Fractals and 3D printing

Presentation

by Jules Ruis (1944)

on Tuesday 27 May 2014

for students of

Fontys Hogeschool Techniek en logistiek

Venlo

Fractals and 3D printing

Introduction Jules Ruis

Worked more then 50 years at

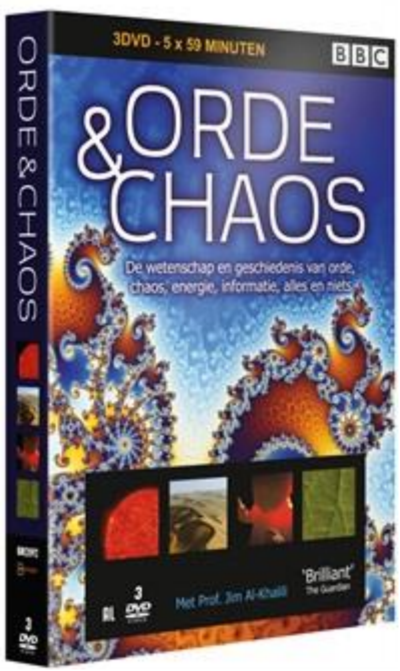
- SME, Philips and Eindhoven University of Technology
- Topopleiding Interaction Management (TIM)
- Triple Helix and Brainport

Now: Fractal Design and Consultancy

Fractals and 3D printing

Introduction Fractal

Introduction video ''Secret Life of Chaos''



Alan Turing (morfogenesis)

Boris Belousov (chemistry of nature)

Benoit Mandelbrot (mathematics of nature)

Fractal Geometry

Evolution

Fractals and 3D printing

Introduction 3D Printing

Introduction video 3D Printing

https://www.youtube.com/watch?v=s1fOdPrnPog

Applications 3D Printing

5. Architecture

4. Food

3. Clothing

2. Cars

1. Human Body Parts

Fractals and 3D printing

Content

Fractals and 3D printing

1. What are fractals?

- A fractal is a geometric object (like a line or a circle)
- that is rough or irregular on all scales of length (invariant of scale).
- A Fractal has a broken dimension.
- By zooming-in and zooming-out the new object is similar to the original object: fractals have a self-similar structure.
- The most well-known fractals are the Mandelbrot Set and Julia Sets.
- Jules Ruis developed the so called Julius Ruis Set. This is a smart presentation of 400 Julia sets, showing that the Mandelbrot Set is the parameter basin of all closed Julia Sets.

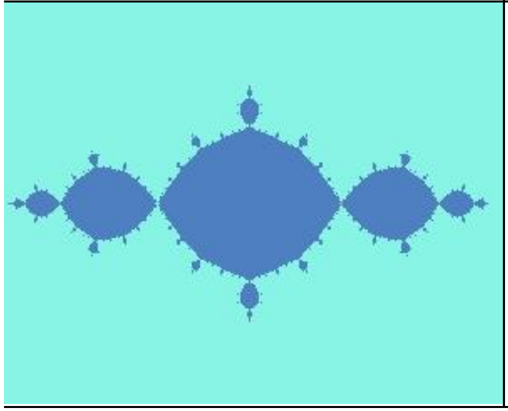
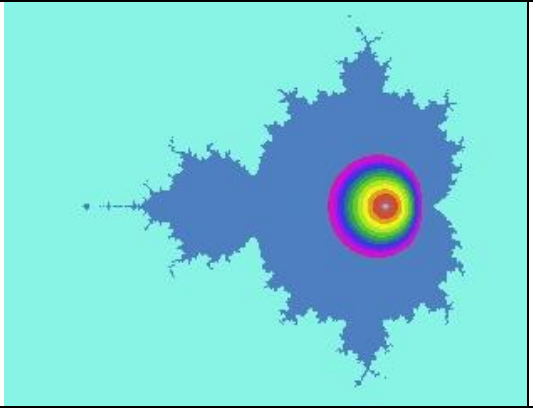
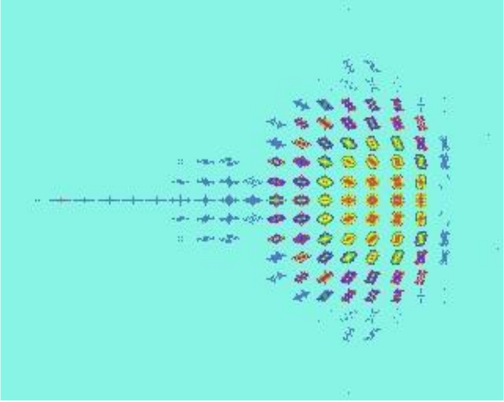
2. Examples of fractals

