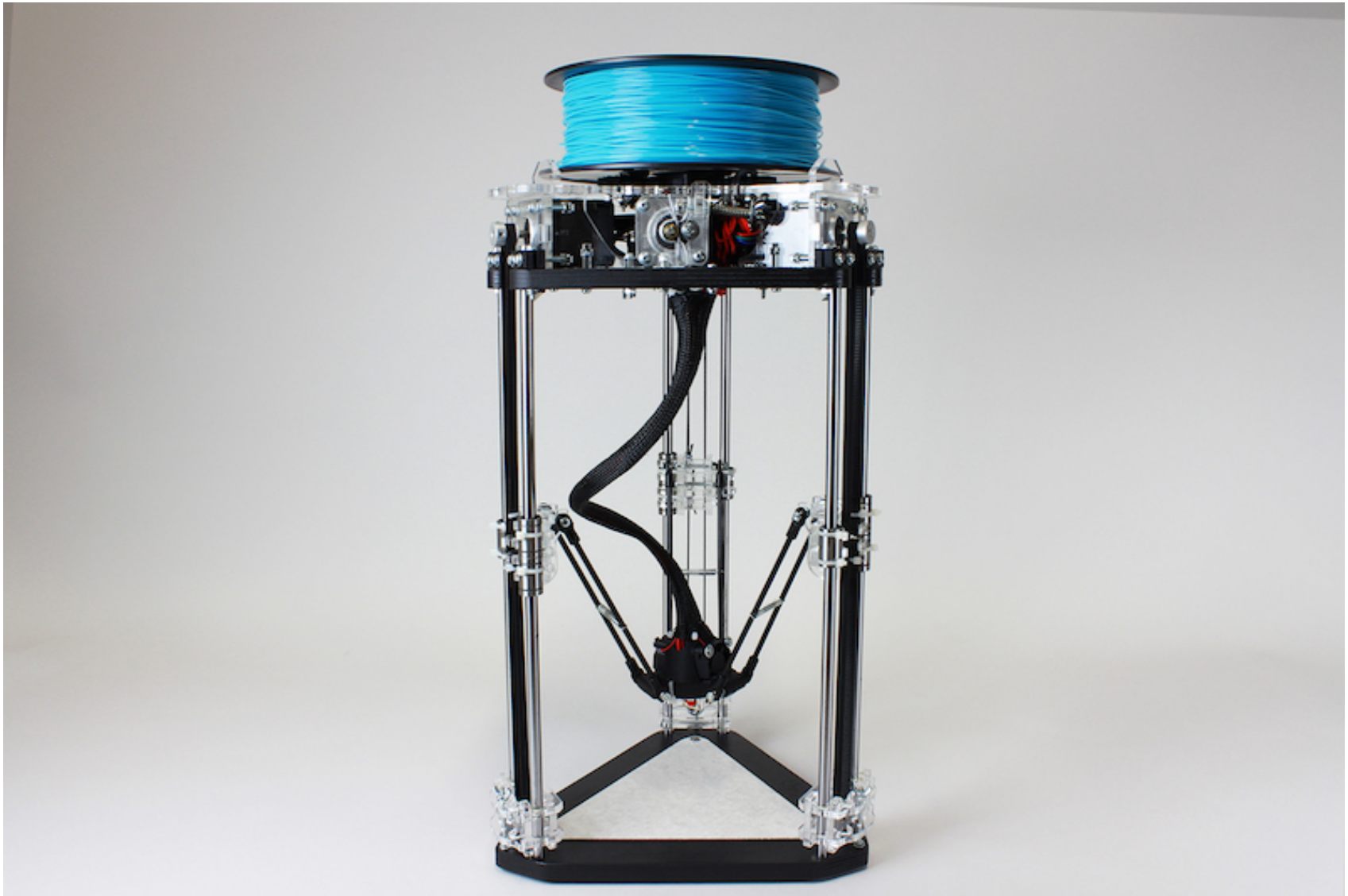
How expensive is FDM 3D-printing ?

A “turnkey” Ultimaker: $\sim$ 2000 EUR



How expensive is FDM 3D-printing ?

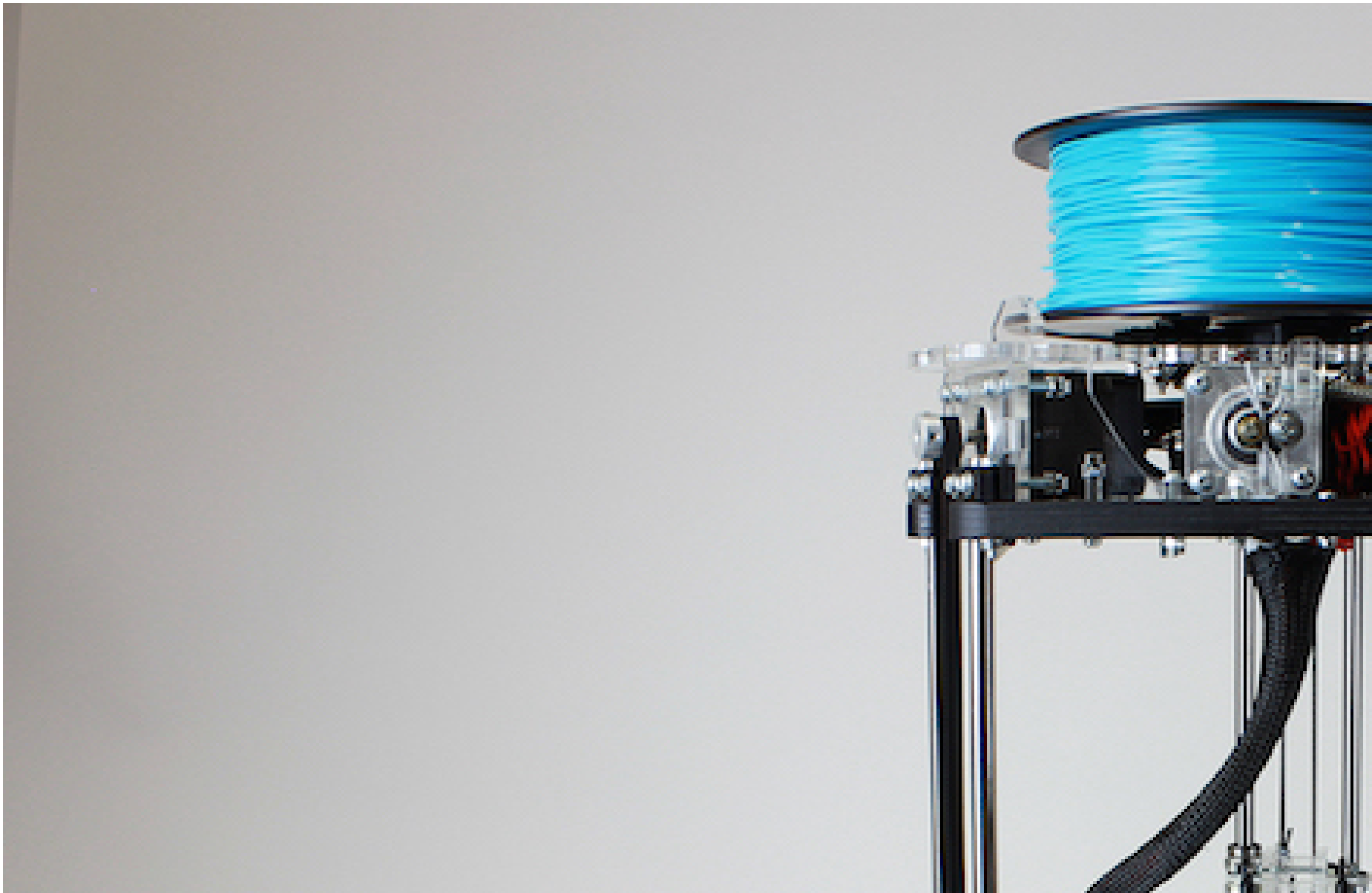
A Reprap-like 3D-printer in kit: $\sim$ 200 EUR



Example: The μDelta from eMotion Tech

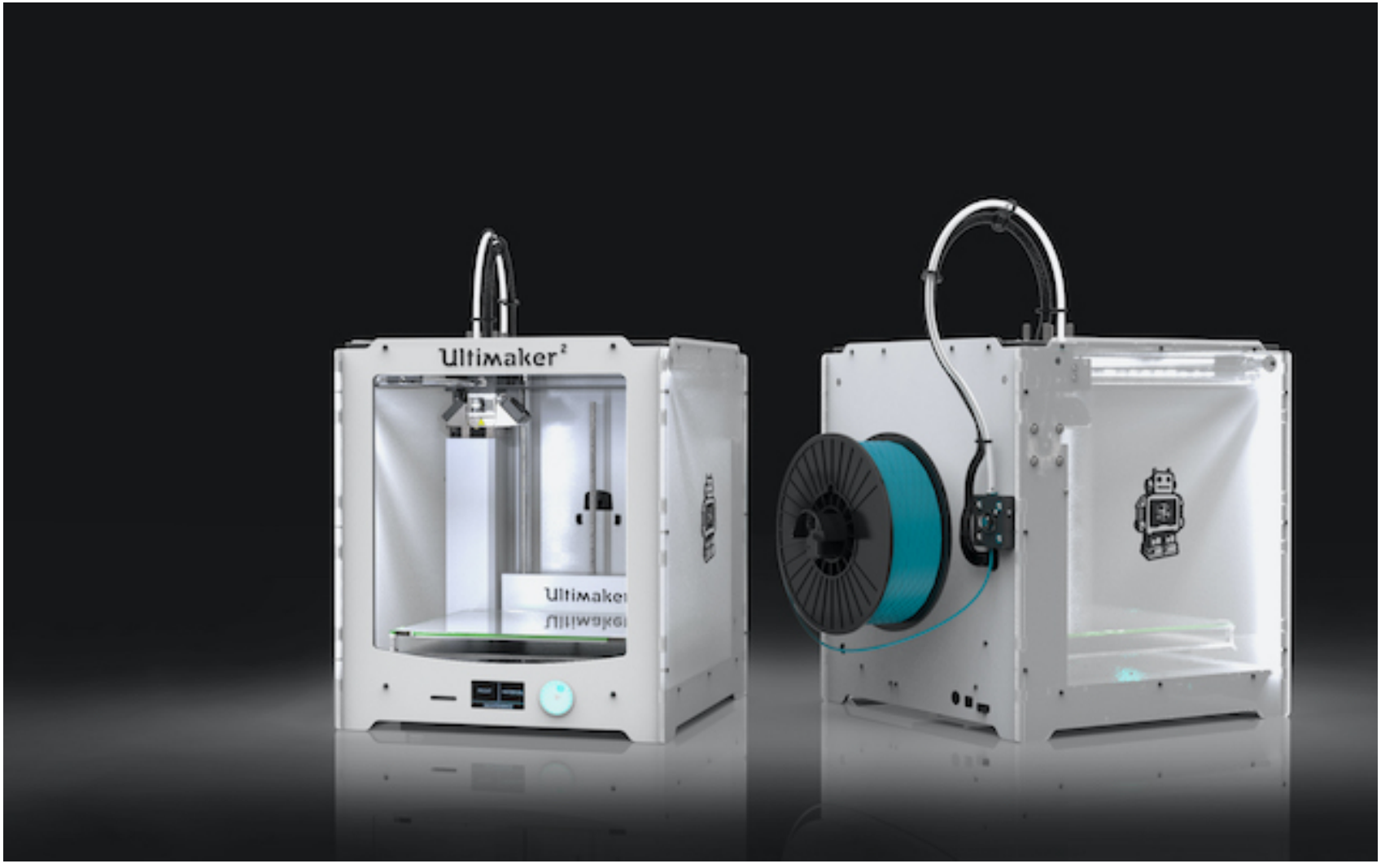
How expensive is FDM 3D-printing ?

