DIMACS WORKSHOP on ALGORITHMIC MATHEMATICAL ART

Is Popularization of Polynomiography Possible?

Bahman Kalantari
Department of Computer Science
Rutgers University

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(in a PBS Science program on the origin of Time)

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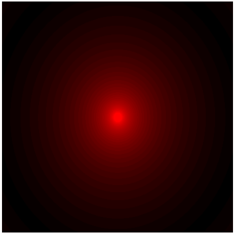

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There are endless images and discoveries waiting to be unveiled.

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A BLENDING of **ART**, **MATH**, **SCIENCE**

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A BLENDING of **ART**, **MATH**, **SCIENCE**

A VEHICLE to **ATTRACT KIDS** to **MATH** and **SCIENCE**

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A **MEDIUM** for **ALL K-12 STUDENTS** and **TEACHERS**

A **MEDIUM** for **ART** and **MATH** and **SCIENCE** and **FUN** and **GAMES**

A Sort of Pedagogical Analogy

PHOTOGRAPHY versus POLYNOMIOGRAPHY

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- Photographer

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PHOTOGRAPHY

- Photographer
- Camera(Lenses)

A Sort of Pedagogical Analogy

PHOTOGRAPHY versus POLYNOMIOGRAPHY

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Q and A

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A. No, but you should be warned that you may end up liking math in the process.

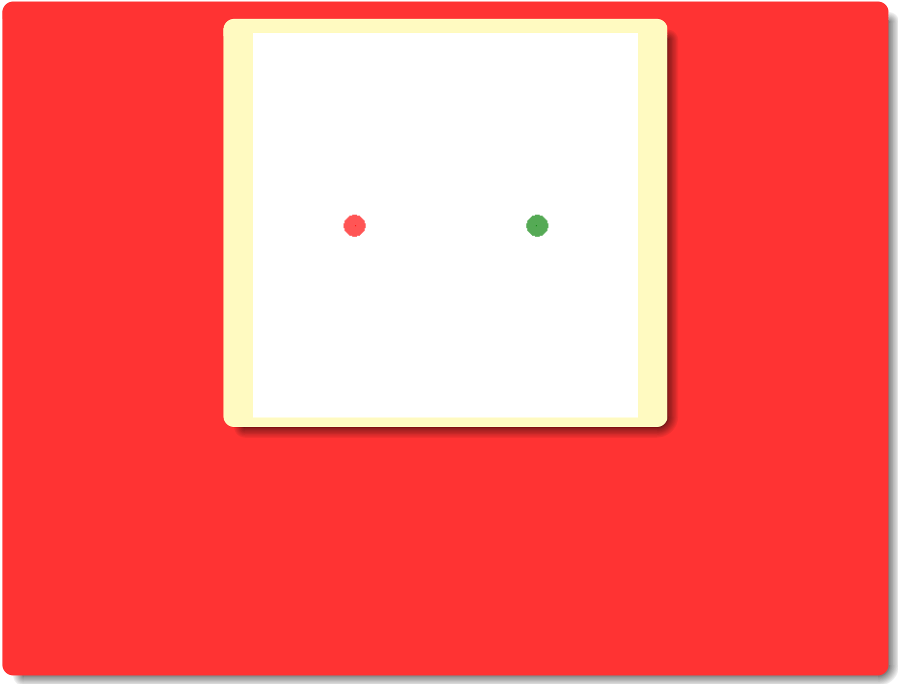
Q. Is there an age limit on playing this game?

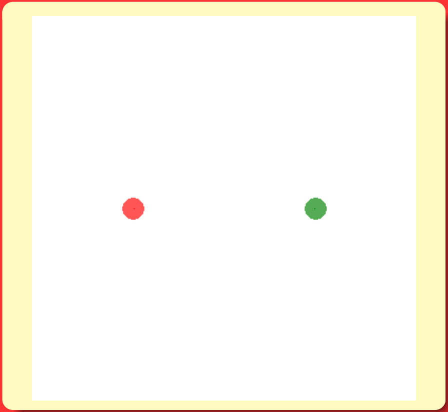
A. Yes, with appropriate development of the software the recommended age is between 5 and 125.

Let’s Play Hide-and-Seek

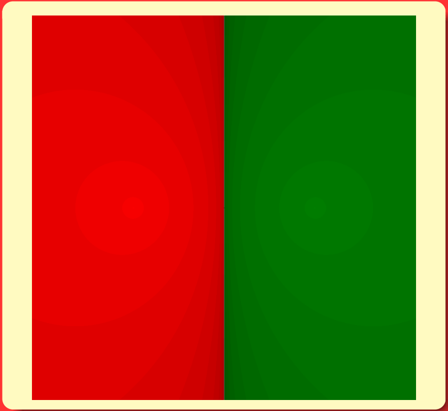
Let’s Play Hide-and-Seek

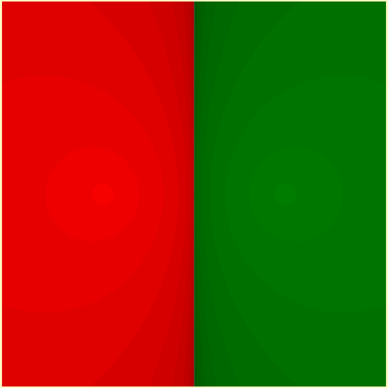
Let’s Take Two Dots



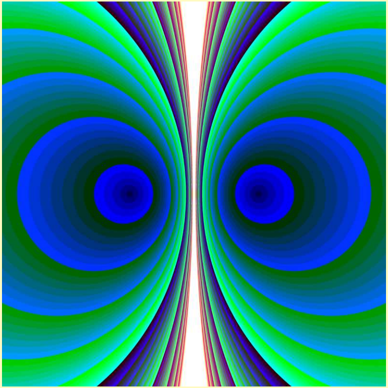


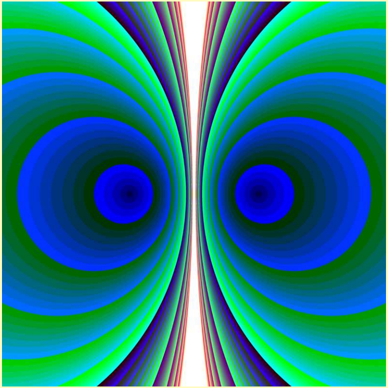
Hiding Equation: $x^2 - 2 = 0$.





A *polynomiograph* of the equation $x^2 - 2 = 0$.



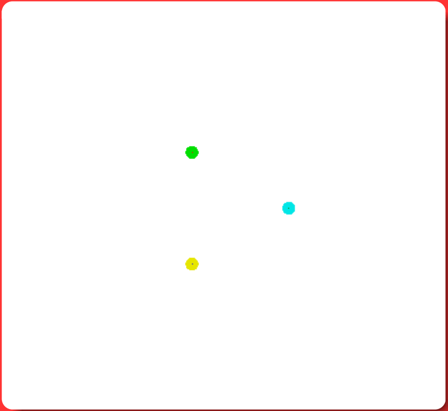


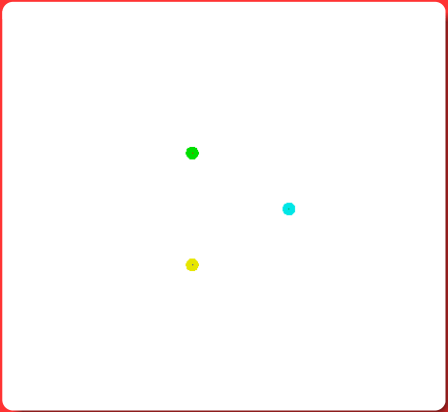
Another polynomiograph of the equation $x^2 - 2 = 0$.

Let's Play Hide-and-Seek Again

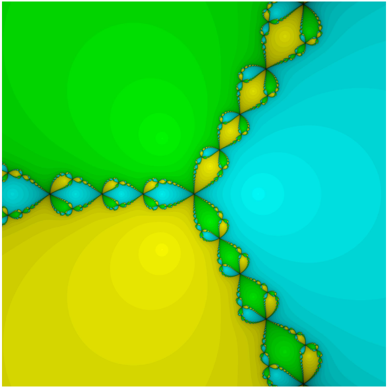
Let’s Play Hide-and-Seek Again

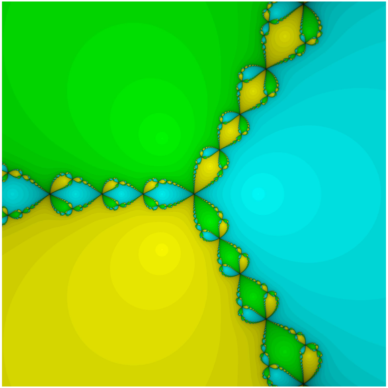
Let’s Take Three Dots



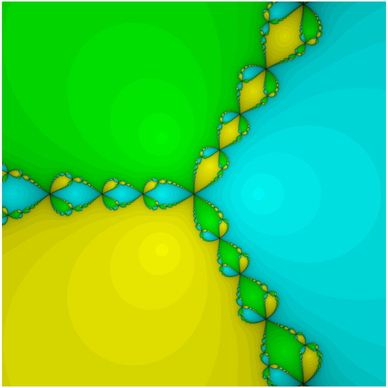


Polynomial Equation: $x^3 - 1 = 0$.





A polynomiograph of $x^3 - 1 = 0$.



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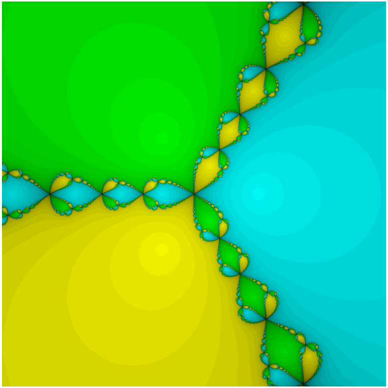
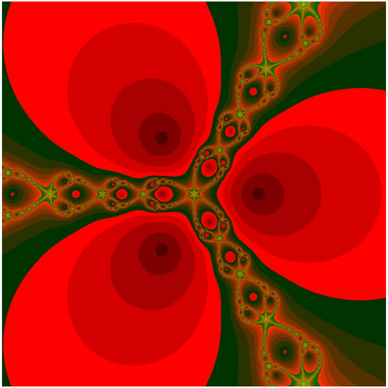
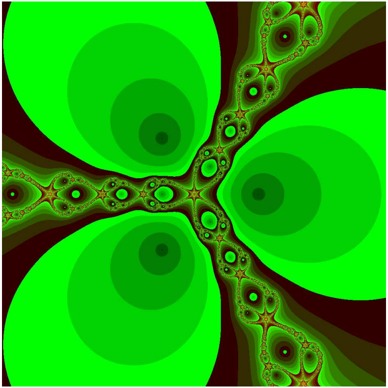
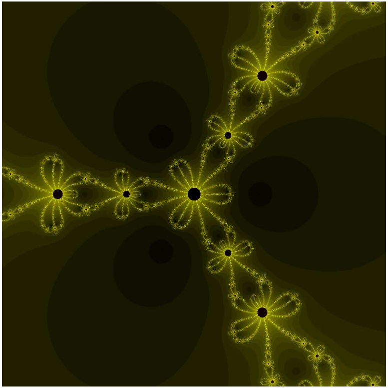
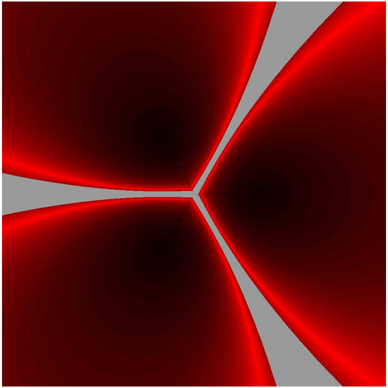


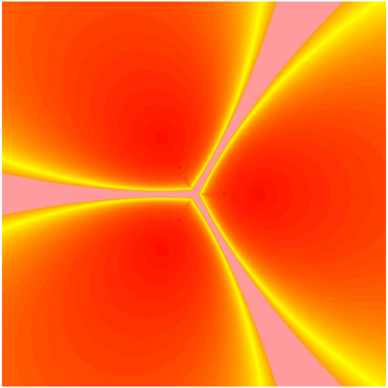
A polynomiograph of $x^3 - 1 = 0$.
Can we create other images from this equation?
Yes, many more ...

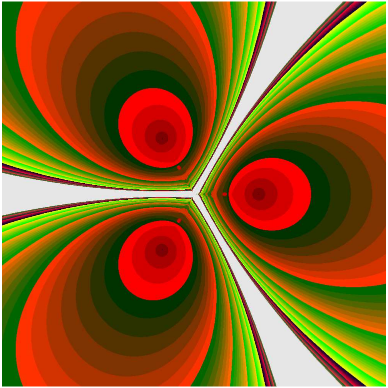


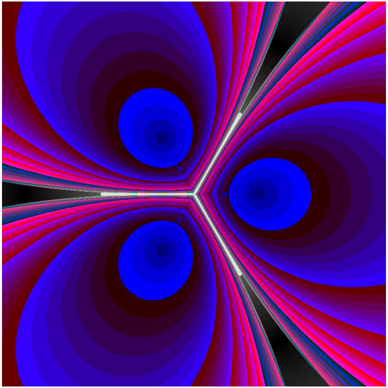


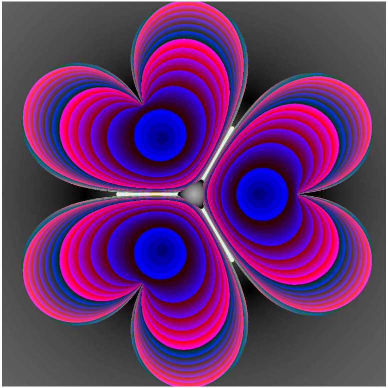


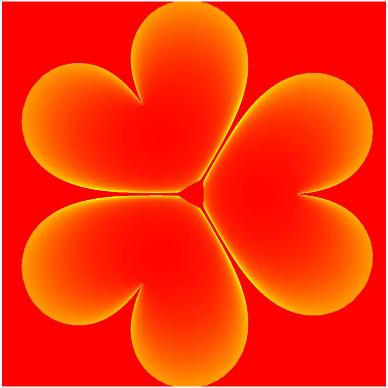


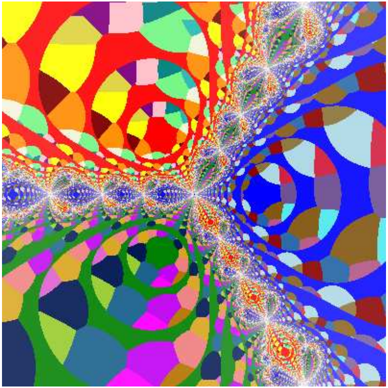


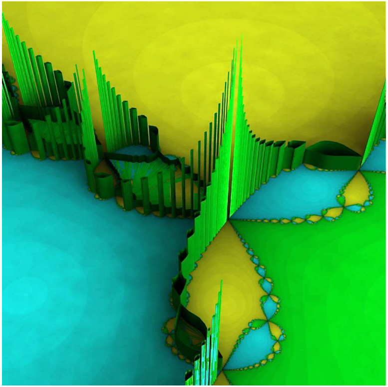


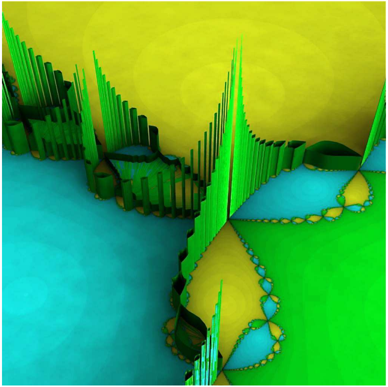












For a 3D animation based on $x^3 - 1$ see YouTube:
“Rise of Polynomials" at www.polynomiography.com

Polynomial Equation

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Polynomial Equation

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$$p(z) = a_n z^n + a_{n-1} z^{n-1} + \cdots + a_1 z + a_0 = 0$$

where $a_n, a_{n-1}, \ldots, a_1, a_0$ are numbers called *coefficients*. $a_n \neq 0$, and n is called the *degree* of the polynomial.

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where $a_n, a_{n-1}, \ldots, a_1, a_0$ are numbers called *coefficients*. $a_n \neq 0$, and n is called the *degree* of the polynomial.