2.1. Natural fractals

2. Examples of fractals

2.2. Mathematical fractals

Formula: $z_{n+1} = z_n^2 + c$

Julia Set	Mandelbrot Set	Julius Ruis Set
		

2. Examples of fractals

2.3. Mathematical Fractal Tree (iteration)

http://gallery.fractal.org/#!album-32-2

Fractals and 3D printing

3. Fractal Geometry

Fractal Geometry

1. Fractal Geometry is the iteration of complex functions like (inverted) polynomials (z^2, z^3, etc) and complex (inverted) transcendental functions (sin(z), cos(z), tan(z), exp(z)).
2. A complex number has the form $z=x + i*y$ or $c=a + i*b$ with $i^2 =-1$
3. In fractal formulas z_{n+1} means z(new) and z_n means z(old).
4. Formula in function is iterated from 1 to maximal ‘k’ times.
5. Iteration goes on until predetermined small/great value has been reached (function is going to zero or infinity).
6. Quantity of real done iterations is called ‘f’ (‘flightnumber’).
7. Instruction at the end of the procedure, coupled on reached ‘f’, is : pset color, position machine printhead (ink, matter, cell or molecule, etc), manipulate beam/bundle or position motor.
8. Calculate next computer-pixel and manipulate next machine-voxel, layer for layer.

4. Why Fractal Geometry?

Fractals provide scientists with a new vocabulary to read the book of nature. Euclides circles and triangles are insufficient to describe nature in all its rugged complexity.

In addition, the fact that natural objects are commonly self-similar, makes fractals ideal models for many of those objects.

Fractal geometry also provides scientists with a new way of looking and experimenting with old problems using a different perspective.

What is most exciting about fractals is that they successfully bring geometry to where it did not appear to belong, an idea reminiscent of general relativity, which is based on the introduction of geometry to understand the cosmos.

5. 1. Where are Fractals good for?

Fractal geometry is a compact way of encoding the enormous complexity of many natural objects. By iterating a relatively simple construction rule, we see how an original simple object can be transformed into an enormously complex one by adding ever increasing detail to it, at the same time preserving affinity between the whole and the parts, or scale invariance.

Just think of a big oak tree in winter. Its branches are naked so it is easy to distinguish the way in which a twig splits and becomes two which then split again, to become four; in much the same way in which the trunk first split into slender branches which split again and then again, and again. The self-similarity is evident, the whole looks just like its parts, yet not exactly. Nature has slightly altered the construction rule, introducing some degree of randomness which will make one oak slightly different from any other oak tree in the world.

Now, imagine packing all the information required by the tree to become a beautiful large oak tree into the smallest possible space, with the greatest economy of means. It would appear logical that rather than encoding all the unique, intricate complex branching of a mature oak in its seed (an acorn), all the details of its evolving shape, nature simply encodes the splitting rule, and the urge to repeat it, to iterate. This, plus a little randomness during growth that changes the number of splits or their place in a branch is enough to create a unique oak tree.

5.2 Fractal Geometry:
a design principle for living organisms

Fractal geometry: a design principle for living organisms

E. R. Weibel
Department of Anatomy, University of Berne, Switzerland.

Fractal geometry allows structures to be quantitatively characterized in geometric terms even if their form is not even or regular, because fractal geometry deals with the geometry of hierarchies and random processes. The hypothesis is explored that fractal geometry serves as a design principle in biological organisms. The internal membrane surface of cells, or the inner lung surface, are difficult to describe in terms of classical geometry, but they are found to show properties describable by fractal geometry, at least sectionwise and within certain bounds set by deterministic design properties. Concepts of fractal geometry are most useful in characterizing the structure of branching trees, such as those found in pulmonary airways and in blood vessels. This explains how the large internal gas exchange surface of the lung can be homogeneously and efficiently ventilated and perfused at low energetic cost. It is concluded that to consider fractal geometry as a biological design principle is heuristically most productive and provides insights into possibilities of efficient genetic programming of biological form.

6.1. From Fractal Geometry to Fractal Trigeometry

We want to calculate 3D fractals called the Mandelbulb, Juliusbulb and Juliabulb. Similar to the original 2D Mandelbrot the 3D formula is defined by $z \rightarrow z^n + c$ but where 'z' and 'c' are hypercomplex ('triplex') numbers representing Cartesian x, y, and z coordinates.