Supplies: PLA (corn plastic) spools cost $\sim$ 30 €/kg



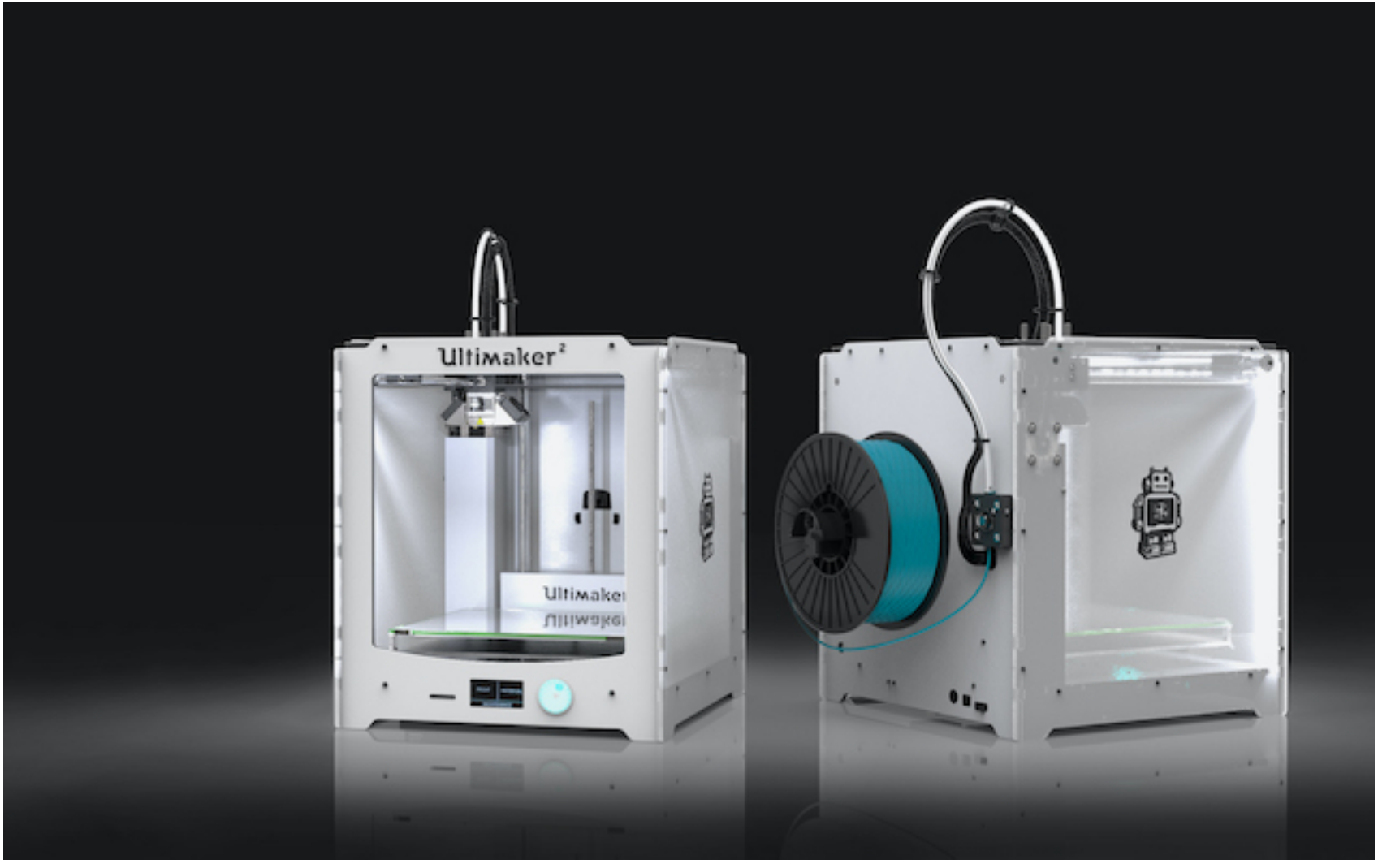
How does 3D printing work?

Focus here: FDM technology (ask me about "powder" printers)



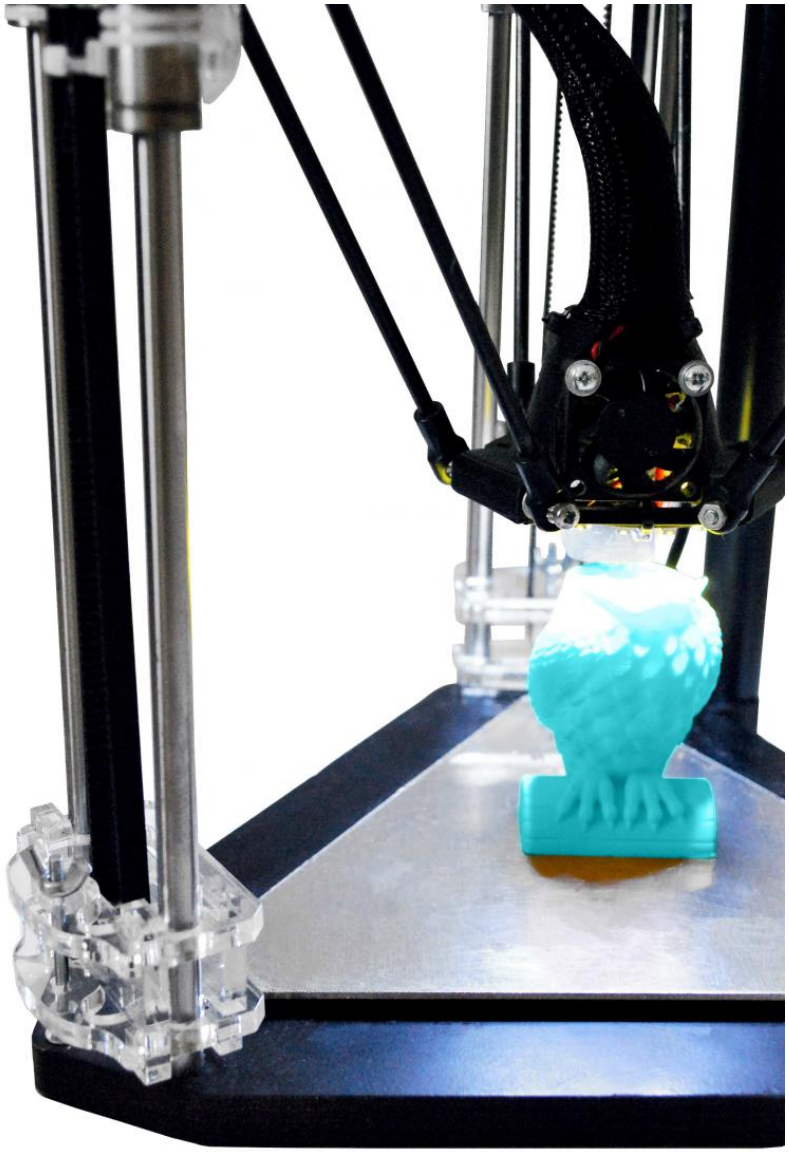
How does 3D printing work?

Plastic wire pulled by tiny motor,



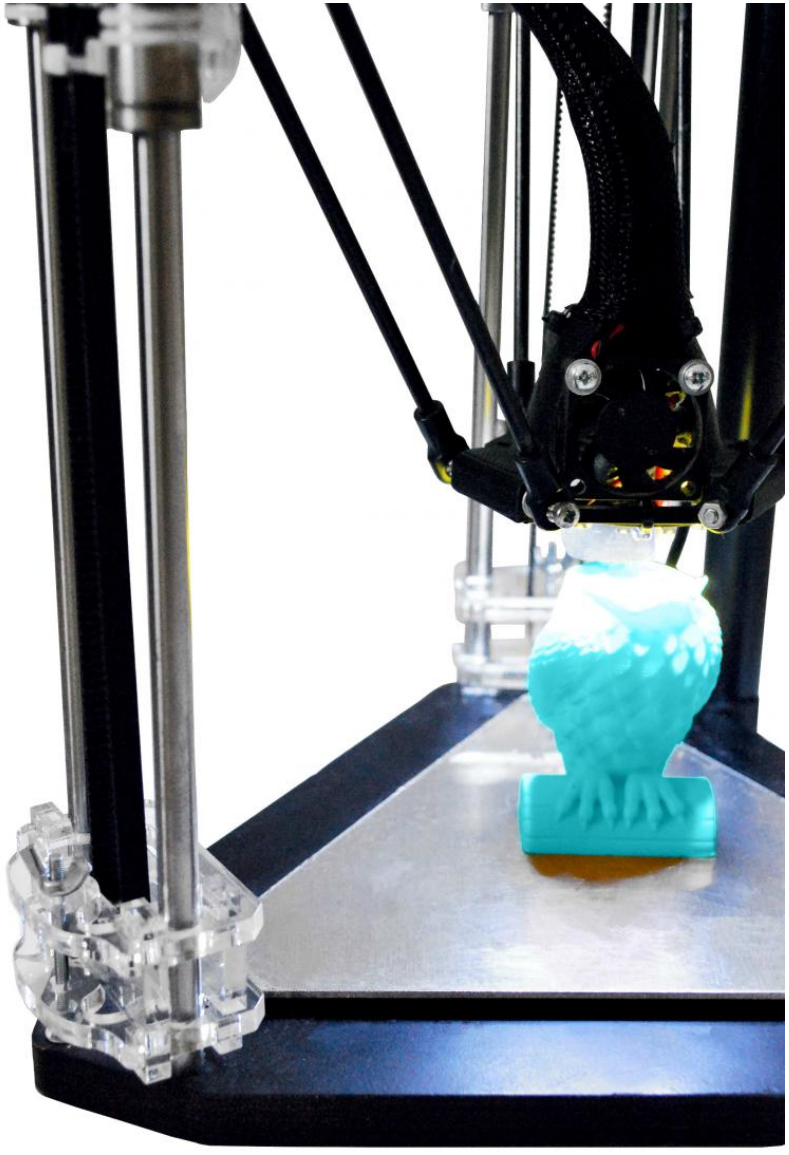
How does 3D printing work?