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$$p(z) = 7z^{45} - 25z^{36} + 43z^8 - 5z^6 + 2z - 9 = 0$$

Solution to Polynomial Equation (“root," or “zero")

Example.

$$p(z) = z^2 - 2 = 0.$$

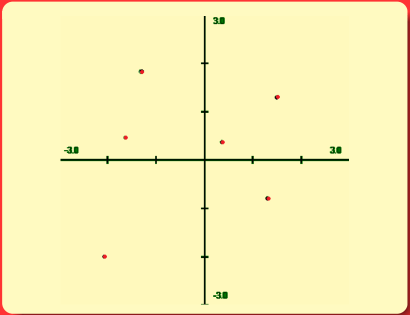
Solutions (root, zero):

$$z = \sqrt{2} = 1.414...$$

$$z = -\sqrt{2} = -1.414...$$

Zero of Polynomial has Dual Nature

It is a NUMBER and it is a POINT in the plane.



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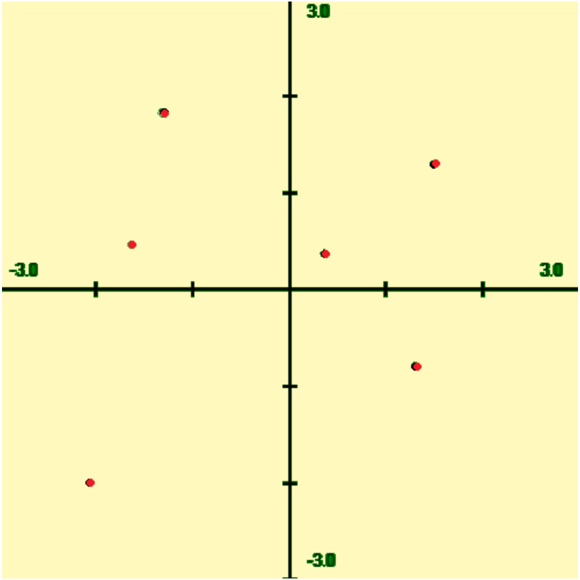
- These discoveries took a few centuries!


3.0
-3.0
3.0
-3.0

Polynomial Equation:

$$p(z) =$$
$$z^6 + (1.92 - 1.2i)z^5 + (-.2362 - 4.2545i)z^4 +$$
$$(-11.4353 - 1.7346i)z^3 + (8.638 + 11.8811i)z^2 +$$
$$(32.5353 - 13.6329i)z + (-14.3137 - 8.9646i)$$
$$= 0.$$

Fundamental Theorem of Algebra

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Number of roots = Degree of Polynomial

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$p(z) = 5z^{17} - 4z^3 - 21$ has 17 roots.

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$p(z) = 5z^{17} - 4z^3 - 21$ has 17 roots.

$p(z) = z^3 - 1$ has 3 roots.

Polynomial Root-Finding is a Historic Problem

Many have investigated the root-finding problem:

The **Sumerians**, the **Babylonians**, the famous Persian mathematician and poet **Omar Khayyam**, the most famous mathematicians of the past such as **Euler**, **Newton**, **Lagrange**, **Descartes**, **Galois**, **Abel**, **Gauss**, **Caley**, **Shröder**; and the great contemporary mathematicians such as **Hermann Weyl**, and **Steve Smale**.

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It has even inspired the study of Newton's method in the complex plane and more general rational functions by **Fatou**, and **Julia** whose work in turn inspired **Mandelbrot** who coined the famous term **fractal**.

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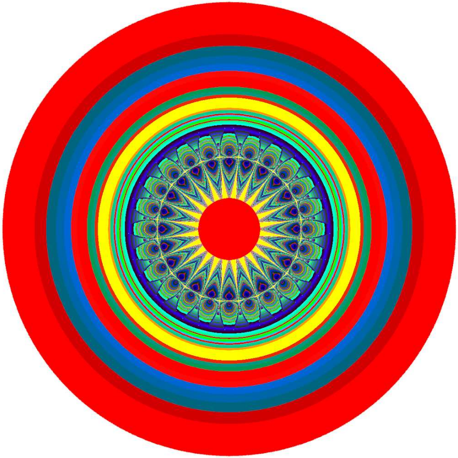
And for degree five and higher there is no GENERAL formula!

Really, even the quadratic formula is not useful if we are trying to approximate square-root of numbers such as square-root of 2.

$$10z^{48} - 11z^{24} + 1 = 0$$

Is this a nice polynomial?

A Polynomiograph of $10z^{48} - 11z^{24} + 1 = 0$



Newton’s Method

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θ is a root of $p(z)$ if and only if it is a *fixed point* of $N(z)$, i.e.

$$N(\theta) = \theta.$$

Example. If $p(z) = z^2 - 2$, Newton's iteration is

$$z_{k+1} = z_k - \frac{z_k^2 - 2}{2z_k}$$

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Suppose $z_0 = 1 + 2i$, where $i = \sqrt{-1}$, can we still compute Newton's iterations?

Computing Newton's Iteration for Complex Input

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$$z_1 = \frac{z_0^2 + 2}{2z_0} = \frac{(1+2i)^2 + 2}{2 * (1+2i)} = \frac{1 + 4i + 4i^2 + 2}{2 + 4i}$$

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$$= \frac{14 + 12i}{20} = 0.7 + 0.6i.$$

Take an object.

Take an object.

Do something with it.

Take an object.

Do something with it.

Then do something else.

Take an object.

Do something with it.

Then do something else.

Jasper Johns

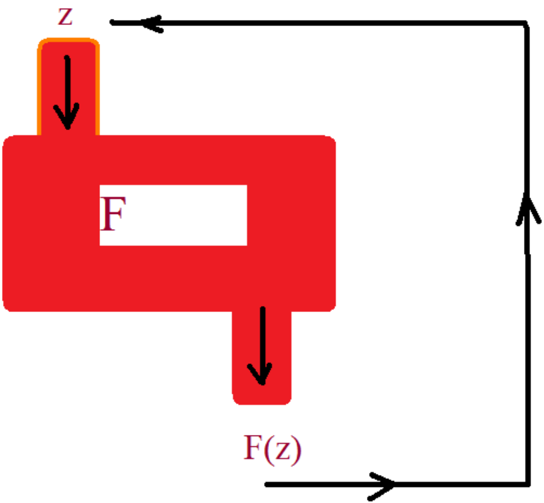

Figure: General Iteration Function, $F(z)$.

Take a tiny dot on the canvas.

Take a tiny dot on the canvas.

Move it somewhere else.

Take a tiny dot on the canvas.

Move it somewhere else.

Then somewhere else.

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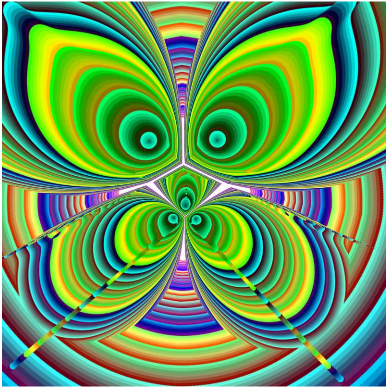
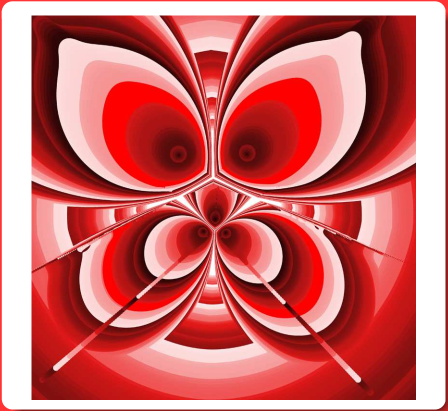
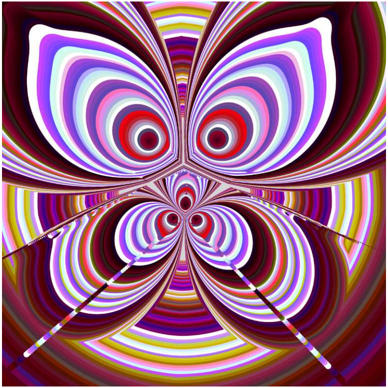
More Points and Artistry:

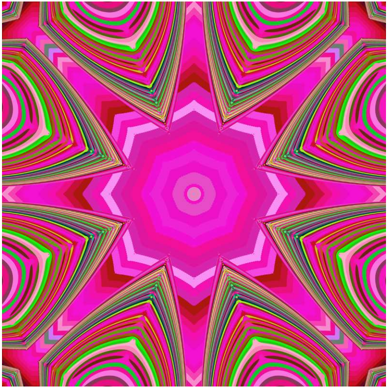
Butterfly

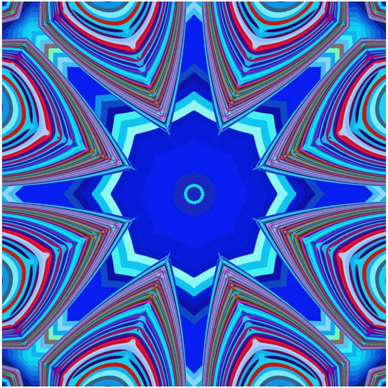


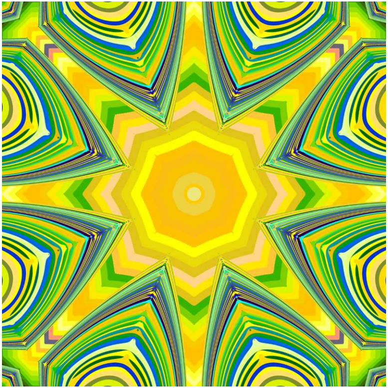




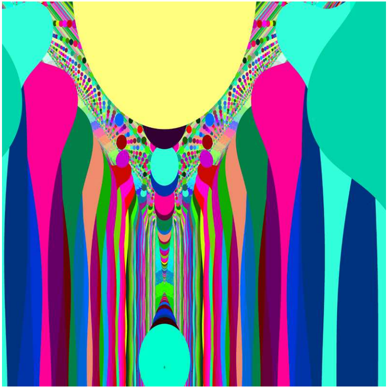
Symmetry

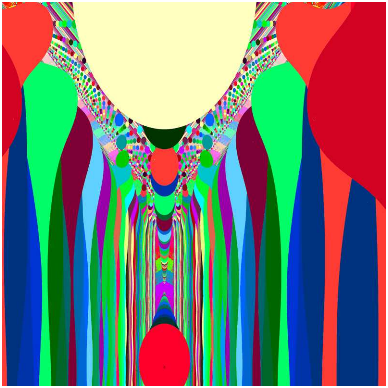






Cathedral





Some Quotes

“*Lose your fear of math with computer graphics that displays the beauty and symmetry hidden within algebraic equations.*”

DISCOVER Magazine … *on polynomiography*

“*Over the centuries, mathematicians have developed a variety of methods of solving equations. Bahman Kalantari of Rutgers University has developed visualization software that brings the process of finding the roots of a polynomial equation into the realm of design and art.*”

Ivars Peterson *SCIENCE NEWS*

“*Professor Kalantari’s work combines in a very striking way mathematics and visual arts. His work on ‘polynomiography’ is very original and pretty.*”

Cumrun Vafa *Professor of Physics, Harvard*

“*Bahman Kalantari’s work on Polynomiography is visually striking and provides profound insight into root finding algorithms.*

In future generations, I expect that visualization of mathematical algorithms will become an expected part of mathematical research.
Bahman Kalantari’s skills are here now and we can enjoy the beautiful results as he has applied them to Polynomiography.”

Cliff Reiter *Professor of Mathematics Lafayette College, Pennsylvania*

“*The visual results are often elegant. This method has led [Kalantari] to develop a new and powerful method of artistic creation, ..., a playful and instructive technique where mathematics helps art, which gratefully, comes to support mathematics.*”

Claude Bruter *Professor of Mathematics, U. of Paris*

"*Polynomiography ... has an enormous and fruitful field of applications in visual arts, education and scientific research...*"

Vera W. de Spinadel *President of International Mathematics & Design Association, Argentina*

“*POLYNOMIOGRAPHY!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!*
I lOVE IT!!!
It was so incredibly cool.
I just want to take it home and play on it the rest of the summer!”

Alexandria Munger *(age 14, a middle schooler at Girls Plus Math Camp., Illinois)*

“I didn’t know math could make such beautiful images.”

A 9 year old boy *(Rutgers Day, April 25th, 2009)*

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What is the **Reimann Hypothesis problem**? What is an open problem? Why is there a million dollar prize on it?

Our First Encounter With A Polynomial Equation

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Linear equation

Middle school word problems

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Middle school word problems

When a math problem asks you to find the value of x, the goal is to isolate x, by doing things to both sides of the equation –until x is all by itself on one side and there is a number on the other side - and that number is your answer.

Danica McKellar *author of best selling book MATH DOESN'T SUCK*

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Danica is right, but in most real-life problems we need to solve equations which are not linear...motion, business,

Why Is Solving Polynomial Equations Important?

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The very ideas of abstract thinking and using mathematical notation are largely due to the study of polynomial equations.

Furthermore, solving polynomial equations has historically motivated the introduction of some fundamental concepts of mathematics ...

Victor Pan, an internationally recognized leader in the field of computer science

A Futuristic Love Story

A Futuristic Love Story

(*Setting: A street in a city in the world*)

WOMAN: Excuse me Sir, is there any post office around here?

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WOMAN: Thank you! That's very romantic.

MAN: May I invite you to dinner at your favorite restaurant?

WOMAN: (After a pause) I cannot promise, but my favorite restaurant's location is a solution to this polynomial:

$$x^{17}+(-0.99+2.865\sqrt{-1})x^{16}+(-4.0289-3.7579\sqrt{-1})x^{15}+(7.6906-8.1716\sqrt{-1})x^{14}+(10.1661+10.81\sqrt{-1})x^{13}+(-14.9238+14.8406\sqrt{-1})x^{12}+(-17.6515-21.7828\sqrt{-1})x^{11}+(19.445-19.7326\sqrt{-1})x^{10}+(26.861+26.7445\sqrt{-1})x^{9}+(-4.5597+36.2215\sqrt{-1})x^{8}+(-23.0202+22.955\sqrt{-1})x^{7}+(-103.1901+18.1539\sqrt{-1})x^{6}+(-56.6536+20.3531\sqrt{-1})x^{5}+(-47.8313+228.2366\sqrt{-1})x^{4}+(-208.2068-229.4483\sqrt{-1})x^{3}+(-117.5589-248.0972\sqrt{-1})x^{2}+(-1092.4738-7.5769\sqrt{-1})x+(103.3231+536.4582\sqrt{-1})$$

The woman leaves.

The woman leaves.

The man falls in love.

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The man falls in love.

He uses Polynomiographaphy to create an art piece from it.

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In the process he discovers a unique shape in the solutions.

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And knowing the restaurant locations now he desperately searches for her and eventually finds her, sitting alone.

The woman leaves.

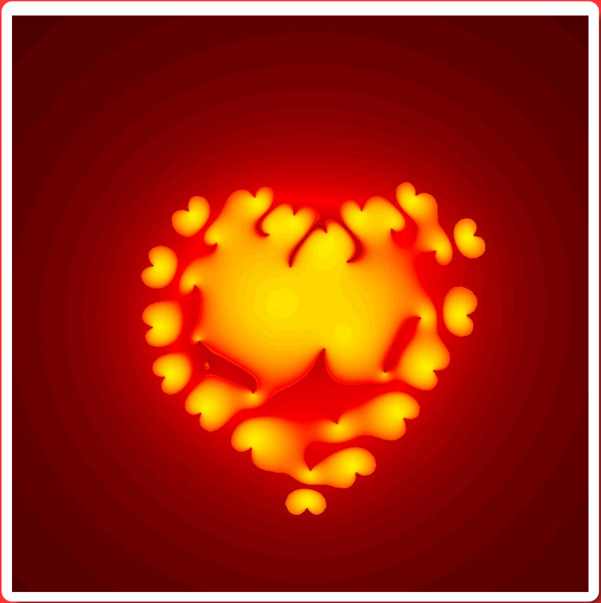
The man falls in love.

He uses Polynomiographaphy to create an art piece from it.

In the process he discovers a unique shape in the solutions.

And knowing the restaurant locations now he desperately searches for her and eventually finds her, sitting alone.

He presents her the artwork:



She immediately falls in love.

She immediately falls in love.

They decide to get married.

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And have

She immediately falls in love.