Plastic wire pulled by tiny motor, “print head” = “nozzle” heats it,



How does 3D printing work?

Plastic wire pulled by tiny motor, “print head” = “nozzle” heats it, wire gets deposited along 2D designs, layer by layer



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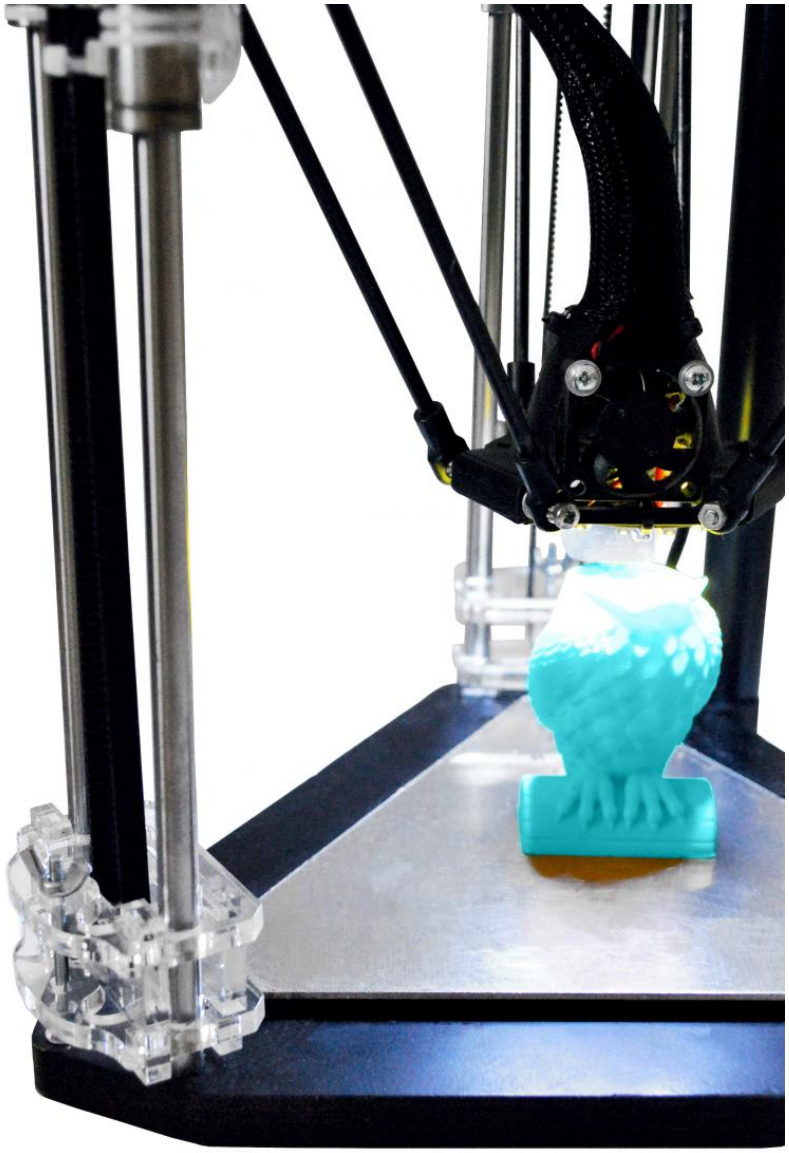

Together the layers make the 3D object: 10 wraps/mm

Thus, how do we get a 3D surface out of its equations?

What software? What filetypes?

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1. Mesh Compute mesh from equation using SageMath, MathMod or similar; save result typically into `.obj`, `.ply` or `.stl` file.

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3. Slice To tell the nozzle what path to follow, which is the only thing that the 3D-printer understands directly, use a slicer like Cura (install it) or IceSL (online), giving a `.gcode` file.

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These are the three basic steps when everything goes fine.

Do you wanna dive in?

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Get inspired: a tour of contemporary mathematical creation

Silviana Amethyst – silviana.org

Mathematical galleries

by silviana amethyst

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mixed media

Interactive Barth Sextic

A 3d printed electronic Arduino-powered interactive art piece. Much of my current work is in this vein.

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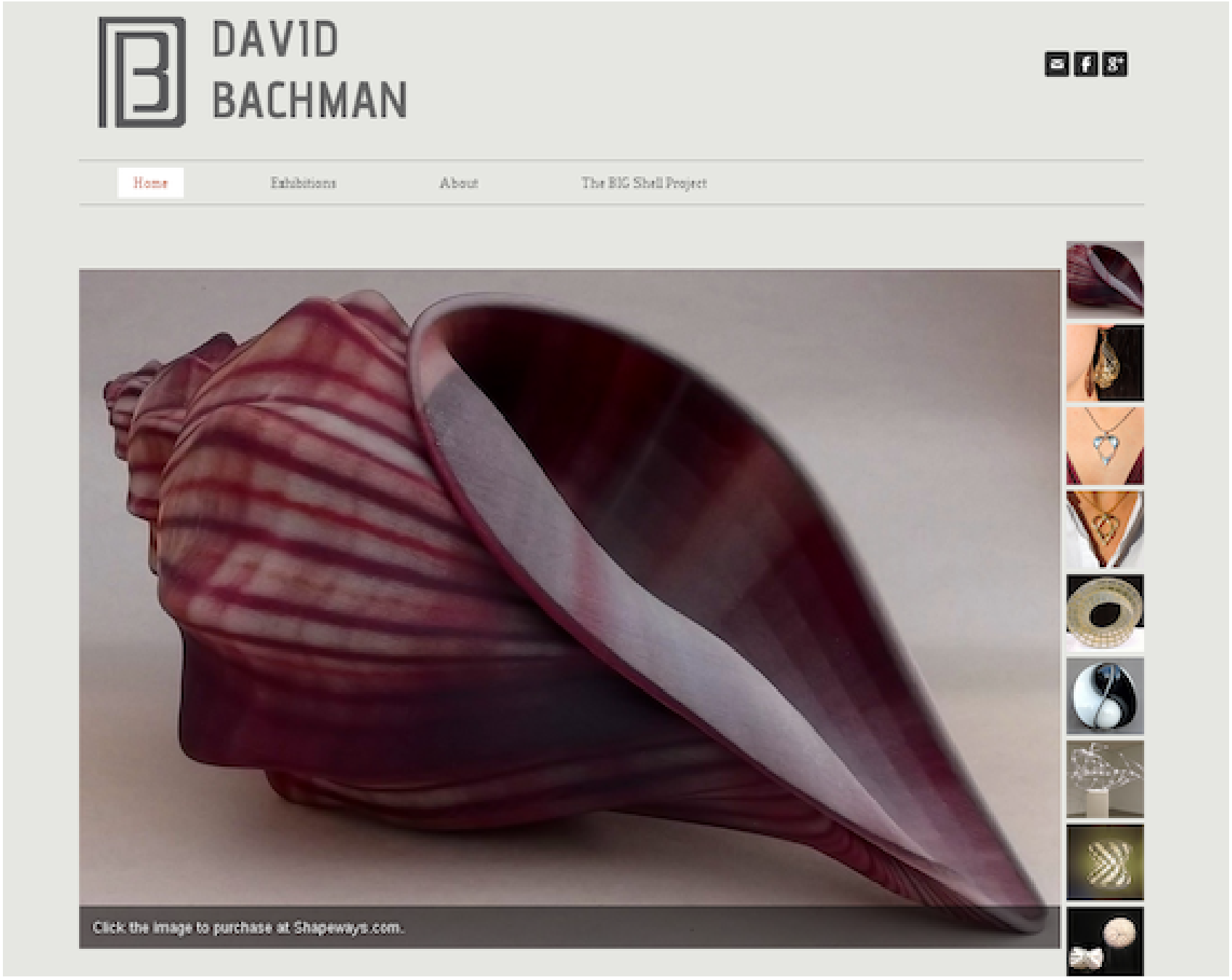
plastic

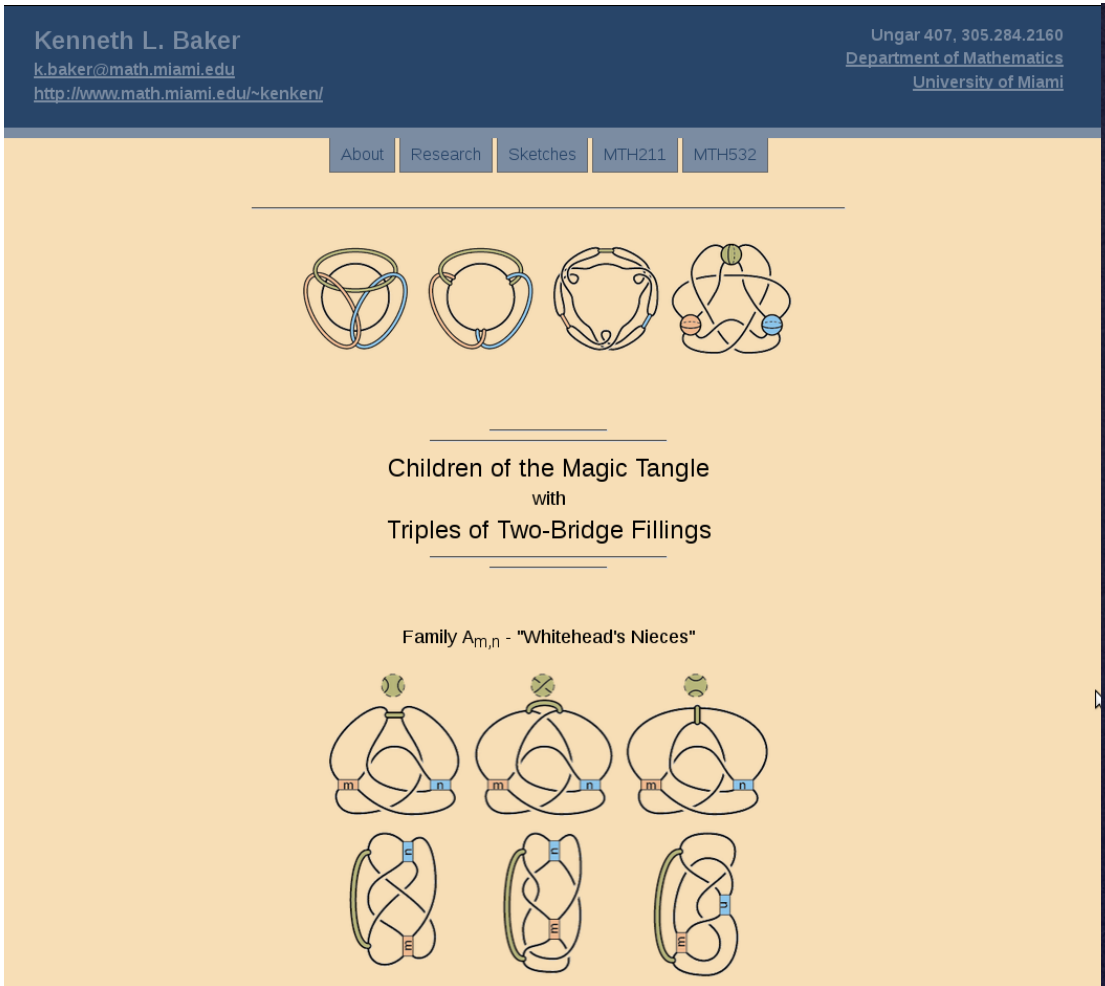
Hauser's algebraic surfaces

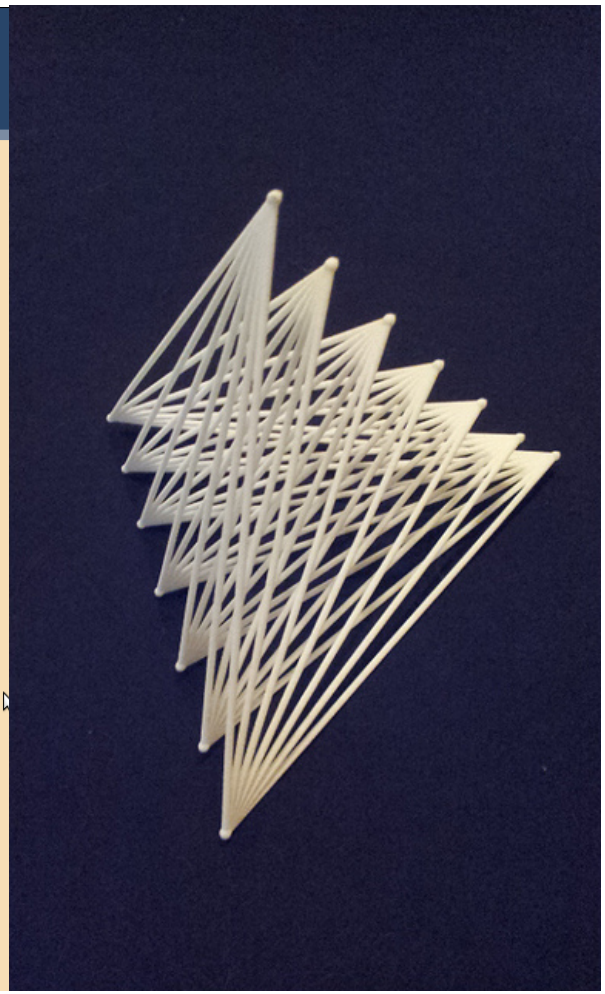
a reproduction in plastic of Herwig Hauser's gallery

David Bachman – davidbachman.org



Kenneth L. Baker – math.miami.edu/∼kenken





Ken Brakke – facstaff.susqu.edu/brakke

Susquehanna University

Ken Brakke
Mathematics Department

Office: 308 Fisher Hall
Phone: 570-372-4466
Fax: 570-372-2743
Email: brakke@susqu.edu
Snail mail: Mathematics Department, Susquehanna University, Selinsgrove, PA 17870-1164

Office Hours (spring, 2016): 1:00-3:00 MWF, 9:00-11:00 TTh officially, but feel free to come in whenever I am there (usually 8:30-5:00 except for classes and lunch and meetings).

Class schedule, Spring 2016:

- MATH:108-04: Introduction to Statistics, 3:00-4:05 MWF, Fisher 339.
- MATH:201-01: Linear Algebra 10:00-11:05 MWF, Fisher 338.
- MATH:221-01:Multivariate Calculus 8:45-8:50 MWF, Fisher 305.

The Surface Evolver

Version 2.70, August 25, 2013

My Surface Evolver is an interactive program for the modeling of liquid surfaces shaped by various forces and constraints. The program is available free of charge.

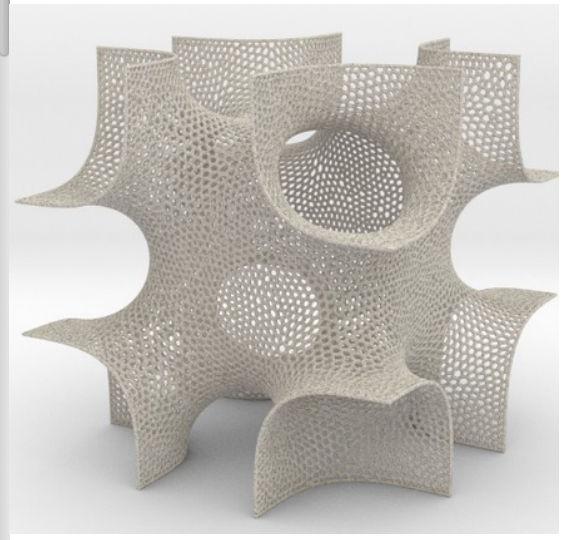
Book on Microdroplets, using Surface Evolver

Jean Berthier and I have collaborated on a book about the behavior of liquids in microfluidic circumstances. Over a hundred Evolver models, available for download from the book's website (if you buy the book).

Plateau's book translated into English

The result of my amateur attempt to translate Joseph Plateau's famous 1873 book on soap films and surface tension.

Random Fractals



Arnaud Chéritat – math.univ-toulouse.fr/∼cheritat

Arnaud Chéritat

English version:

Directeur de Recherches (CNRS) à l'Institut de Mathématiques de Toulouse.

pour m'écrire, suivez ce lien.

Activité professionnelle :

- Parcours, CV.
- Recherche (en anglais).
- Publications, prépublications.
- Gestion de l'ANR ABC.
- Vulgarisation

Travaux, documents et réalisations accessibles sur cette page web :

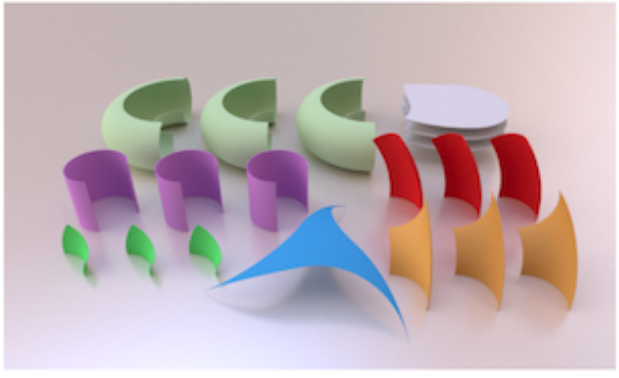
- Les manuscrits d'Herman, tapés en français et en anglais.
- Quelques illustrations mathématiques.
  - Galerie I : Fractals.
  - Galerie II : Dynamique holomorphe et analyse complexe.
  - Galerie III : Géométrie.
  - Animations mathématiques.
- **Applets java** : liens vers mon travail de programmation en Java.
- Logiciel traçant ensembles de Julia et Mandelbrot, Windows 95 (350KO). ©1999 Arnaud Chéritat
- Logiciel (work in progress: Snapshot (800KO)) didactique pour explorer la dynamique de z^2+c, Windows XP. ©2008,2010,2012 Arnaud Chéritat.
- Page web de la conférence en l'honneur des 70 ans d'Adrien Douady (du 9 au 11 mai 2006).
- Exposés.

Sélection :

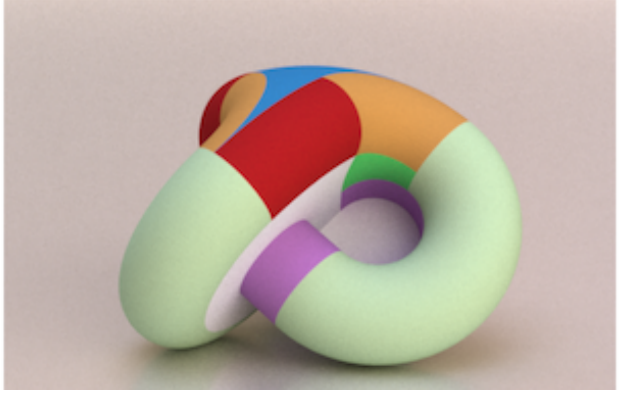
A model of Boy's surface in Constructive Solid Geometry

What is it about?