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And have $(1 + 2\sqrt{-1}) \times (1 - 2\sqrt{-1}) = 5$ children.

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Moral of The Story:

First: solving a polynomial equation could be romantic.

Second: solutions of a polynomial equation are like locations on a map.

Third: we can hide any bunch of locations behind a single polynomial equation.

Fourth: polynomiography can turn any equation, scary looking or not, into a beautiful image.

Fifth: solving polynomial equations could be a beautiful experience.

How Do I Select a Cool Polynomial?

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There are many ways.

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You can select a polynomial through the location of its roots and by click of the mouse.

You can even convert an ordinary number into a polynomial:

Take any number, say 387624730. You can convert it into a polynomial in many ways.

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$$3x^8 + 8x^7 + 7x^6 + 6x^5 + 2x^4 + 4x^3 + 7x^2 + 3x + 0$$

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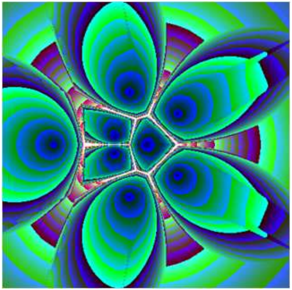
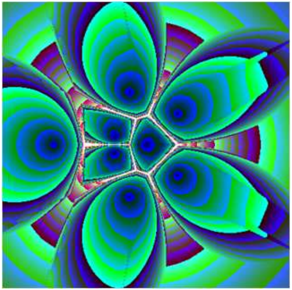
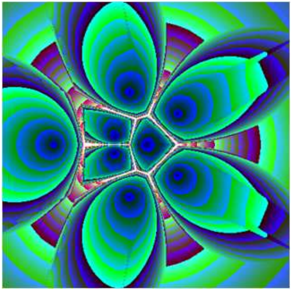
One can capture infinitely many polynomiographs of this single equation.

Here is one:





Could this lead to a futuristic ID number?



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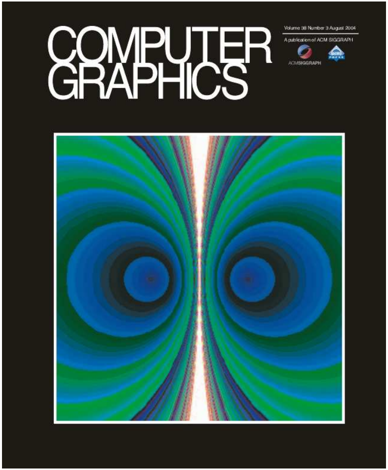
At the very least polynomiography's ability to encrypt ordinary numbers visually encourages the youth to take an interest in numbers and polynomials in the process of which they will learn and discover many properties of these and many other concepts of math.

Polynomiography In Media


COMPUTER GRAPHICS
Volume 38 Number 3 August 2004
A publication of ACM SIGGRAPH
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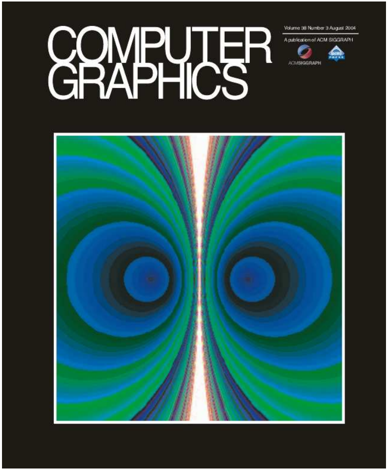

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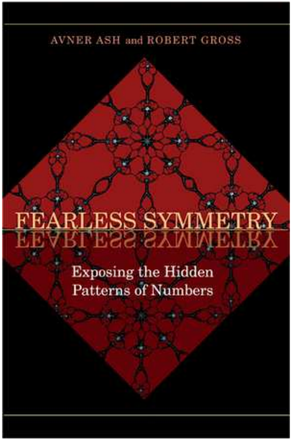
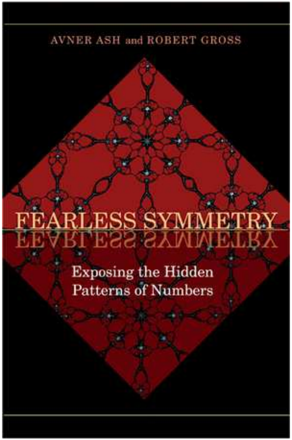

AVNER ASH and ROBERT GROSS
FEARLESS SYMMETRY
Exposing the Hidden
Patterns of Numbers



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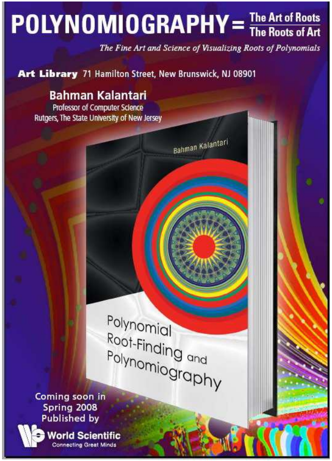
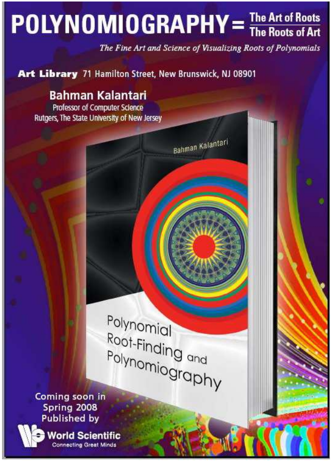
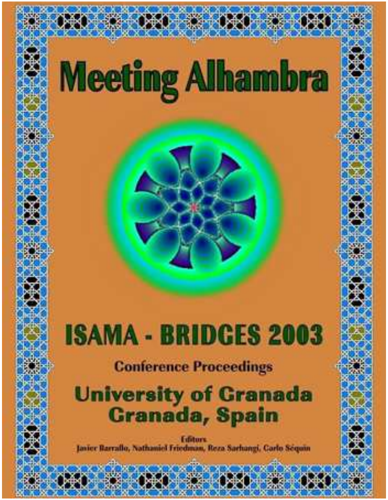

POLYNOMIOGRAPHY = The Art of Roots
The Roots of Art
The Fine Art and Science of Visualizing Roots of Polynomials
Art Library 71 Hamilton Street, New Brunswick, NJ 08901
Bahman Kalantari
Professor of Computer Science
Rutgers, The State University of New Jersey
Bahman Kalantari
Polynomial Root-Finding and Polynomiography
Coming soon in Spring 2008 Published by
World Scientific
Connecting Great Minds



World Scientific, "POLYNOMIAL ROOT-FINDING and POLYNOMIOGRAPHY"


Meeting Alhambra
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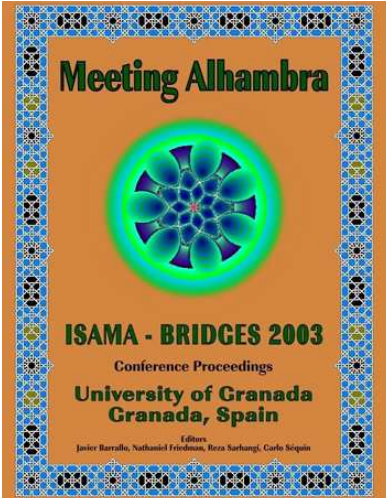
Conference Proceedings
University of Granada
Granada, Spain
Editors
Javier Barrallo, Nathaniel Friedman, Reza Sarhangi, Carlo Séquin



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BEAUTIFUL MATTER

Symmetry is central to modern physics. Source: Bahman Kalantari/Science Photo Library

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physicsworld.com

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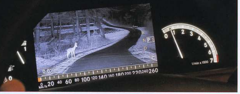
Physicsworld

Un visor infrarrojo facilita la conducción

Nuevos ojos en la noche

El mismísimo coche fantástico envidiaría a los nuevos automóviles equipados con visores infrarrojos que facilitan la conducción nocturna. Estos ojos de lince, que cuestan 3.514,80 € y sólo pueden adquirirse en combinación con los faros bixenón, alumbran la carretera 200 metros. La cámara se sitúa en uno de los faros y capta la imagen, que aparece en la pantalla del salpicadero. Con este sistema se logra una visión similar a la obtenida con las luces largas, pero con la ventaja de que no deslumbran al resto de conductores, ya que la longitud de onda de los infrarrojos no es perceptible a simple vista. El automovilista, al ver el obstáculo en la carretera con mayor antelación, puede reaccionar antes frenando o desviándose.

Los ingenieros de Mercedes Benz son de los primeros que han instalado el aparato en sus vehículos, más concretamente en sus berlinas de lujo y los automóviles de la clase S, pero otros fabricantes no se han quedado atrás y también están equipando sus modelos estrella con este útil invento que puede evitar accidentes. ■



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■ Matemáticas

Arte con los números

Bienvenidos a la polinomiografía, término inventado por el profesor de informática de la Universidad Rutgers, EE UU, Bahman Kalantari para describir cómo se puede hacer arte usando un ordenador y determinados polinomios, las funciones matemáticas más famosas de nuestros tiempos de escuela. En esencia, lo que hace Kalantari es buscar los ceros de determinados polinomios, esto es, buscar para qué valores la función polinómica se hace cero. Una vez identificados, se programa la función y se "adereza" según el sentido artístico del matemático, esto es, con las estructuras y colores que ha seleccionado. Así, las soluciones numéricas se convierten en bellas imágenes.

Estas imágenes se usan resolviendo polinomios, unas funciones matemáticas con formas como esta: $10x^{45} - 11x^{14} + 23x^{5} - 2$

FOTOS: BAHMAN KALANTARI/SPL

INSÓLITO... PERO CIERTO

¿Un porrito? *Las 10.000 toneladas de cannabis recolectadas cada año en EE UU convierten este cultivo en el principal producto agrícola del país, según su valor en el mercado.*

La señal del pez. *El primer símbolo de los cristianos no fue la cruz. Antes se identificaban con un pez, que en griego se dice ixthus. Con la palabra formaron el acróstico Iesous Xhristos Theou Hyios Soter (Jesucristo, de Dios el Hijo, Salvador).*

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32 muy

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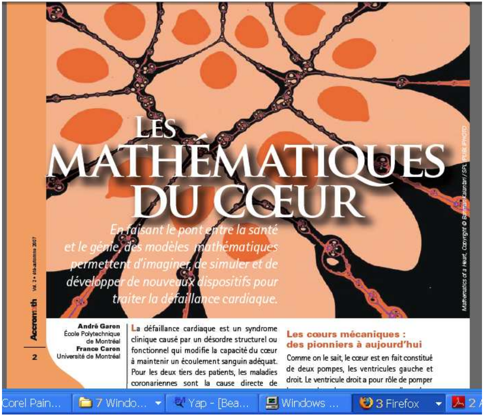


Accromath Vol. 2 • été-automne 2007

2

Les mathématiques du cœur

En faisant le pont entre la santé et le génie, des modèles mathématiques permettent d'imaginer, de simuler et de développer de nouveaux dispositifs pour traiter la défaillance cardiaque.

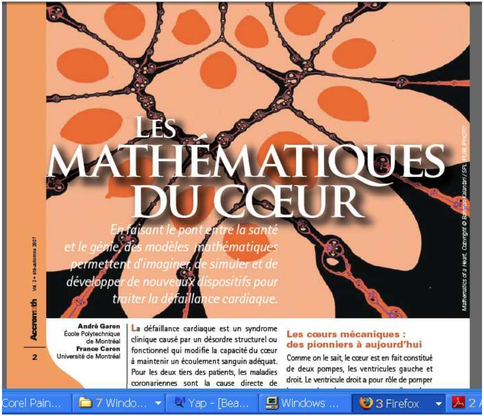
Mathematics of a Heart, Copyright © Bahman Kalantari / SPL / PUBLIPHOTO

André Garon
École Polytechnique de Montréal
France Caron
Université de Montréal

La défaillance cardiaque est un syndrome clinique causé par un désordre structurel ou fonctionnel qui modifie la capacité du cœur à maintenir un écoulement sanguin adéquat. Pour les deux tiers des patients, les maladies coronariennes sont la cause directe de

Les cœurs mécaniques : des pionniers à aujourd'hui

Comme on le sait, le cœur est en fait constitué de deux pompes, les ventricules gauche et droit. Le ventricule droit a pour rôle de pomper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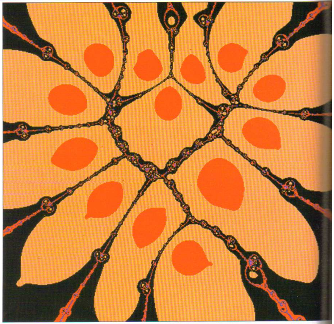
SPRING 2003

BY LEE LUSARDI CONNOR



BEAUTY BY THE NUMBERS

What if you could use a computer to turn equations into dazzling, colorful designs? That's the kind of question only a computer scientist—a particularly *creative* computer scientist—would ask.

Enter Bahman Kalantari, an associate professor of computer science at Rutgers University in New Brunswick. His answer: "polynomiography"—a computer art form created by turning polynomials, a fundamental algebraic function, into patterns. (Polynomials are defined as "linear combinations of integral powers of a variable," such as x-1.) "We can 'shoot pictures' of polynomials and then color them using our own personal artistry," says Kalantari. "Just as with photography and painting, with practice one gets to be better and better at it."

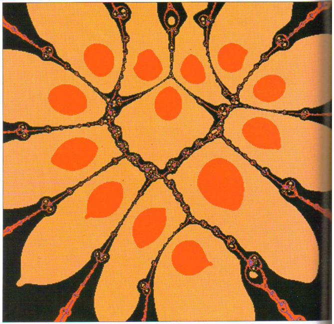
Shown above is Kalantari's "Mathematics of a Heart." The possibilities are limitless, he says. "You can design images that would look wonderful as abstract painting, greeting cards, upholstery or any kind of decorative fabric."

Patents are now pending for software that will make polynomiography available to the public. In the meantime, check it out at www.polynomiography.com.

SPRING 2003

BY LEE LUSARDI CONNOR

PEOPLE & PLACES



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New Jersey Savvy-Living

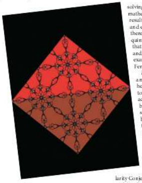
The roots of complex problems

Fearless Symmetry: Exposing the Hidden Patterns of Numbers
by Avner Ash & Robert Gross
Princeton University Press: 2006. 302 pp. $24.95, £15.95

Timothy Gowers

If you ask somebody who knows a little mathematics what is meant by the symbol i, they will probably tell you, correctly, that it stands for the square root of -1. But there is a subtlety to the question that is easy to overlook. Suppose that you pedantically point out that there are two square roots of -1. The response is likely to be that the other square root is $-i$. But now comes a much harder question: which square root is i and which one is $-i$?

The more one thinks about this question, the more one realizes that it does not have an answer. In fact, the question doesn't really make sense, and mathematicians even have a way of proving that it doesn't make sense. The rough idea of the proof is this. If z is any complex number, written in its usual form $a+ib$, where a and b are real numbers, then we define the complex conjugate of z to be $a-ib$, and denote this number by $\bar{z}$. It can then be proved that, for any two complex numbers z and w, $\overline{z+w}=\bar{z}+\bar{w}$ and $\overline{zw}=\bar{z}\bar{w}$. In mathematical terminology, the function that takes each complex number to its conjugate is an automorphism, because it 'preserves' the basic arithmetical operations.



Polynomiographs such as this one, *Acrobats*, are created using mathematical formulae.

Because of this automorphism, there is no true mathematical sentence about i that is not equally true when all occurrences of i (both implicit and explicit) are replaced by $-i$. This is the sense in which i and $-i$ are indistinguishable and is the reason that one cannot answer the question: "Which square root of -1 is i?" By contrast, it is possible to distinguish between 1 and -1, for example, as the square of 1 is itself, but the square of -1 is not itself.