Take the following pieces



All pieces are obtained from the following primitive shapes: tori, cylinder, planes, and a sphere, and elementary operations: intersection, difference, union, ... (that's constructive solid geometry). Now glue them together as follows:



Jonathan Chertok – formpig.com

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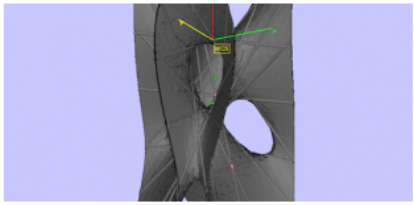
22. mathematical models

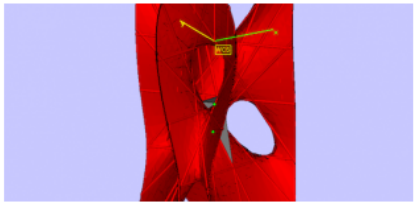
clebsch surface model with spheres



some images of the clebsch surface model with spheres file available on shapeways

Nov 16, 2014 | Have your say »

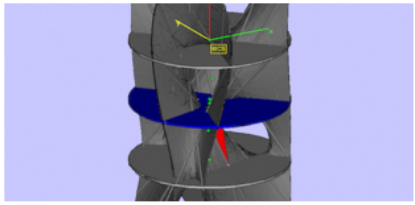
clebsch surface model with pentahedron



some images of the clebsch surface model with pentahedron file available on shapeways

Nov 16, 2014 | Have your say »

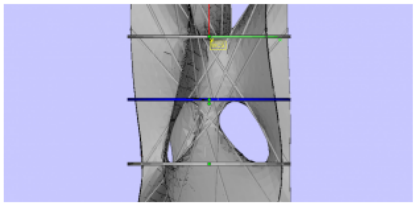
clebsch surface model with 3 horizontal planes and spheres and pentahedron



some images of the clebsch surface model with 3 horizontal planes and spheres and pentahedron file available on shapeways

Nov 16, 2014 | Have your say »

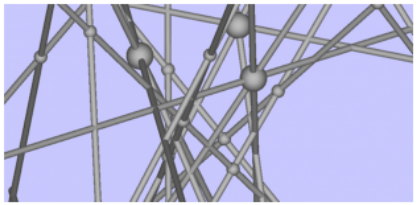
clebsch surface model with 3 horizontal planes



some images of the clebsch surface model with 3 horizontal planes file available on shapeways

Nov 16, 2014 | Have your say »

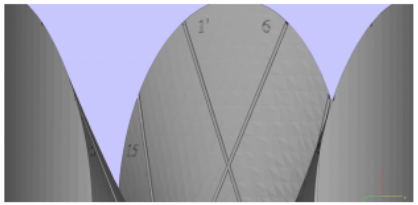
clebsch 23 rods + 31 spheres



some images of the clebsch 23 rods + 31 spheres file available on shapeways

Nov 16, 2014 | Have your say »

numbered clebsch diagonal surface images



some images of the numbered clebsch file available on shapeways

Nov 16, 2014 | Have your say »

classical mathematical model recreation in rapid prototyping printing

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we were quite pleased to recently have our ongoing mathematical model work featured in joshua batson's article in wired magazine. [...]

Aug 31, 2014 | Have your say »

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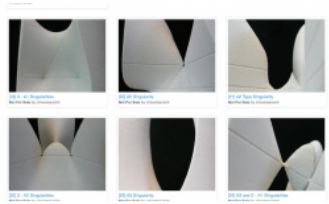
Aug 31, 2014 | Have your say »

mathematical models for sale on SHAPEWAYS



our decades long project to recreate portions of a classical mathematical model collection as rapid prototyping models which were originally [...]

Francesco de Comite – pro.univ-lille.fr/francesco-de-comite/

Myself Anamorphoses Research

Francesco De Comité

Coordinates | Research | Artworks | 3D Printing | Download

Francesco de Comité

Assistant professor in Computer Science

Université des Sciences et Technologies de Lille
Laboratoire d'Informatique Fondamentale de Lille
Bâtiment M3 Informatique
Bureau 218 extension
Cité Scientifique
59655 Villeneuve d'Ascq Cedex
Tel: +33 03 28 77 85 72
Fax: +33 03 28 77 85 37
email: Francesco.De-Comite at univ-lille1.fr

French version

Teaching

- Programming (C, Java)
- Data Mining

Research

Interests

- Machine Learning
- Computer Aided Maths (Geometry)

Administration

- Student Admission.
- In charge of training periods for 3rd year students in Computer Science.

Others

- Image manipulation
- Rendering of mathematical objects
- Book illustrations

3D Printing

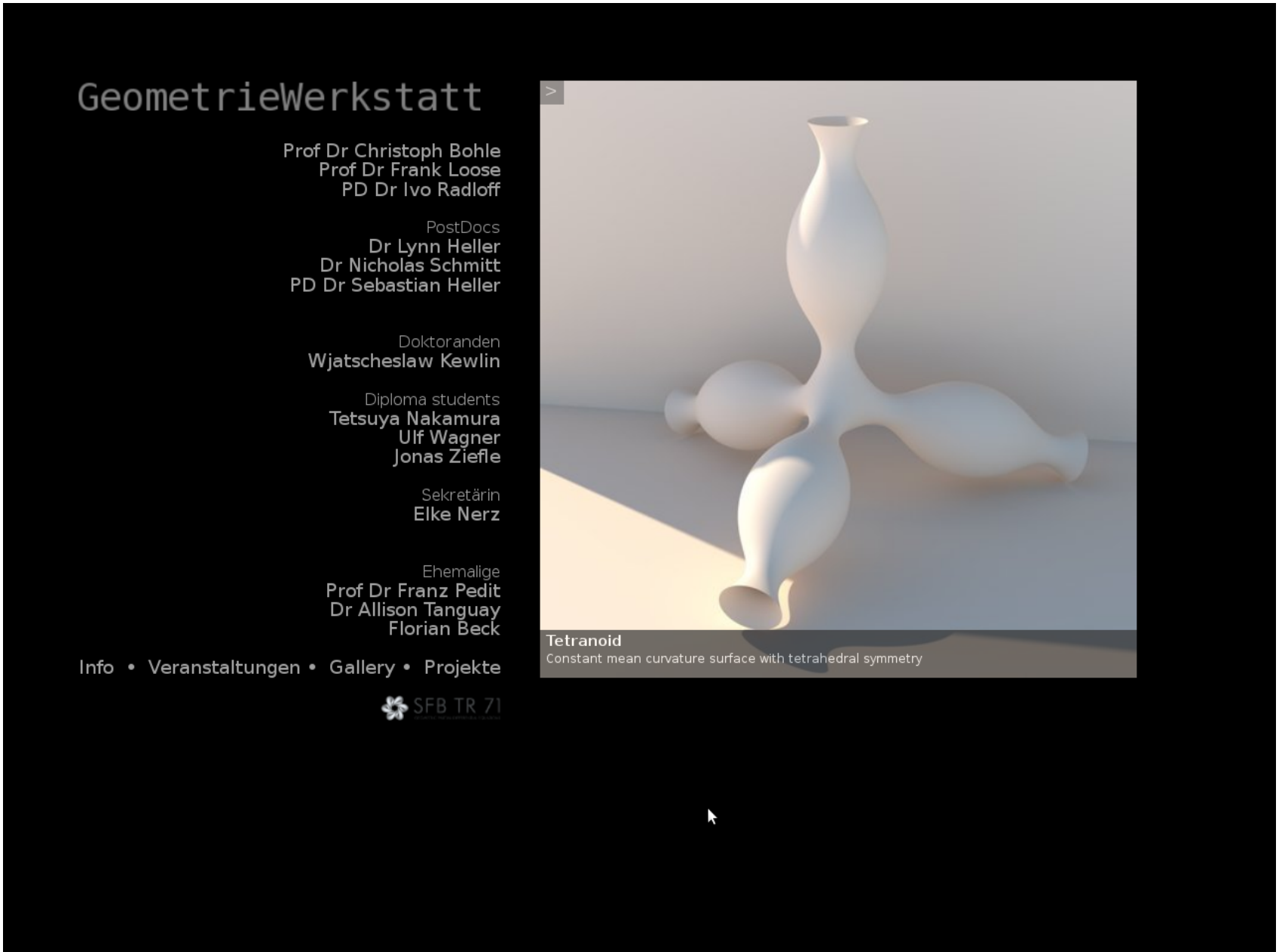
March 2014 : 3D printed hats, based on the Cardioidal Variations, by Milliner Gabriela Ligenza (photos Josh Shiner)

Short listed at 3D PrintShow Fashion Artist of the year, Paris, Octobre 2014.

Music

Marillion's "Sounds that can't be made" album cover

GeometrieWerkstatt – math.uni-tuebingen.de/ab/GeometrieWerkstatt/



Bathsheba Grossman – bathsheba.com

Bathsheba Sculpture

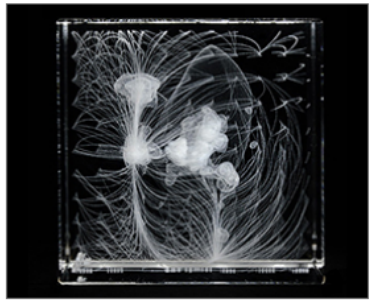
Sculpture | Laser Crystals | Gallery | About | Contact | Cart

Welcome! I'm a designer for 3D printing, mostly in steel. Here you'll find sculpture, pendants, cephalopods, and laser etched glass.

Follow

Follow

News about the state of this art.

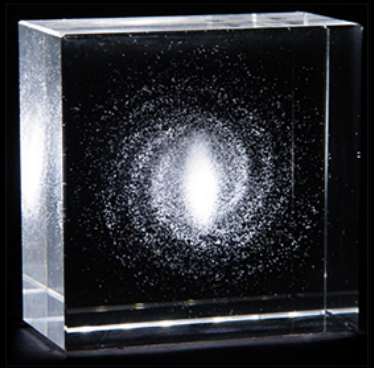


A new cube! Laniakea is a large scale map of galactic clusters.

The Klein Bottle Opener

Laser Glass

Scientific data laser etched in full 3D, inside cubes of clear glass. This begins where 3D printing leaves off: it handles intractable, unstructural information with precision and grace.



The Milky Way, seen from outside

Crystal Proteins

Got your own intractable data? At CrystalProtein I can put it in glass for you. Keychains to large awards, quantities one to hundreds. Proteins and small molecules are a specialty, but it's always interesting to see something different.

George Hart – georgehart.com

George W. Hart

e-mail: george@georgehart.com
http://www.georgehart.com/

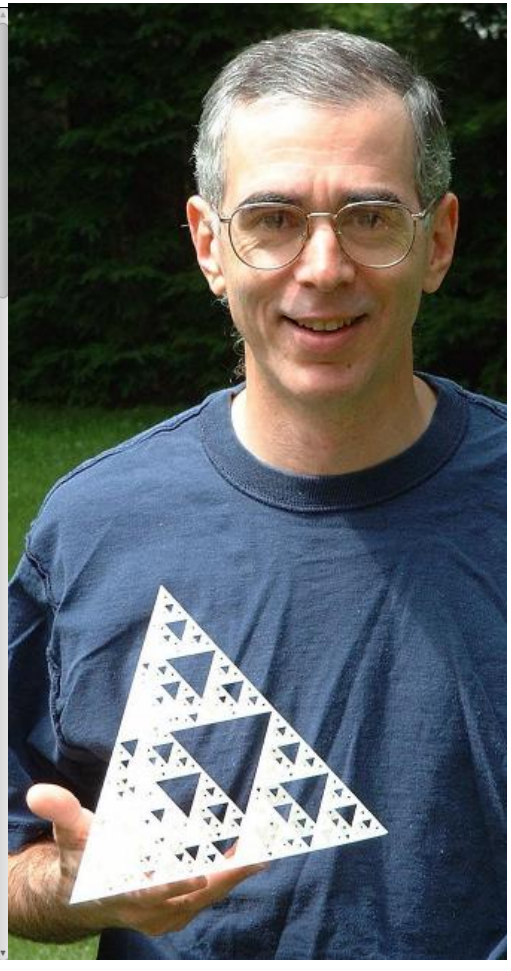
3 Stony Rd.
Stony Brook, NY
11790 USA

I am a research professor in the engineering school at Stony Brook University and a freelance mathematical sculptor/designer. I'm always looking for interesting sculpture, lecture, and workshop opportunities. **Invite me!** I spent much of the past four years helping to create and design the Museum of Mathematics in NY. Yes, I am related to (my daughter) Vi Hart. An enormous amount of my work is freely available on my web pages. There are no ads. If you would like to support my mission of showing the world that math is cool, please feel free to make a donation:

Donate

This is a top-level table of contents into my hundreds of web pages:

- Geometric sculpture (I am a sculptor. Take a look and enjoy my work.)
  - **Color postcards available**
- My YouTube Videos (showing math is cool)
- ***Mathematical Impressions*** -- Video essays I'm making for the Simons Foundation web site. (activities)
- Rapid Prototyping Models (collects RP models from several projects of mine.)
- Puzzles (I also design geometric assembly puzzles)
- Making Math Visible (classroom activities)
- Some Trip and Workshop Photos:
  - **Lafayette College** (Easton, PA, June, 2014)
  - **Phillips Academy** (Andover, MA, April, 2014)
  - **Brown University** (Providence, RI, March, 2014)
  - **Gathering for Gardner Conference** (Atlanta, GA, March, 2014)
  - **TEDx talk at Wellesley** (MA, Feb, 2014)
  - **Sculpture Barn Raising at JMM Conference** (Baltimore, MD, Jan, 2014)
  - **Cardboard Construction at Packer Collegiate Institute** (Brooklyn, NY, Jan, 2014)
  - **Cardboard Construction at St. Paul's School** (Concord, NH, November, 2013)
  - **Princeton University** (October, 2013)
  - **Geometry Ascending a Staircase** (Duke University, NC, October, 2013)
  - **MathCamp 2013** (Colby College, Maine, July, 2013)
  - **Aalto University** (Helsiki, Finland, April, 2013)
  - **Teacher's Workshop at Math for America** (NYC, Feb, 2013)
  - **Running for Office - Twenty Twelve** (Albion, MI, November 2012)
  - **Cardboard Conglobulation at SCSU** (New Haven, CT, October 2012)
  - **Cardboard Construction at the Bridges Conference** (Towson, MD, July 2012)
  - **Math for America** (Manhattan, NYC, January 2012)
  - **Mathcamp 2010** (Mt. Holyoke college, August 2010)



Geoffrey Irving – naml.us

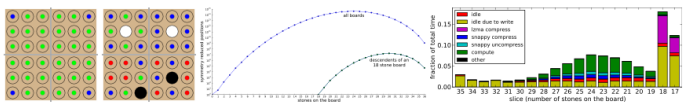
Geoffrey Irving

Ph.D. Computer Science, Stanford
B.S. Mathematics and Computer Science, Caltech
https://naml.us/blog
irving@naml.us

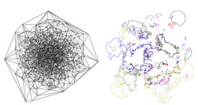
Research

My research interests include computational physics, computer graphics, compilers and languages, and games.

- Solving pentago on a supercomputer, with online exploration of the results.
  Irving, G., "Pentago is a first player win: strongly solving a game using parallel in-core retrograde analysis, 2014, arxiv.org/abs/1404.0743.

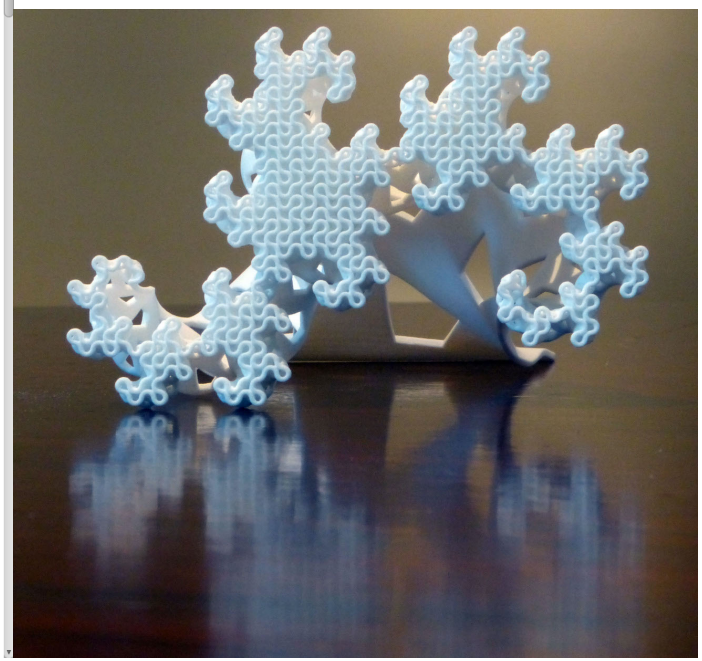


- Robust computational geometry using infinite series of deterministic pseudorandom perturbations (with Forrest Green).
  Irving, G., Green, F. "A deterministic pseudorandom perturbation scheme for arbitrary polynomial predicates, 2013, arxiv.org/abs/1308.1986.

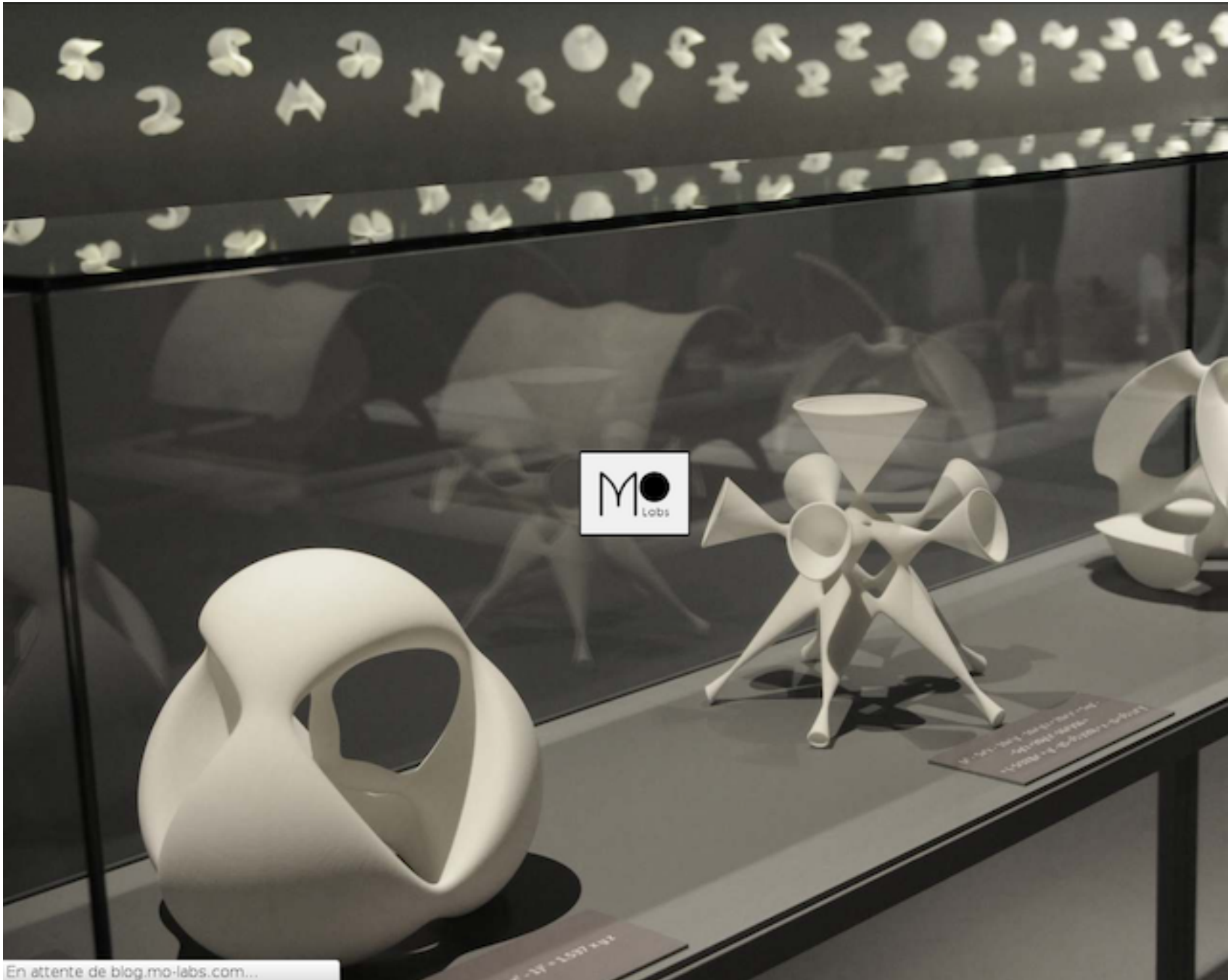


$$f_0 = f(x)$$
$$f_1 = f(x + \epsilon_1 y_1)$$
$$f_2 = f(x + \epsilon_1 y_1 + \epsilon_2 y_2)$$
$$f_3 = f(x + \epsilon_1 y_1 + \epsilon_2 y_2 + \epsilon_3 y_3)$$
$$\vdots$$

- Fractal curves visualized as surfaces using the third spatial dimension to represent complexity (with Henry Segerman).