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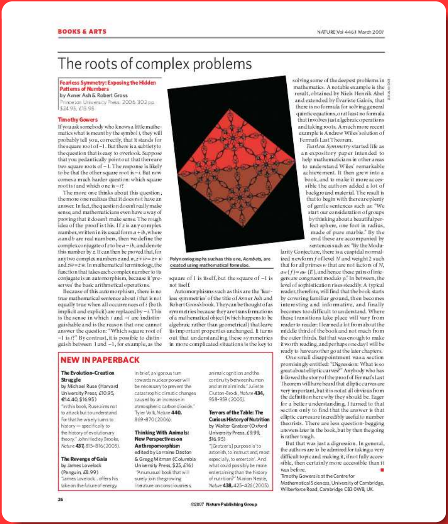

BOOKS & ARTS

NATURE|Vol 446|1 March 2007

The roots of complex problems

Fearless Symmetry: Exposing the Hidden Patterns of Numbers
by Avner Ash & Robert Gross
Princeton University Press: 2006. 302 pp. $24.95, £15.95

Timothy Gowers

If you ask somebody who knows a little mathematics what is meant by the symbol *i*, they will probably tell you, correctly, that it stands for the square root of −1. But there is a subtlety to the question that is easy to overlook. Suppose that you pedantically point out that there are two square roots of −1. The response is likely to be that the other square root is −*i*. But now comes a much harder question: which square root is *i* and which one is −*i*?

The more one thinks about this question, the more one realizes that it does not have an answer. In fact, the question doesn't really make sense, and mathematicians even have a way of proving that it doesn't make sense. The rough idea of the proof is this. If z is any complex number, written in its usual form $a+ib$, where a and b are real numbers, then we define the complex conjugate of z to be $a-ib$, and denote this number by $\bar{z}$. It can then be proved that, for any two complex numbers z and w, $\overline{z+w}=\bar{z}+\bar{w}$ and $\overline{zw}=\bar{z}\bar{w}$. In mathematical terminology, the function that takes each complex number to its conjugate is an automorphism, because it 'preserves' the basic arithmetical operations.

Because of this automorphism, there is no true mathematical sentence about *i* that is not equally true when all occurrences of *i* (both implicit and explicit) are replaced by −*i*. This is the sense in which *i* and −*i* are indistinguishable and is the reason that one cannot answer the question: "Which square root of −1 is *i*?" By contrast, it is possible to distinguish between 1 and −1, for example, as the square of 1 is itself, but the square of −1 is not itself.

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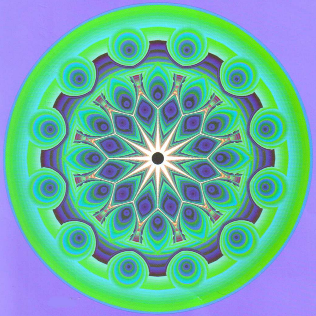
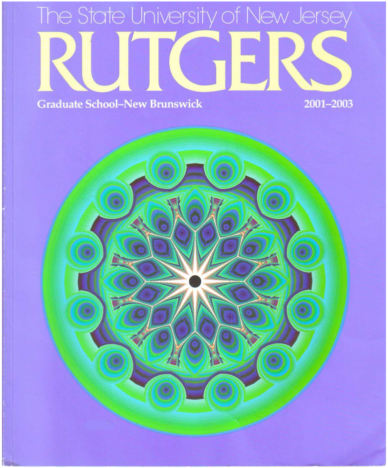
Nature

The State University of New Jersey

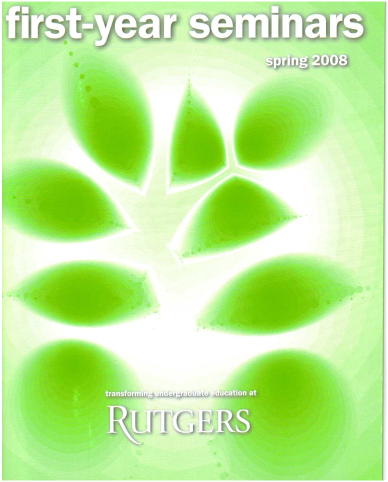
RUTGERS

Graduate School–New Brunswick 2001–2003





Rutgers Graduate Catalog (cover)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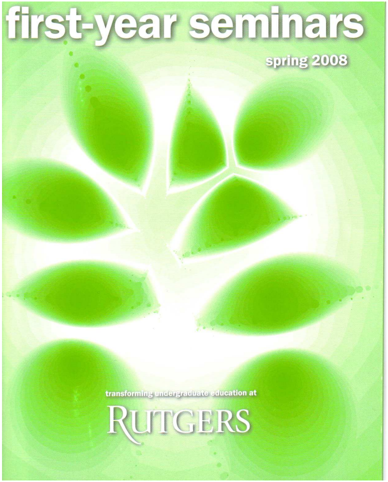
spring 2008
transforming undergraduate education at
RUTGERS



Rutgers First-Year Seminars Catalog (cover)

Also featured in New Jersey media and more

Polynomiography In Schools

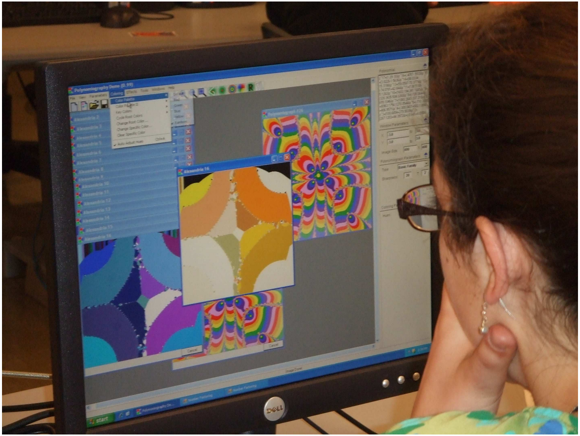
First-Year Seminar Polynomiography students (and their cake)

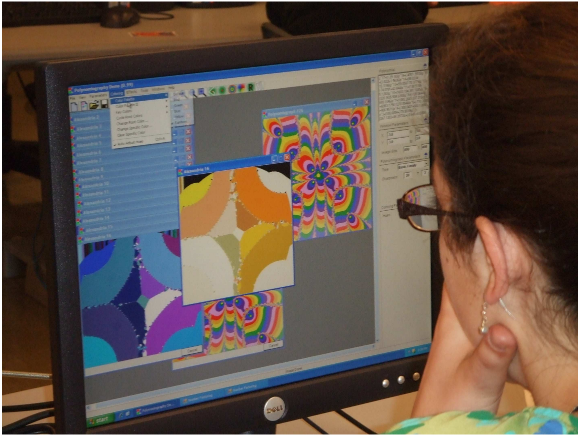

Welcome to Randolph Middle School Dr. Kalantari!

With New Jersey Randolph Middle School Students


POLYNOMIOGRAPHY

Girls Plus Math Camp 6-8th graders (Western Illinois University, Macomb IL)


DELL



Young polynomiographer at work, discovering math and art.

Alexandia returns to the camp for second time. Her request last year was to raise the camper age limit to 14, otherwise she could not attend. First time camper are as enthusiastic.


07/22/2008

A happy camper smiles as she has discovered much beauty behind math and its potentials...

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"*I want to know how all those numbers could make such cool pictures. It seems more interesting now.*"

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"*Gives me ideas to pursue for Discrete Math Curriculum!*"

Polynomiography In Art

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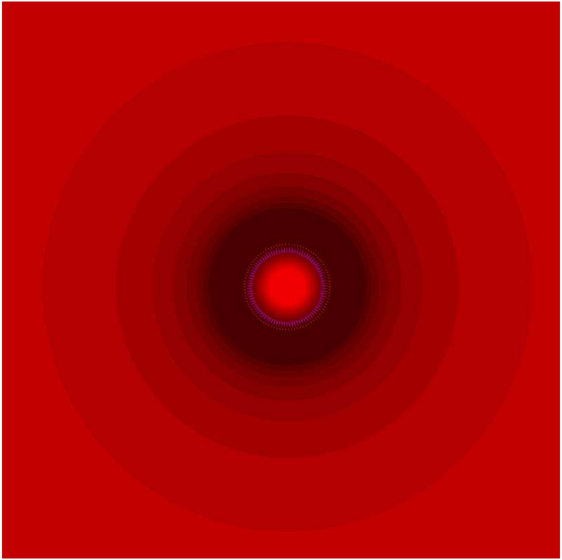
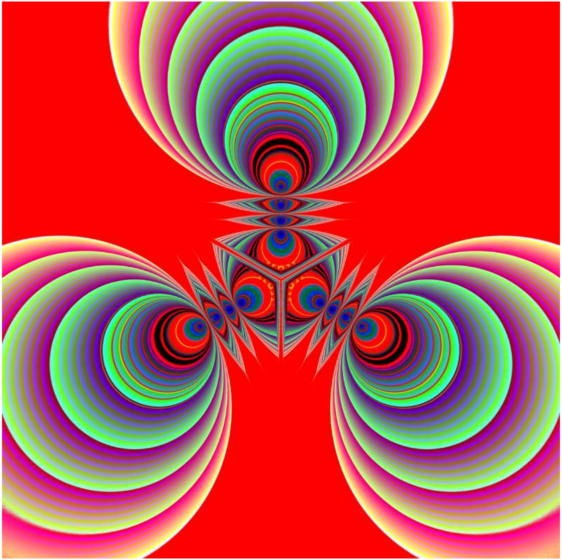
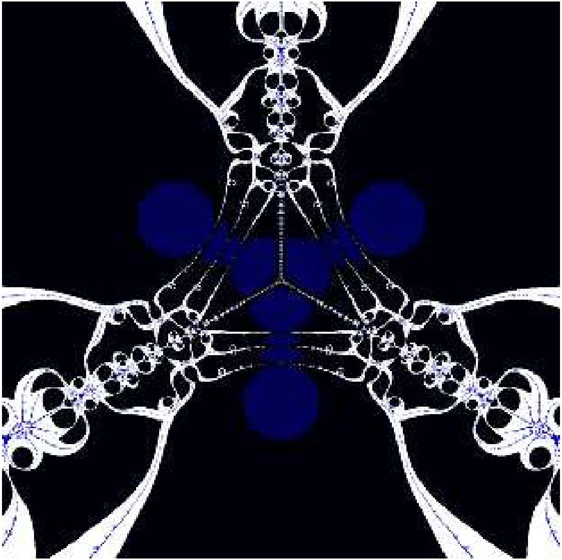
First A Gallery Tour



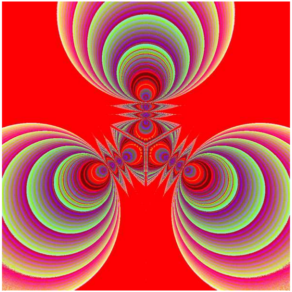
Hal

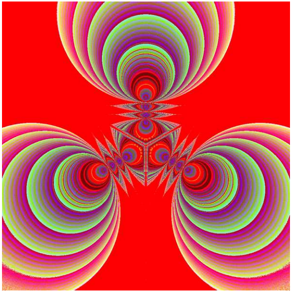
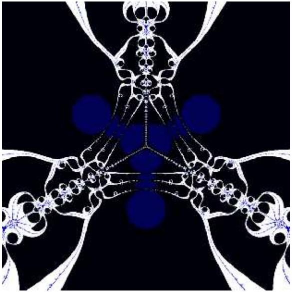


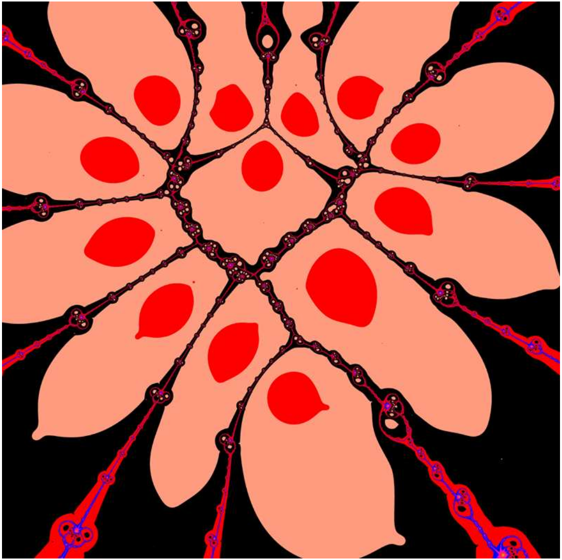
Life



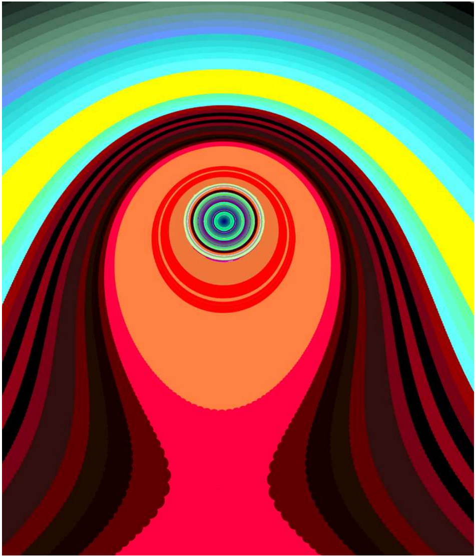
Death



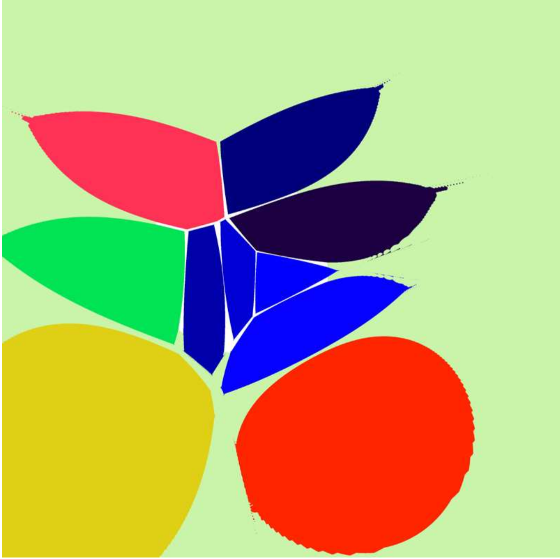





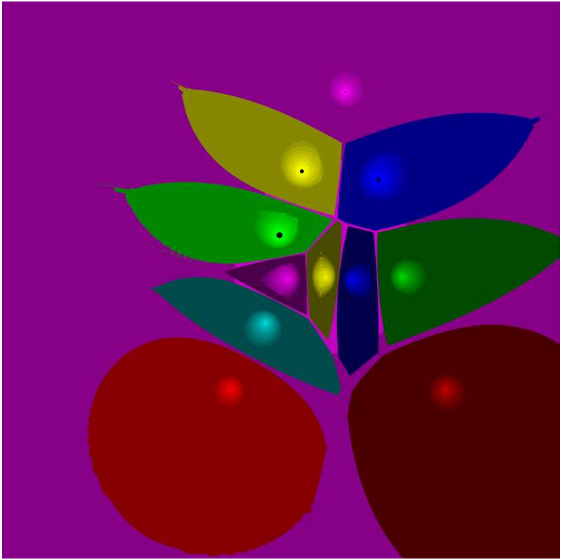
Mathematics of a Heart

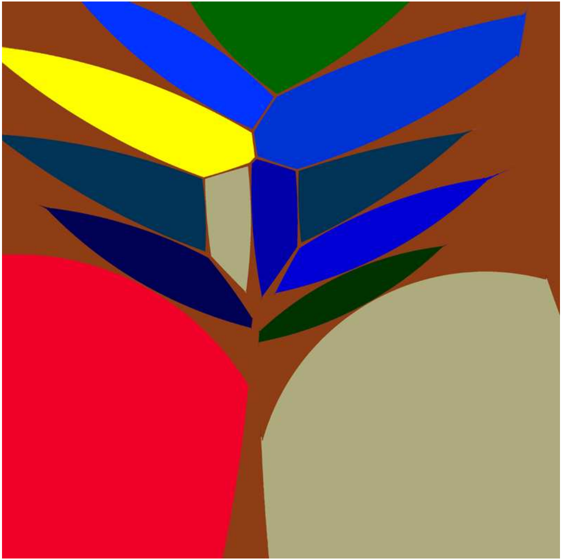


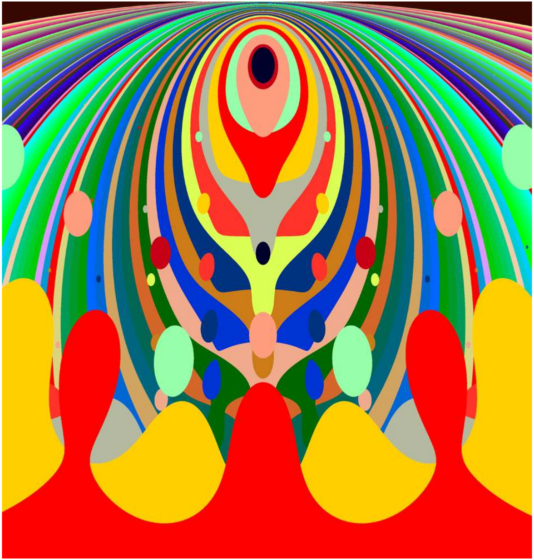
Mona Lisa in 2001



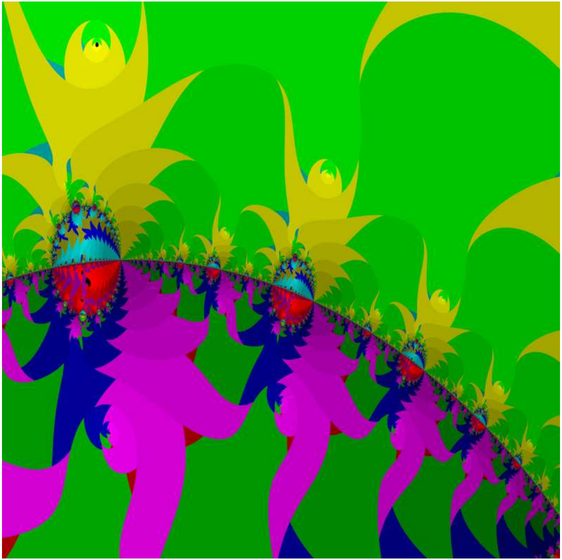
Summer



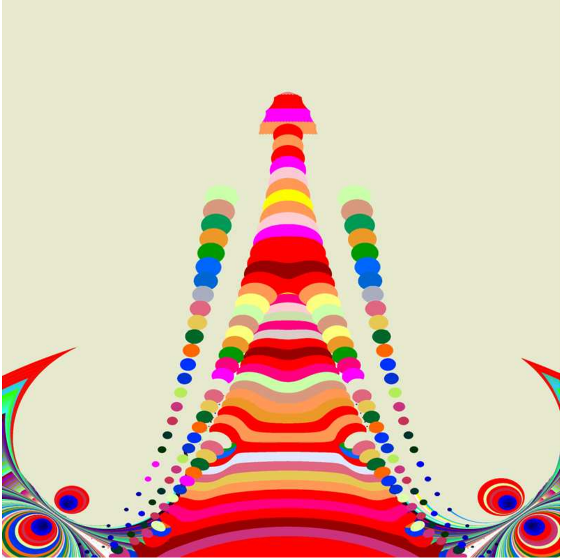




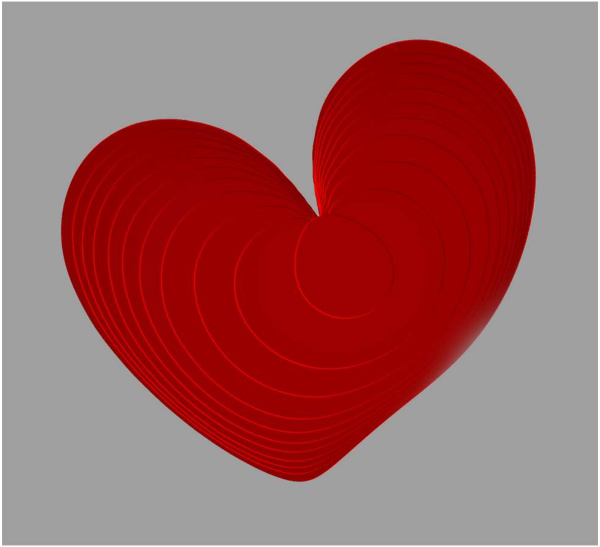
Symphony



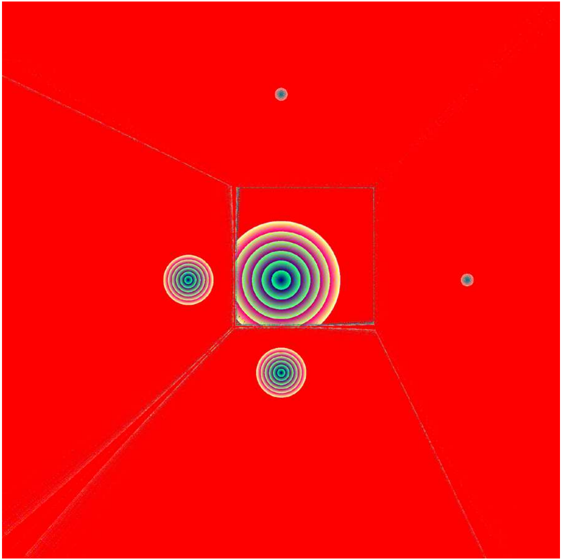
Waltz



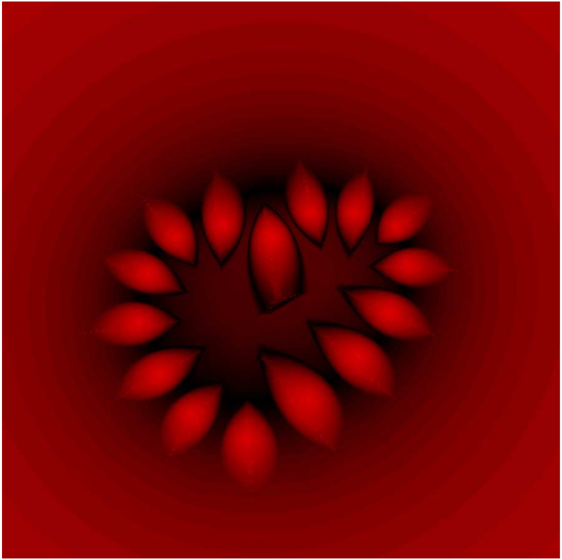
Eiffel Tower



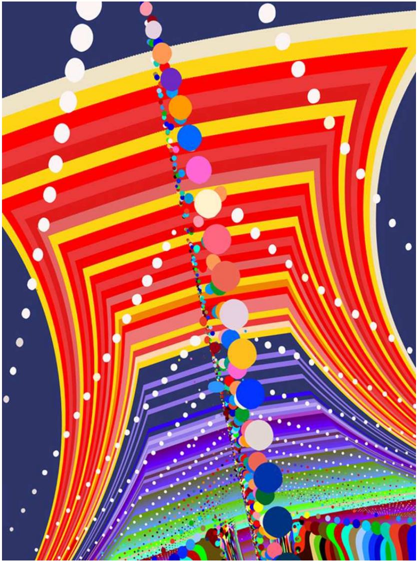
Valentine



SquaringTheCircle

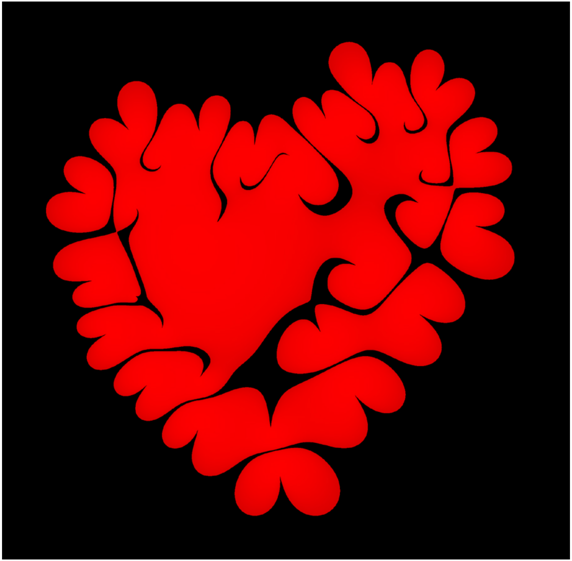


Shaping a Heart

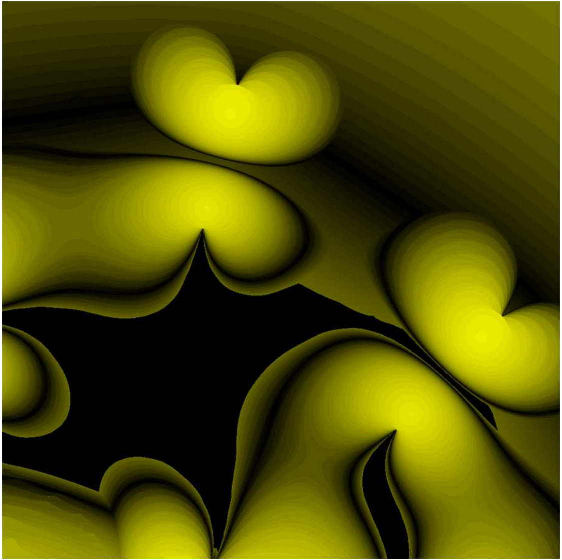


Party on the Brooklyn Bridge

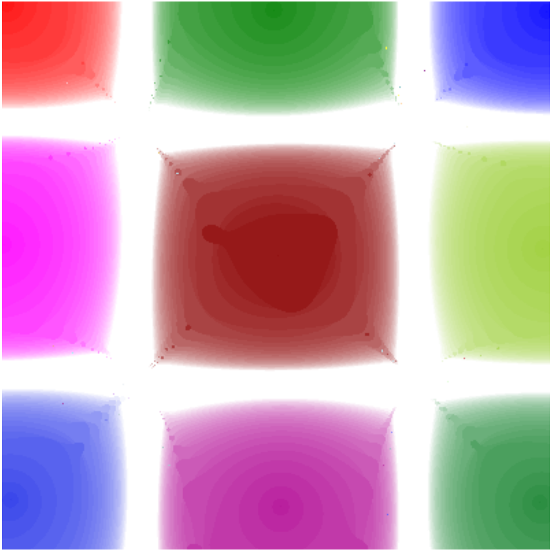
Masked Queen



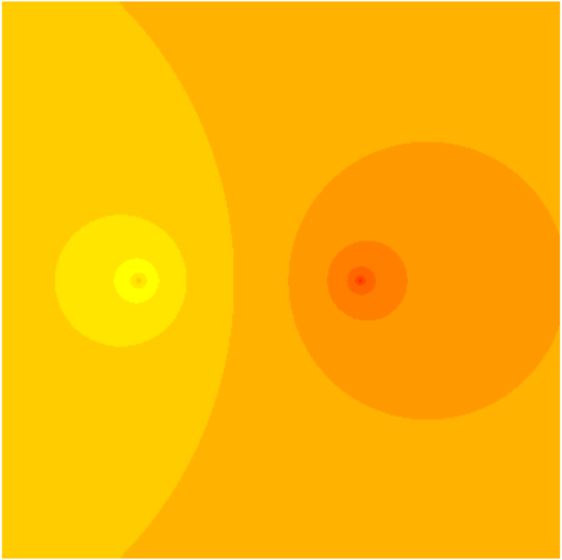
Hearts



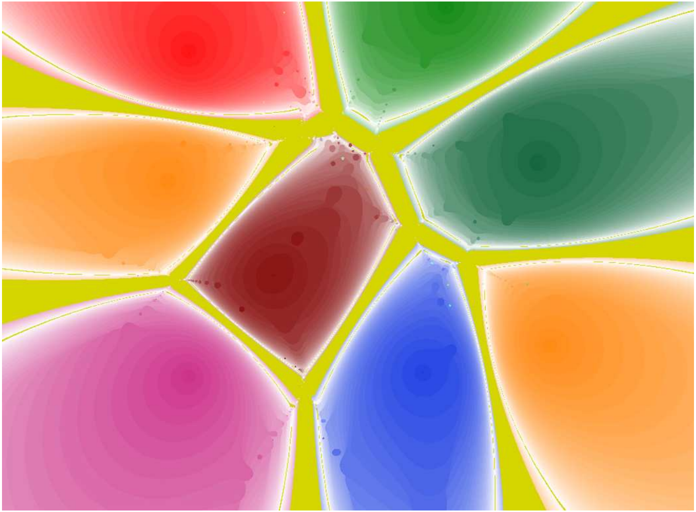
Abstract Hearts

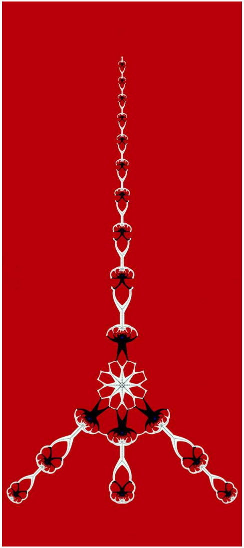


Squares

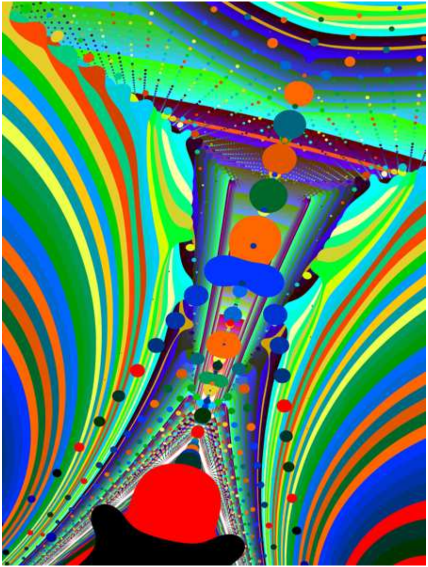


Circles





Acrobats in Paris



Circus

Times Square

Polynomiography In Exhibitions

Exhibition at Rutgers Art Library

Exhibition can also be viewed with 3D glasses

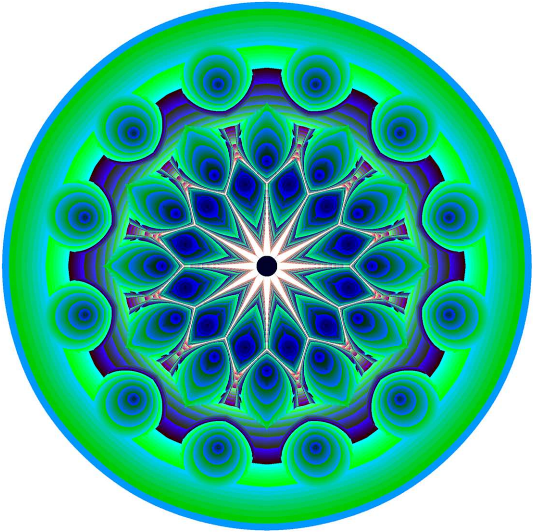
Rutgers' President McCormick visits The Exhibition

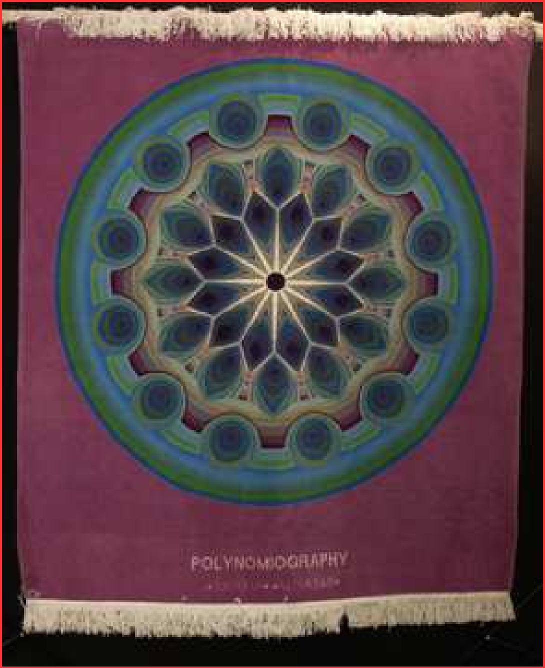
Polynomiography Artwork of Montgomery High School Students, Using a Demo Software