Oliver Labs – mo-labs.com

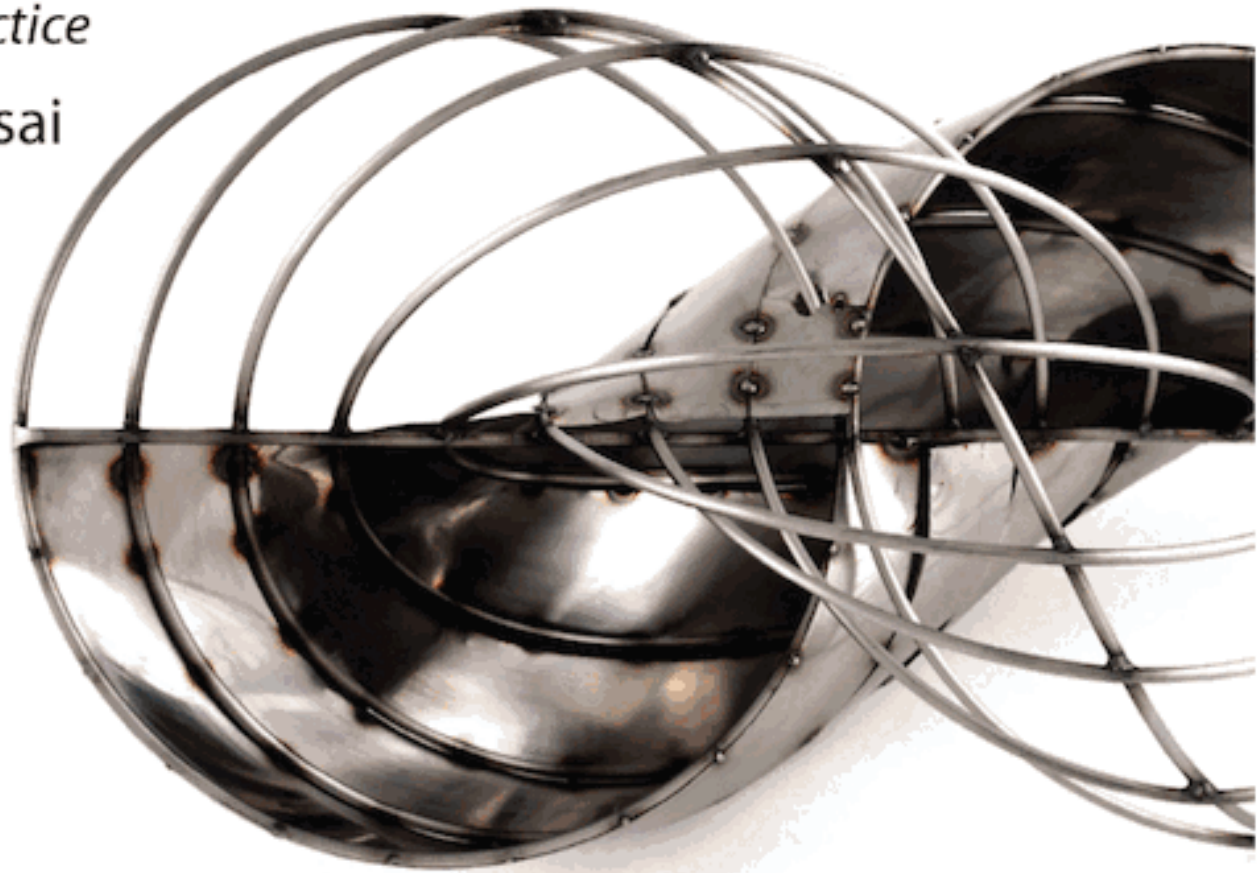


Lun Yi London Tsai – londontsai.com

home exhibition sculpture drawing/painting film biography contact

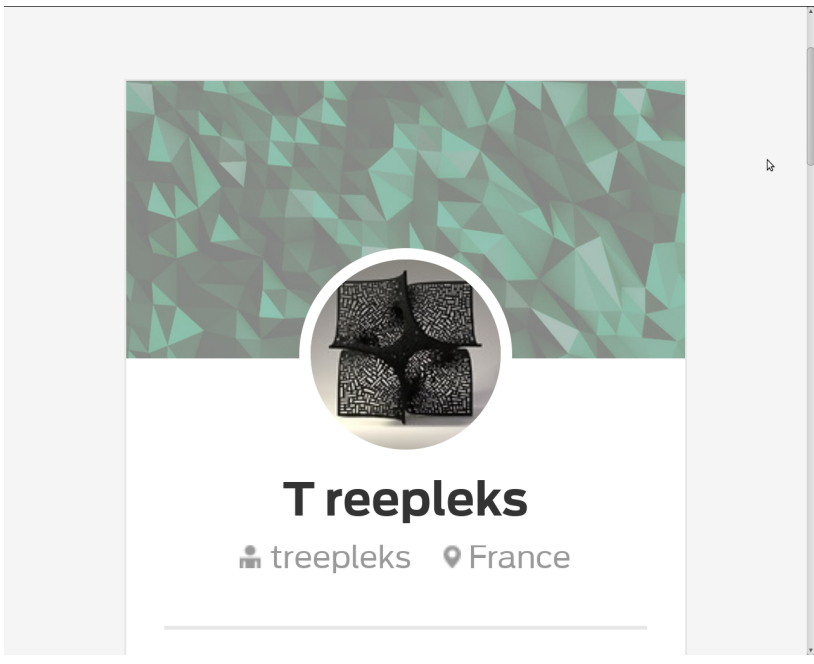
artistic practice

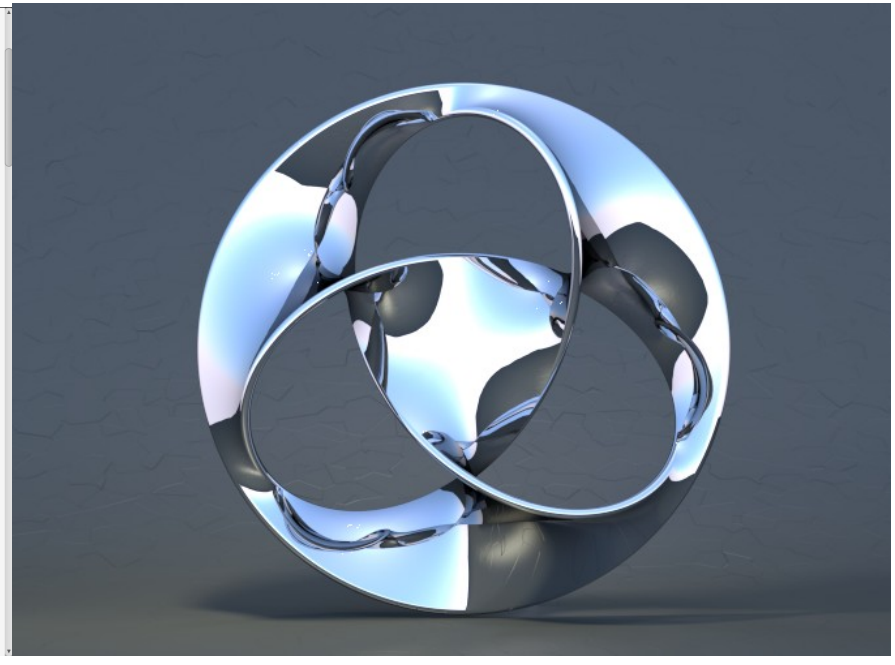
London Tsai



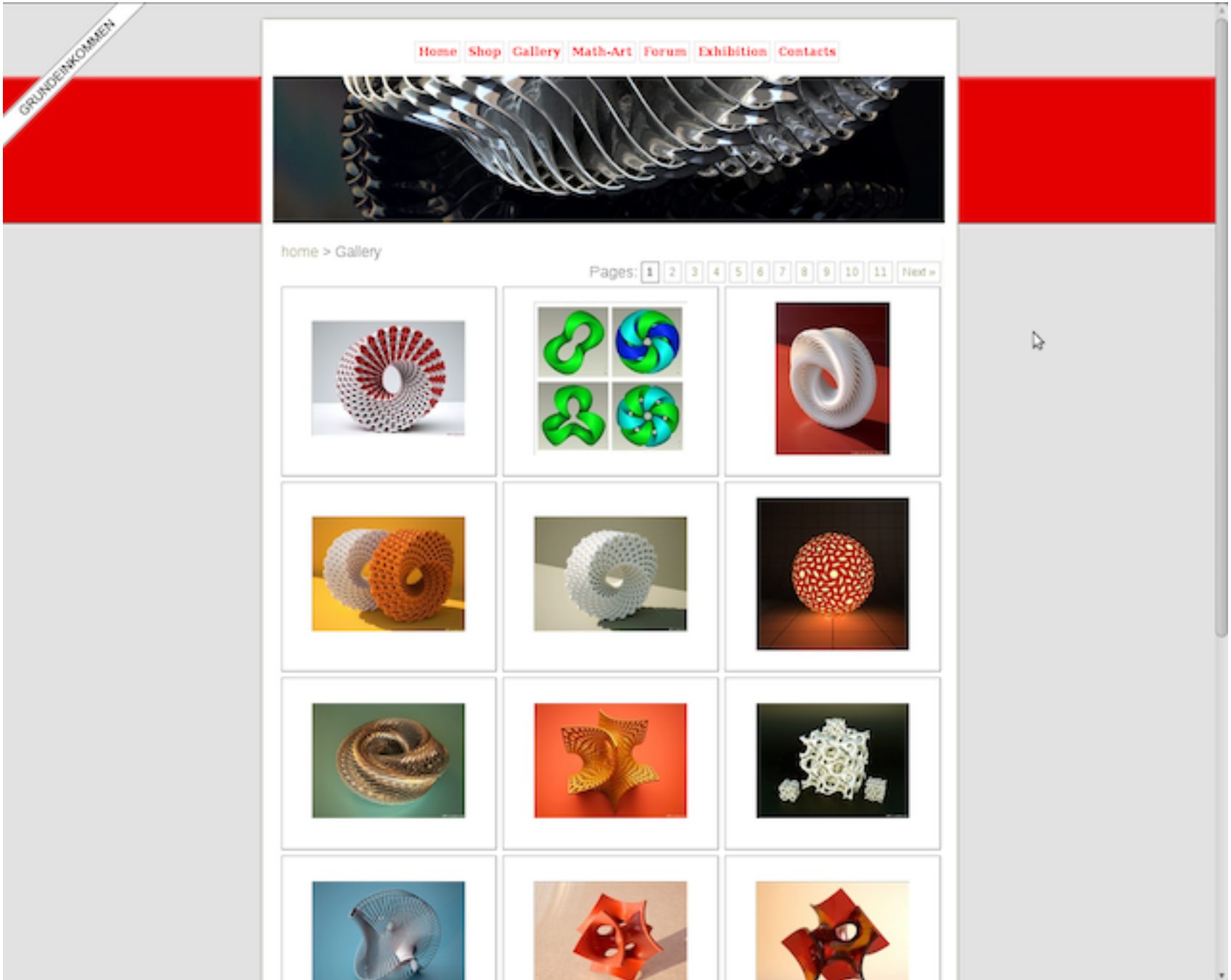
to the ends of the world, 2010, stainless steel, 28 x 14 x 14 in