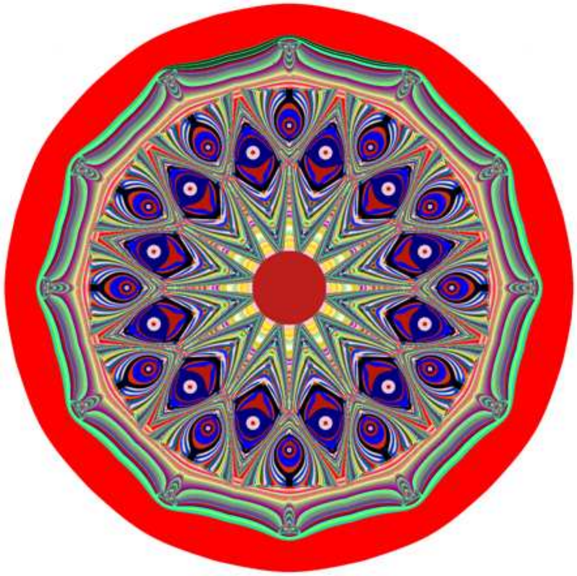
Polynomiography In Design

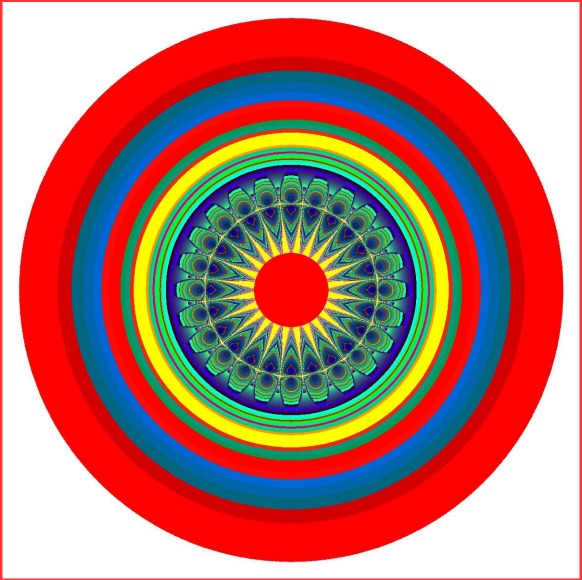
Polynomiography In Design

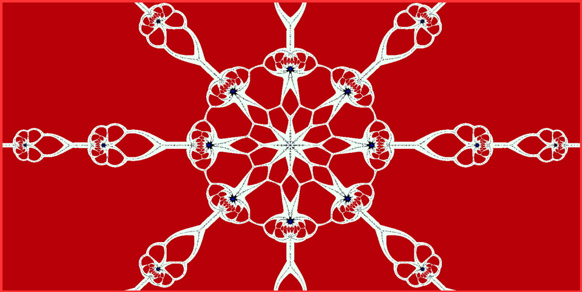
Designing A Carpet

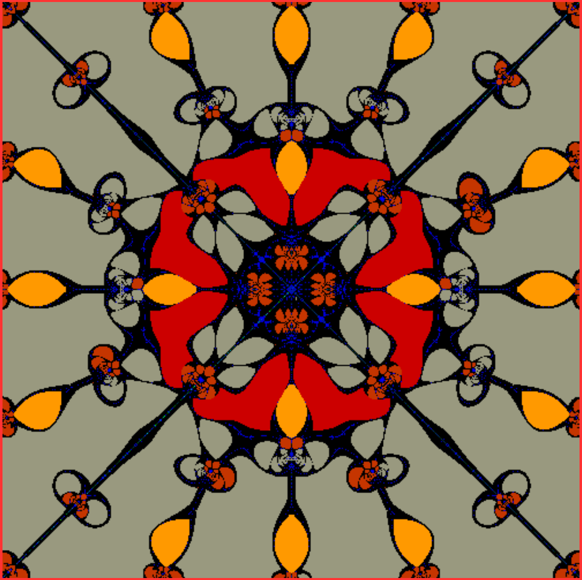


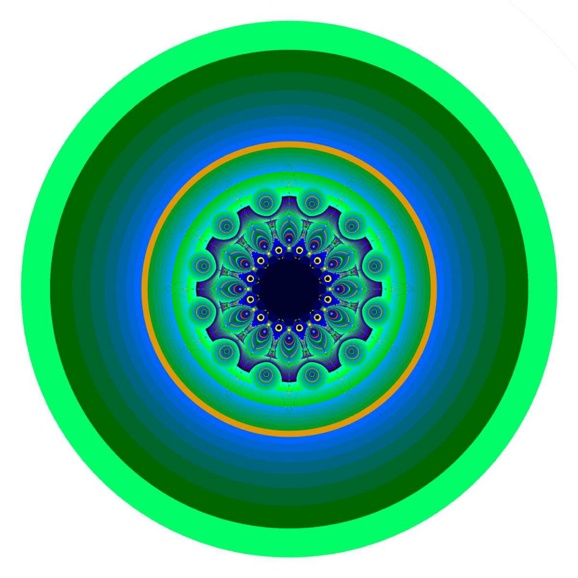

POLYNOMIOGRAPHY

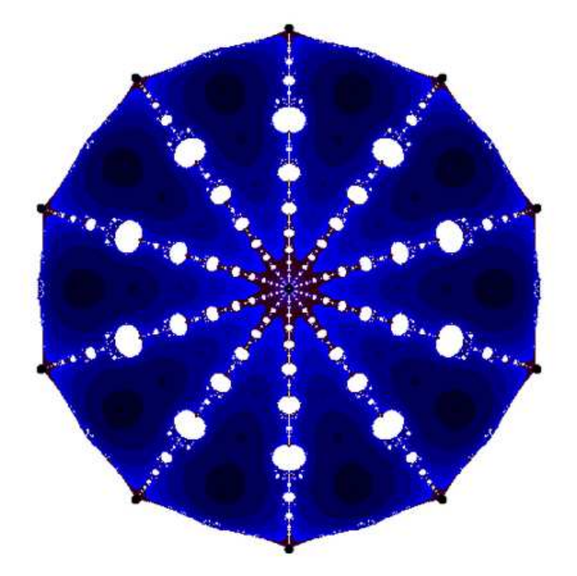


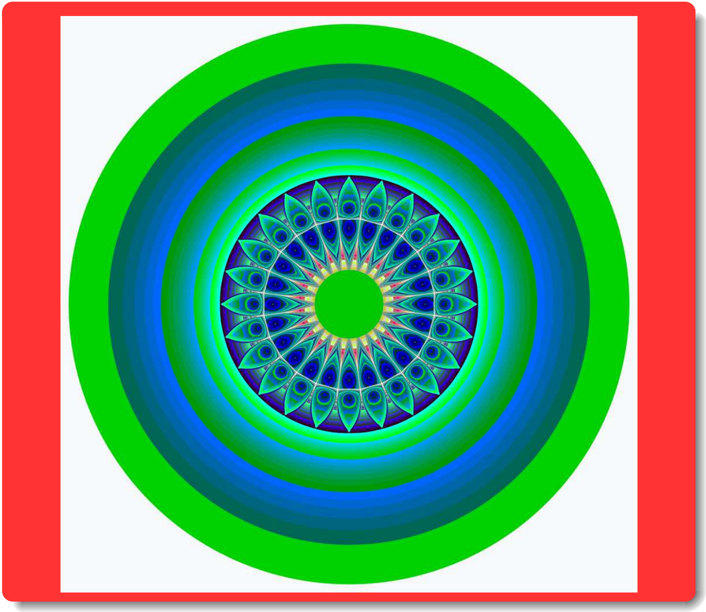


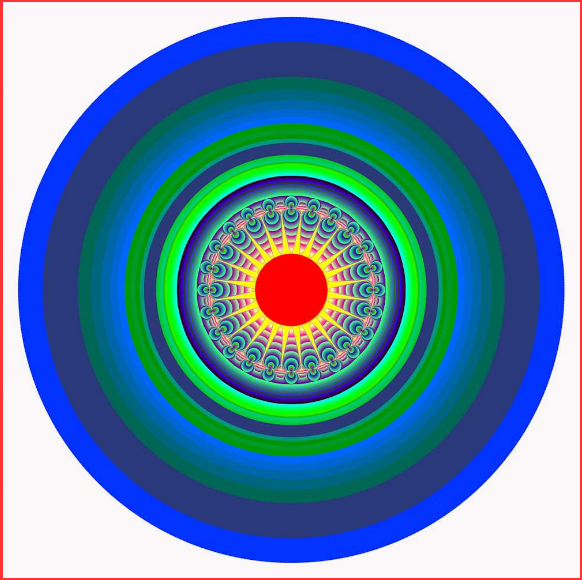




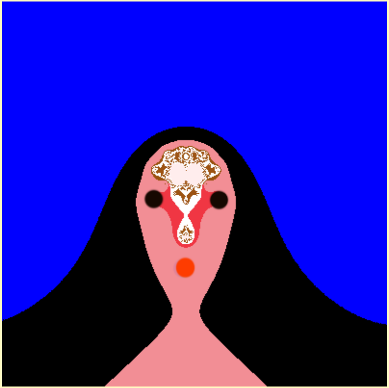


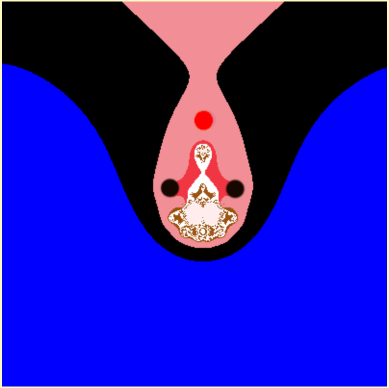






A Girl with a Secret

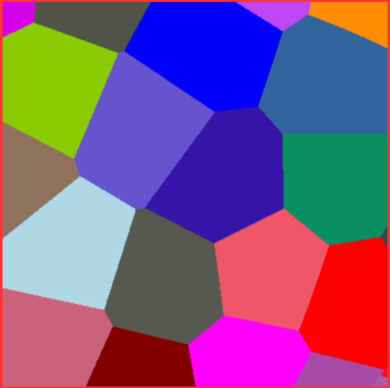


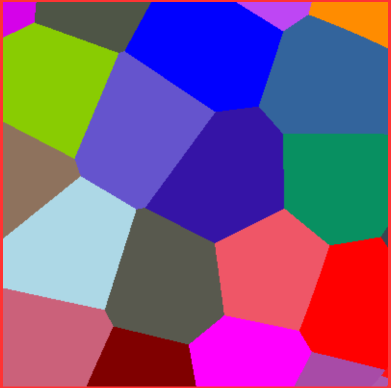


Artists and Polynomiography

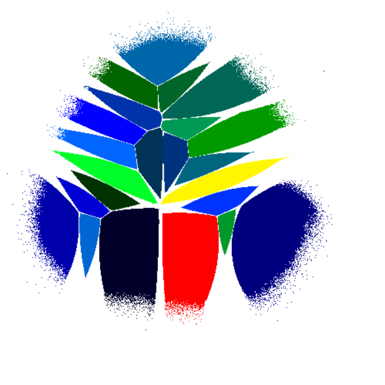
Artists and Polynomiography

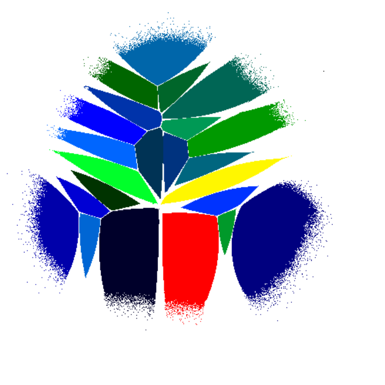
Can We Connect Artists with Polynomiography?



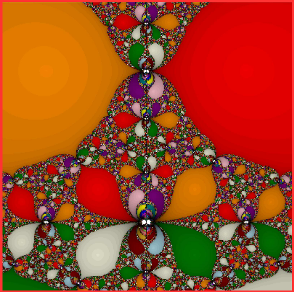
Klee and Polynomiography



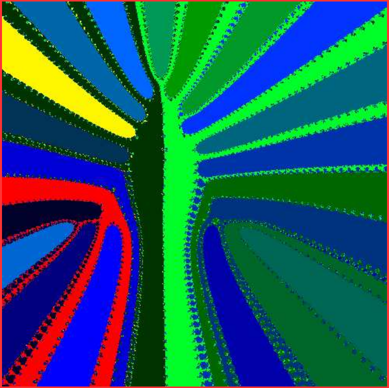
 

Picasso and Polynomiography


Lewitt and Polynomiography

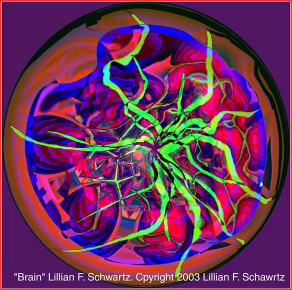



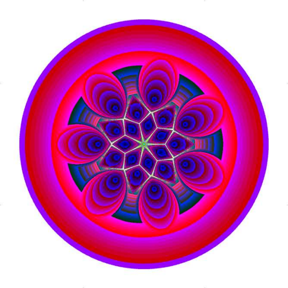
Klimt and Polynomiography

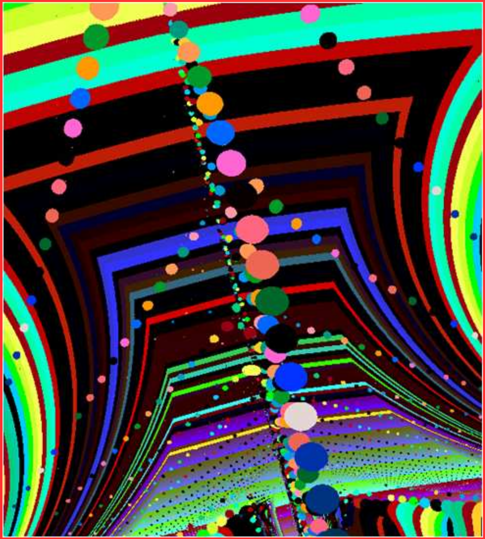


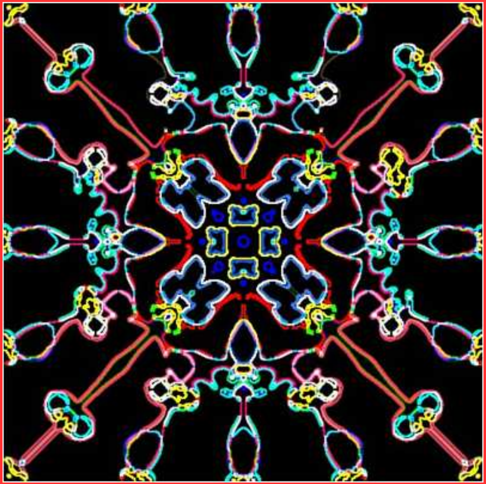


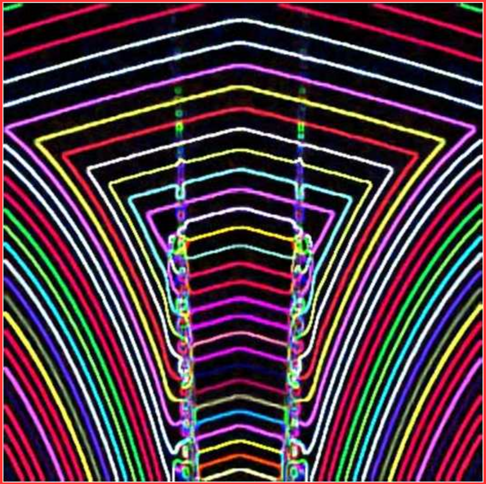
"Brain" Lillian F. Schwartz. Copyright 2003 Lillian F. Schawrtz