T. Reepleks – thingiverse.com/treepleks





Torolf Sauermann – evolution-of-genius.de



Saul Schleimer – homepages.warwick.ac.uk/∼masgar

Saul Schleimer

Office: B2.14 Zeeman
Phone Number: 024 7652 3560
Fax Number: 024 7652 4182
Email address: s.schleimer at warwick dot ac dot uk

Teaching: I am not teaching in term two. Past courses and students.

Office hours: (Term II, 2015-2016) Friday 1:00pm - 2:00pm and by appointment.

Seminars: The geometry and topology seminar. Past seminars.

Conferences: A meta-list of conferences.

Research: My research page, papers at the arXiv and at the Front, and reviews at MathSciNet (subscription only).

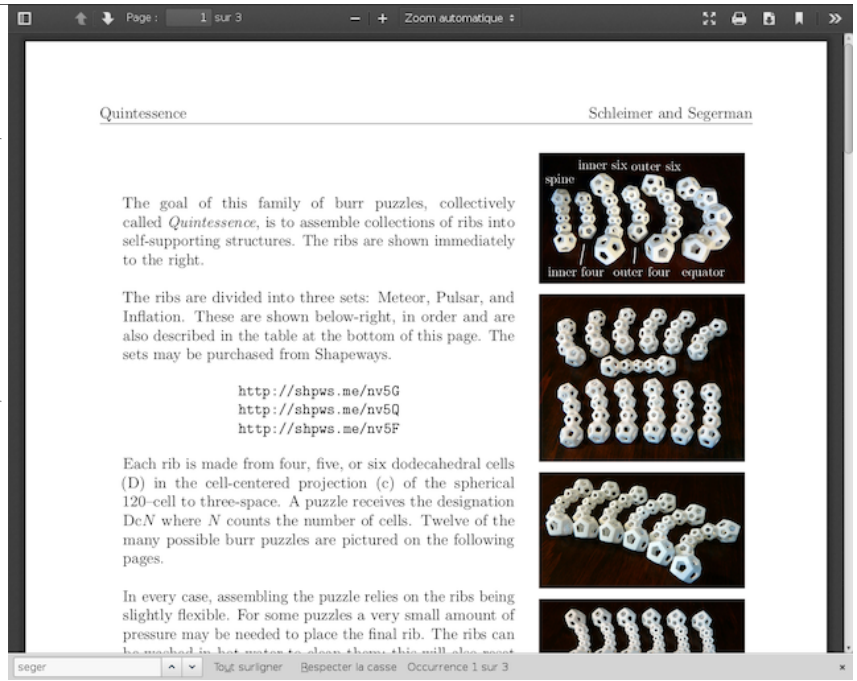
Exhibit and talks: Slides, videos, and/or other links for my art exhibit and various talks.

Junk: Various random links.

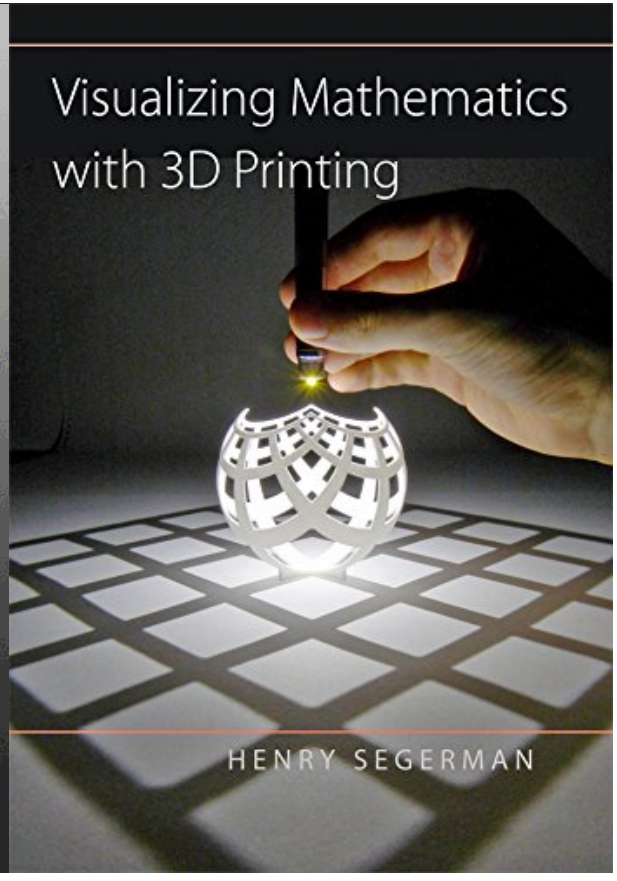
Warwick: Math department webpage.

Last touched: Tuesday, 7 April 2015 15:20:10 BST.

www.ams.org/msnmain?fn=130&pg1=ICN&s1=schleimer



Henry Segerman – segerman.org



Carlo Séquin – people.eecs.berkeley.edu/∼sequin/

Carlo H. Séquin

Professor in the Graduate School, CS Division, EECS Dept., U.C. Berkeley, (Graphics Group)
Facilities Development Officer, College of Engineering

CONTACT:	UNIVERSITY OF CALIFORNIA COLLEGE OF ENGINEERING EECS COMPUTER SCIENCE DIVISION 639 SODA HALL # 1776 BERKELEY CA 94720-1776	Email: sequin(at)eecs(dot)berkeley(dot)edu Phone: (510) 642-5103 FAX: (510) 643-1289

SCHEDULE:	Weekly Schedule, Office Hours	Travel Plans

Soda Hall | Jacobs Dll | Pillar of Engineering | CS39:Symm&Topo | Art & Math | Sculpture | Usr.Gd.Inv.3D.Mod | Sculpting Geometry | Twisted Tori | Trip

Recent Work: SCULPTURES | EXHIBITS | TALKS | PAPERS | REPORTS | VIDEOS | CONSTRUCTION PROJECTS

Recent Teaching Assignments:

- Fall 2014: URAP: UGIS 192 D: Research Physical Sciences/Engineering
- Spring 2014: URAP: UGIS 192 D: Research Physical Sciences/Engineering
- Fall 2013: URAP: UGIS 192 D: Research Physical Sciences/Engineering
- Summer 2013: CompSci 97; CompSci 197: Curricular Practical Training (Field Studies)
- Spring 2013: CS 39: Symmetry & Topology (Freshman Sophomore Seminar)
- Spring 2013: CompSci 97; CompSci 197: Curricular Practical Training (Field Studies)
- Spring 2013: CS299: Graduate Research
- Fall 2012: CS 284: Computer-Aided Geometric Design and Modeling (Splines, Subdivision, Surface Optimization, Texturing)
- Spring 2012: CS299: Graduate Research
- Spring 2012: UGIS 192 D: Research Physical Sciences/Engineering
- Fall 2011: CS 285: (Procedural) Modeling of Solid Shapes (and Rapid Prototyping)
- Spring 2011: CS 184: Introduction to Computer Graphics
- Previous Teaching Assignments

Research Interests and Projects:

Laura Taalman – mathgrrl.com

Featured

- Now
- Recent
- 3D Catalogs

Academic

- Publications
- Courses
- Labs
- Presentations

mathgrrl

- Designs
- Hacktastic
- STRUCTURE

Books

- Brainfreeze Puzzles
- Taking Sudoku Seriously
- Taalman/Kohn Calculus

Back to top

mathgrrl Designs

3D models and other geeky stuff

Perko Morph

Designed with KnotPlot, MeshLab, TopMod, and Meshmixer; 3D printed in full color powder with binder.

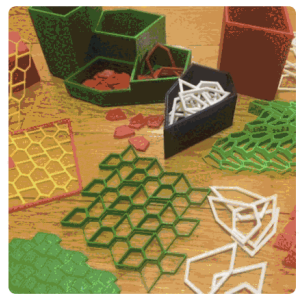
Giant Spiky Perko Knot

Designed with KnotPlot, TopMod, and Cura; 3D printed with FDM in Polylactic Acid with custom supports.

LOSS Pendant

Organic Snowflake Ornament – Estonia

Perko Morph



Pentomizer

→ See All Designs

Recall: from equation to 3D printed surface

The 3 basic steps

1. **Mesh** Compute mesh from equation using SageMath, MathMod or similar; save result typically into `.obj`, `.ply` or `.stl` file.

2. **Solid** If surface not "watertight", i.e. does not enclose volume, thicken using Blender; export result as `.stl` file.

3. **Slice** To describe nozzle path, i.e. pilot the 3D-printer, use slicer like Cura (installed) or IceSL (online); giving a `.gcode` file.