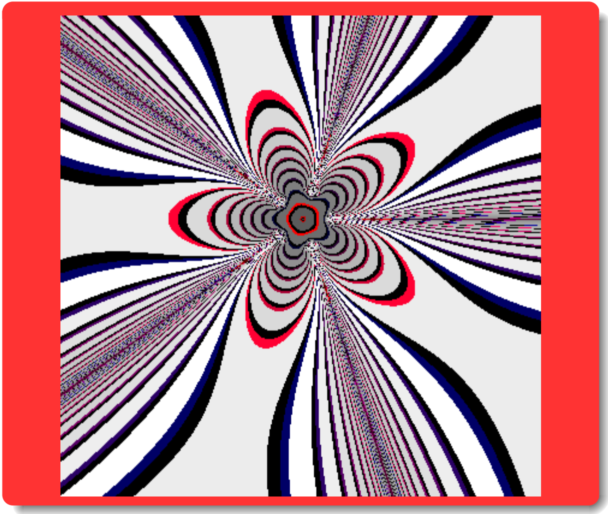

"Brain" Lillian F. Schwartz. Copyright 2003 Lillian F. Schawrtz

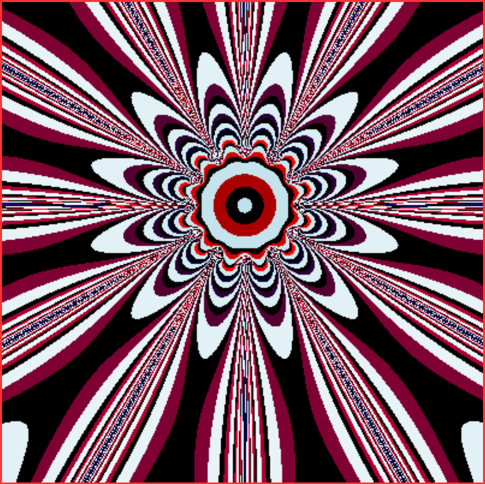


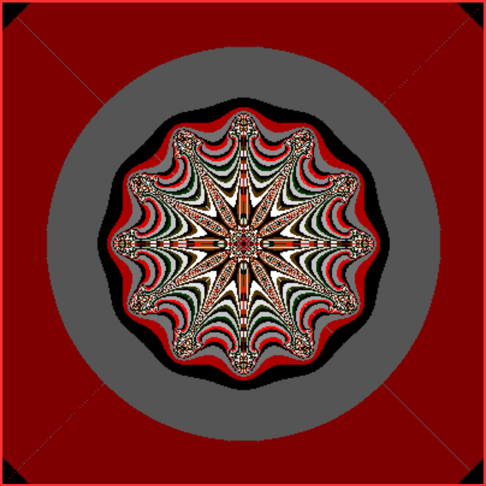


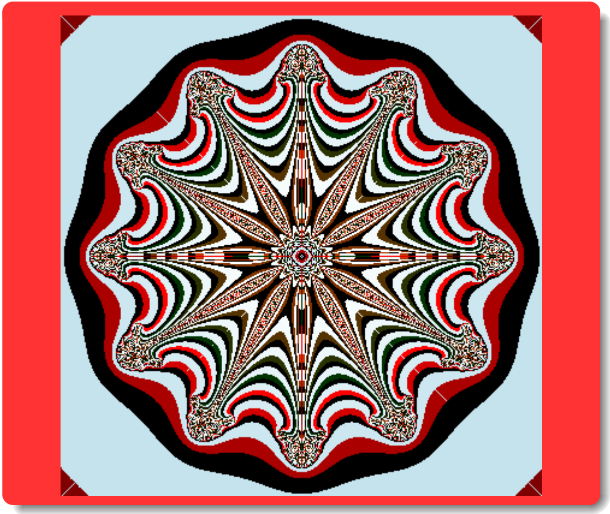


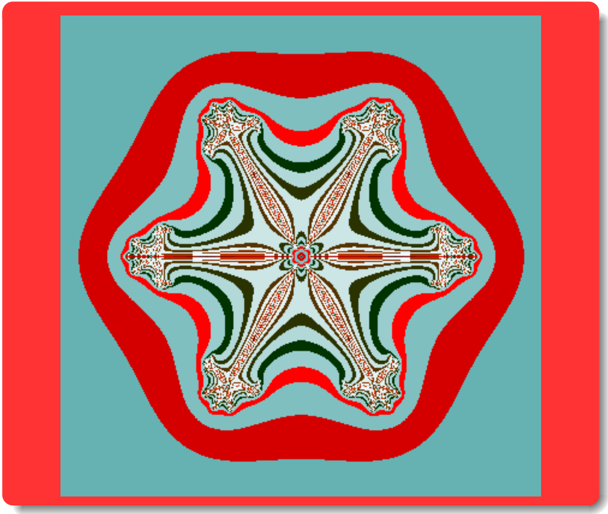


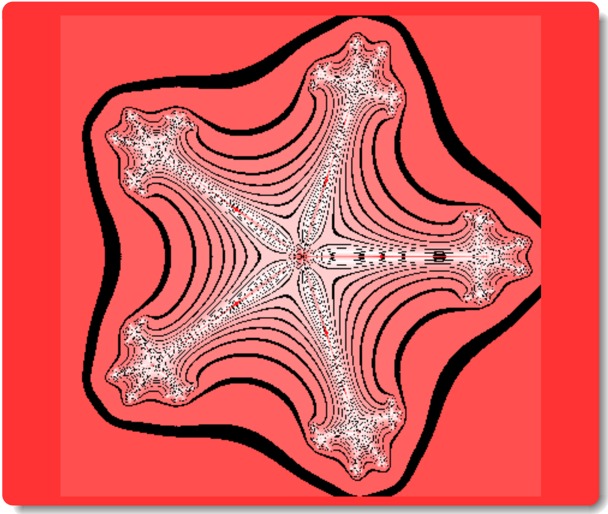


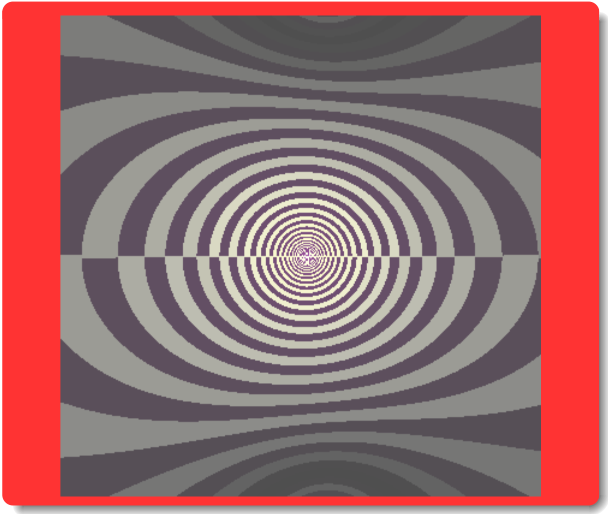


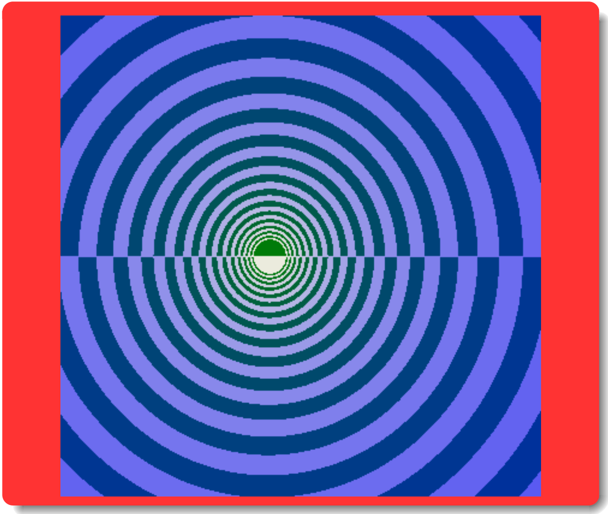


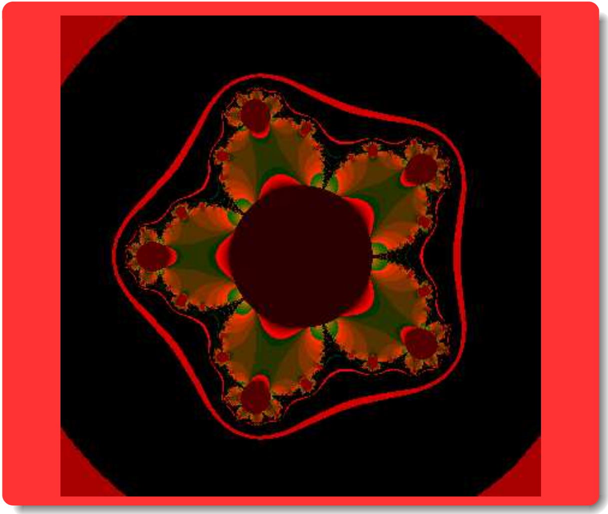


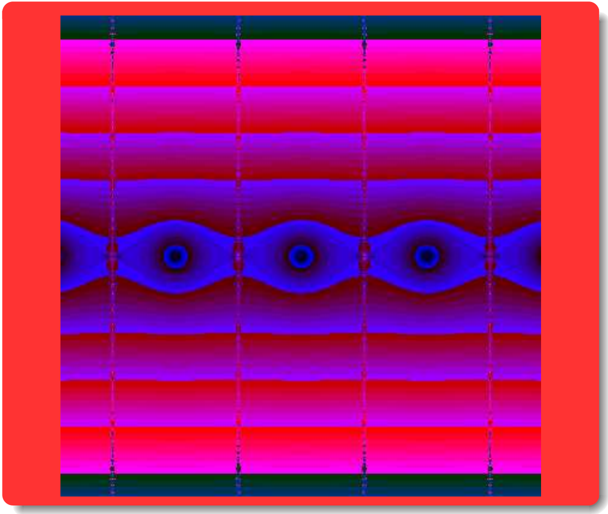


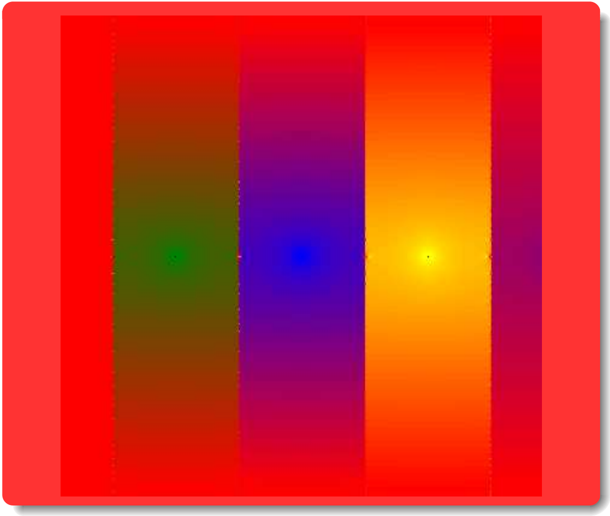


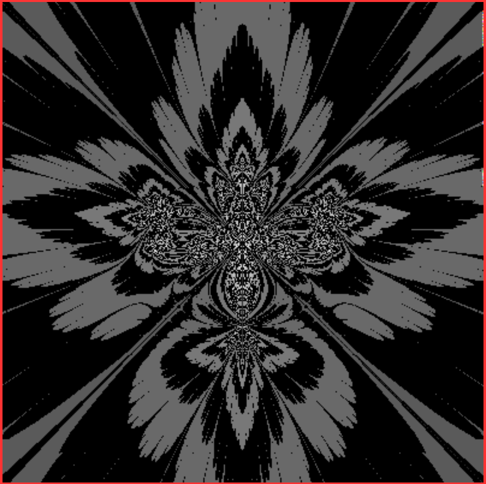




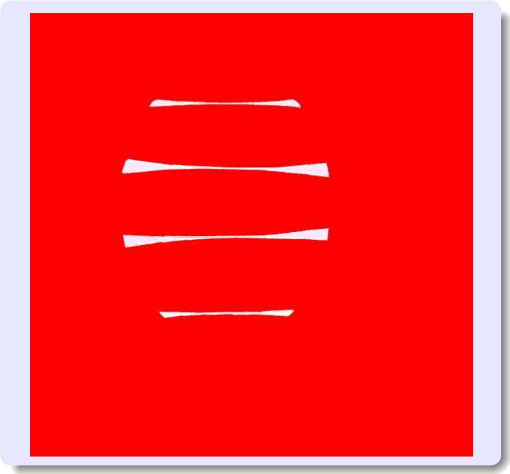


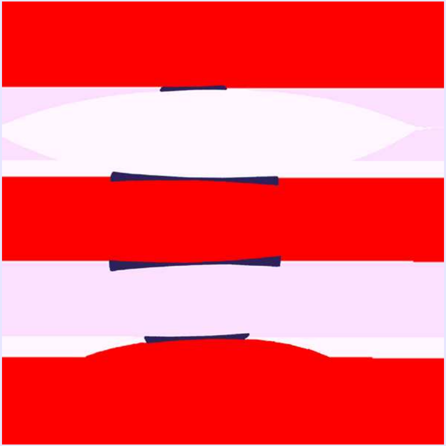


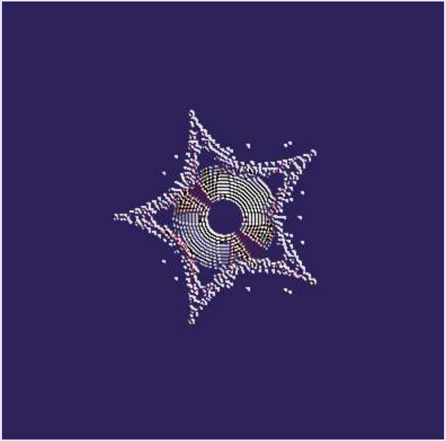


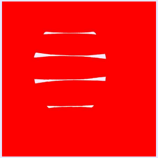


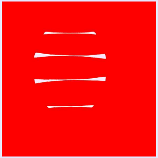
Making US Flag through Polynomiography- Inspired by Jasper Johns

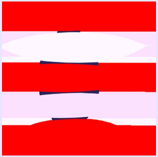


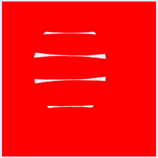


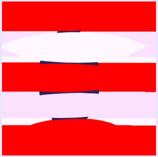


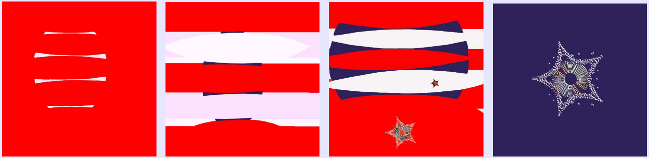










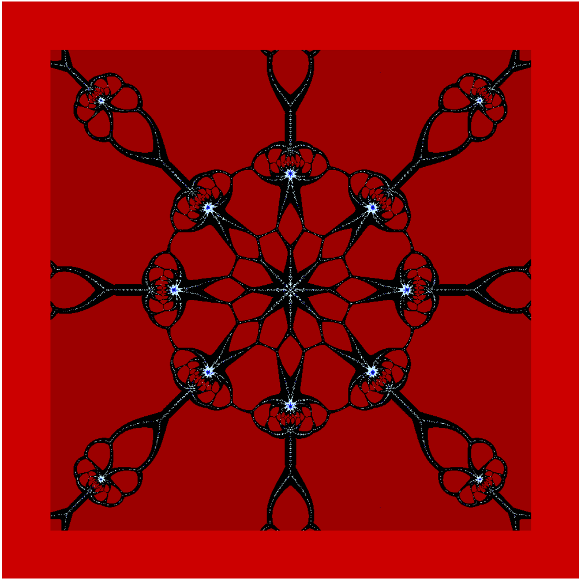


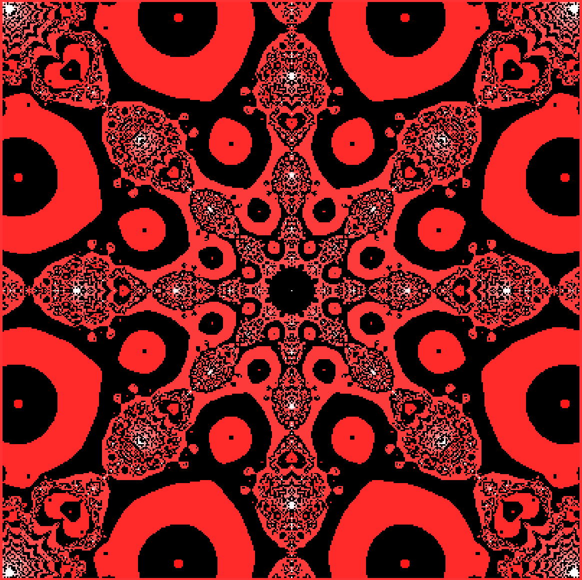
Evolution of Stars and Stripes

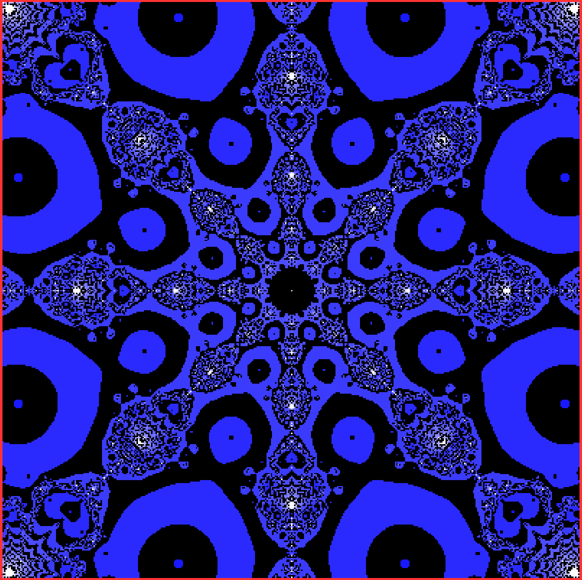
Endless Designs with a Single Polynomial

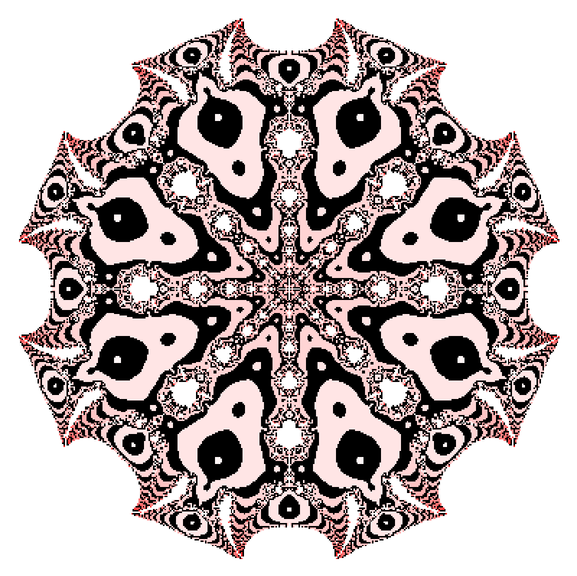
Endless Designs with a Single Polynomial

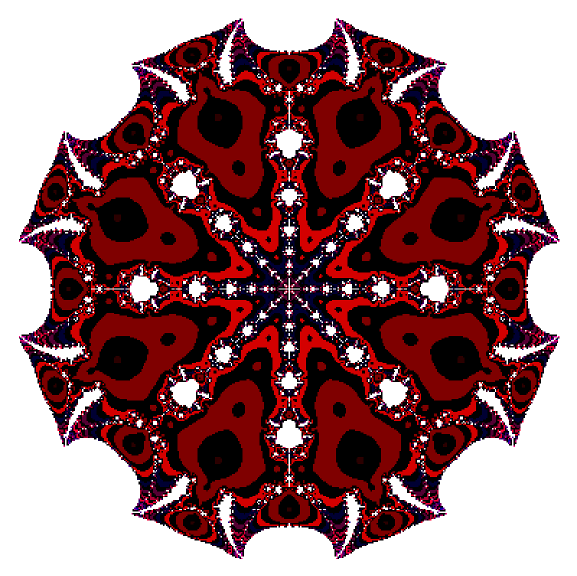
Acrobats

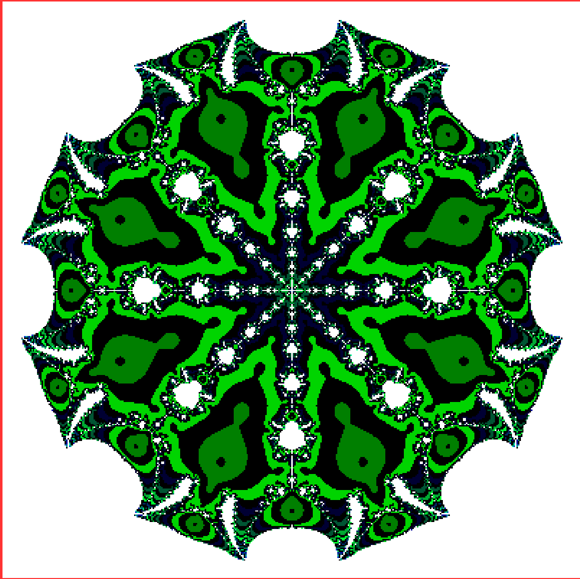


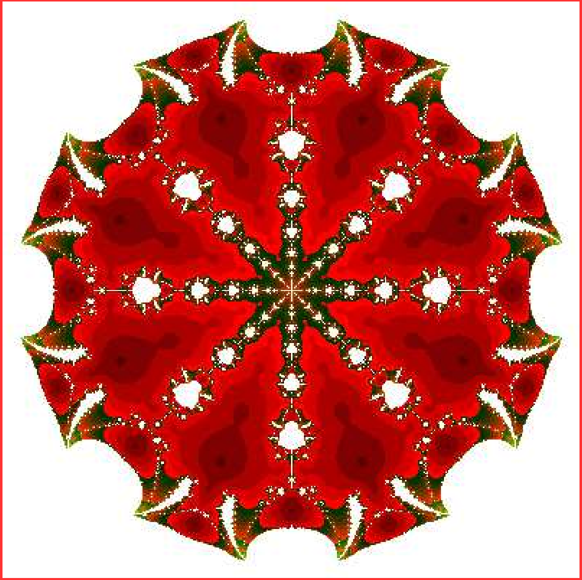


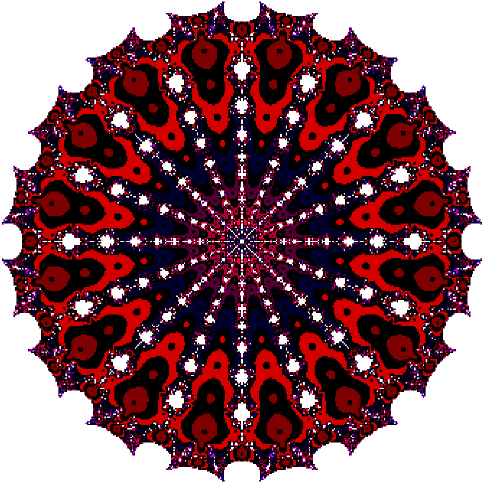


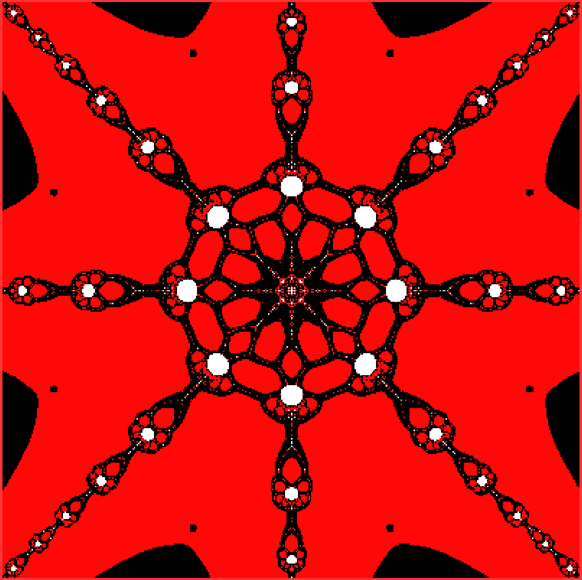


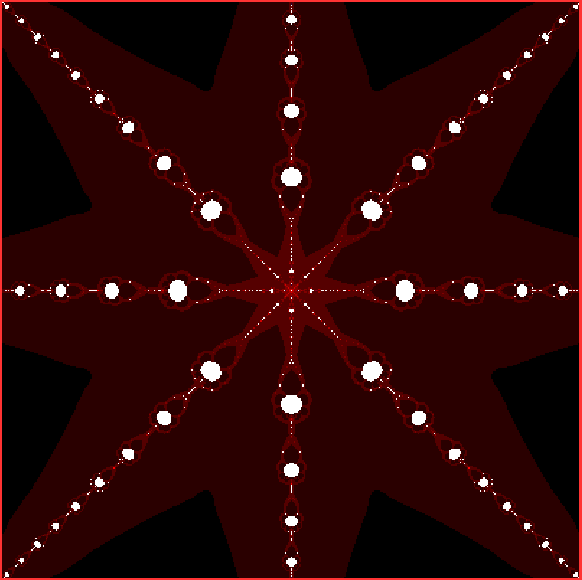


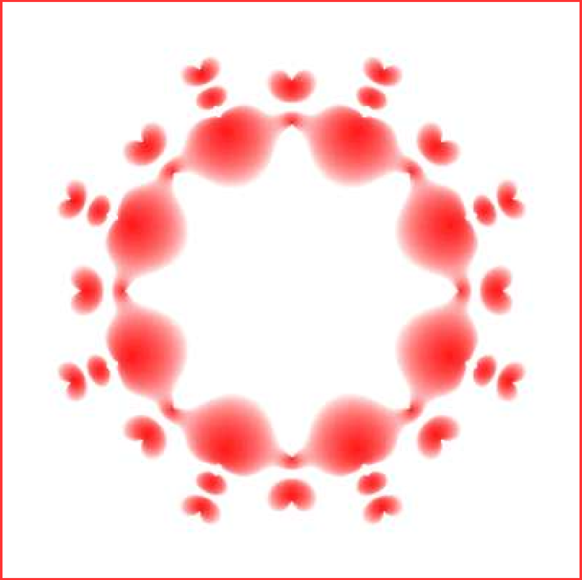


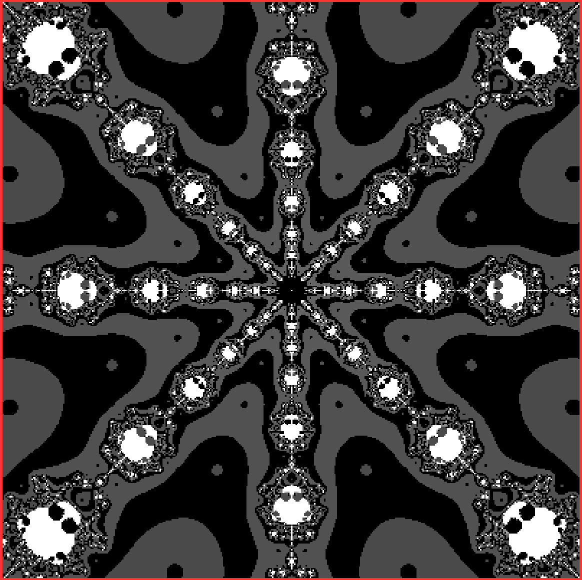












To Whom Can Polynomiography Appeal?

To Whom Can Polynomiography Appeal?

Can it appeal to little kids?

To Whom Can Polynomiography Appeal?

Can it appeal to little kids?

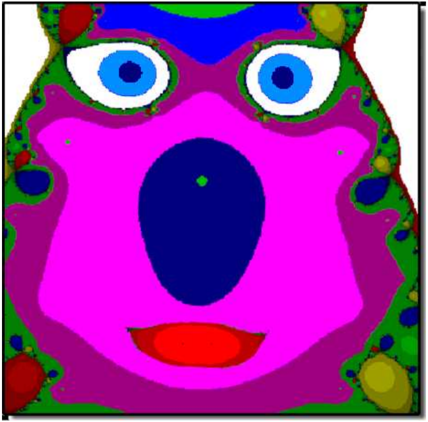
Can it appeal to Hollywood?

To Whom Can Polynomiography Appeal?

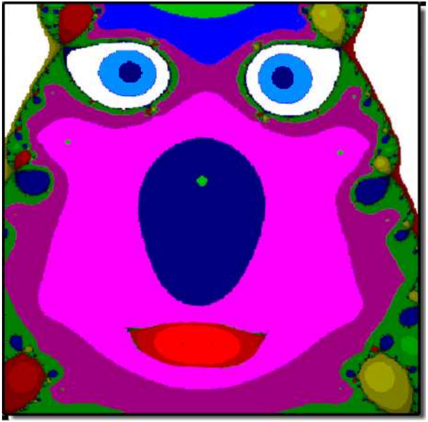
Can it appeal to little kids?

Can it appeal to Hollywood?

Can it lead to games?

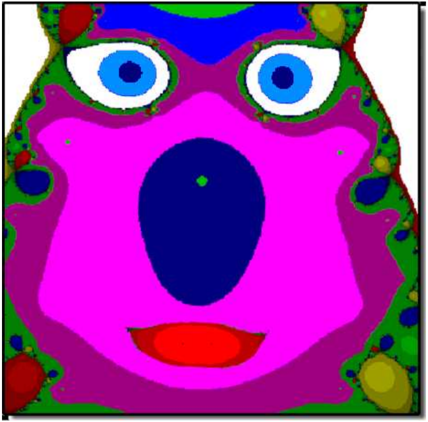


Ms. Poly



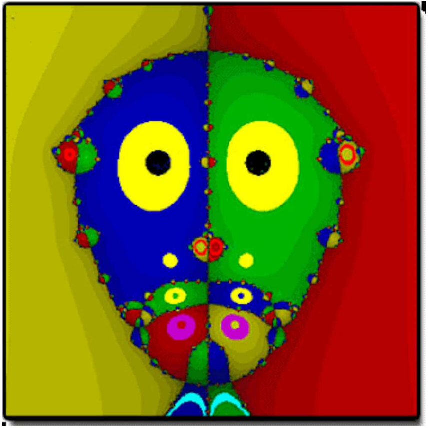
Ms. Poly

"Just give me a bunch of dots I will make Picasso jealous!"

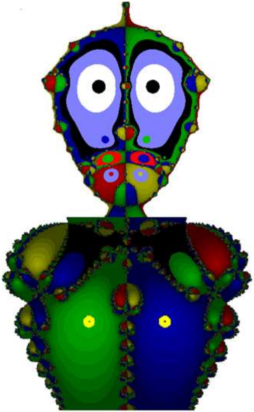


Ms. Poly

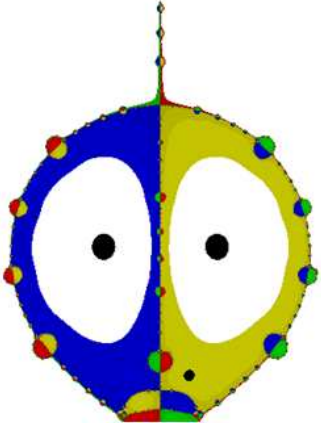
“Just give me a bunch of dots I will make Picasso jealous!”
Ms. Poly (Master of Polynomiography)



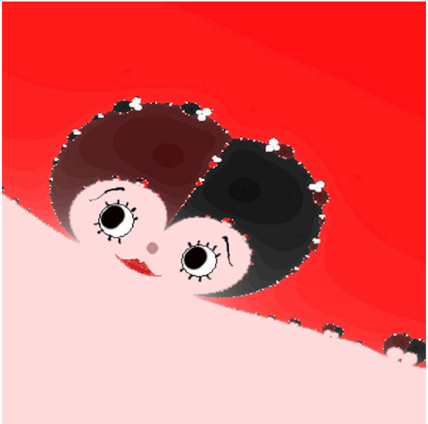
L3


Don Quixote

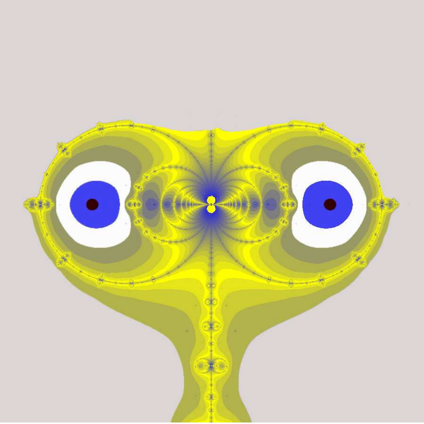
Snoopy on a ride

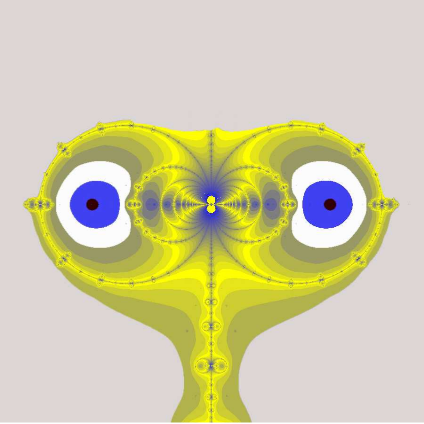


Hi!

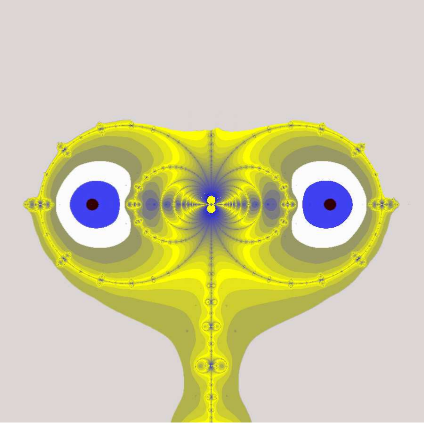


Pretty Betty





They call me Z.T.



They call me Z.T.
Is Popularization of Polynomiography Possible?