The exponentiation term can be defined by:

$\{x,y,z\}^n = (r^n) \{ \cos(n*\phi) * \cos(n*\theta), \sin(n*\phi) * \cos(n*\theta), \sin(n*\theta)\}$

where $r = \mathrm{sqrt}(x^2 + y^2 + z^2)$ and $r1 = \mathrm{sqrt}(x^2 + y^2)$

As we define θ as the angle in z-r1-space and ϕ as the angle in x-y-space

then $\theta = \mathrm{atan2}(z / r1)$ so $\theta = \mathrm{atan2}(z / \mathrm{sqrt}(x^2 + y^2))$ and $\phi = \mathrm{atan2}(y/x)$

6.2. From Fractal Geometry to Fractal Trigeometry

Summary Formula 3D Mandelbulb, Juliusbulb and Juliabulb

$r = \mathrm{sqrt}\ (x\text{^}2 + y\text{^}2 + z\text{^}2)$

$\theta = \mathrm{atan2}\ (z\ /\ \mathrm{sqrt}(x\text{^}2 + y\text{^}2)$

$\phi = \mathrm{atan2}\ (y/x)$

$newx = (r\text{^}n) * \cos(n*\phi) * \cos(n*\theta)$

$newy = (r\text{^}n) * \sin(n*\phi) * \cos(n*\theta)$

$newz = (r\text{^}n) * \sin(n*\theta)$

where n is the order of the 3D Mandelbulb, Juliusbulb/Juliabulb.

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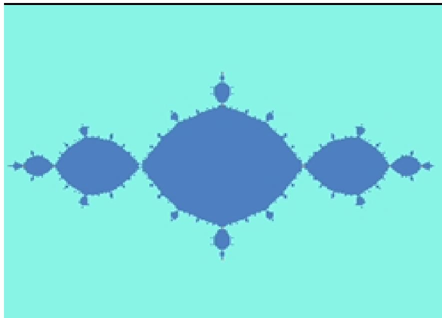
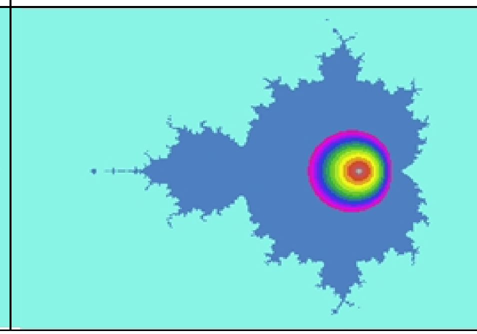
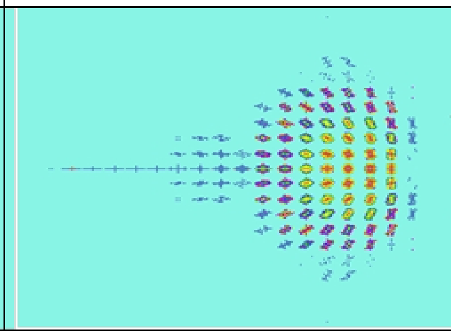
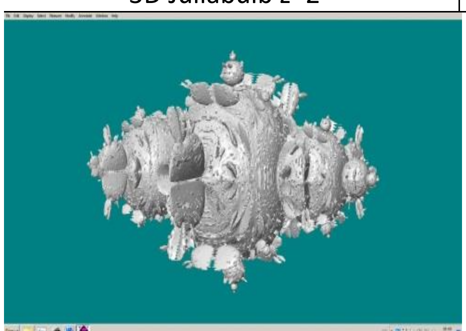
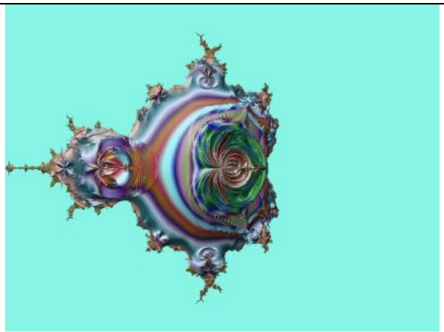
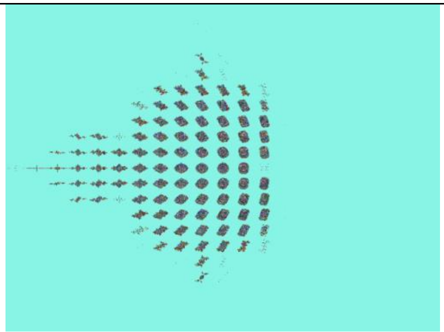
7. Examples of Fractal Trigeometry?

2D

Julia Set	Mandelbrot Set	Julius Ruis Set
		

3D

3D Juliabulb z^2	3D Mandelbulb z^2	3D Juliusbulb z^2
		

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8.1. Fractal Imaginator Software (FI)

Fractal Imaginator

1. The Fractal Imaginator is a software program to create fractals.
2. Using the program Fi you can input your own mathematical formulas and other relevant data.
3. The created images are saved as bmp/jpg/png files or obj/stl files.
4. The parameters of the image are stored in separated data-files .fim files (32bit) or .fi6-files (64 bit)
5. This way of storing saves much computer capacity.
6. After installation of Fi on your own computer the Fi program will automatically start by clicking the .fim files or .fi6 files (just like Adobe pdf files).

8.2. Fractal Imaginator Software (FI)

Freely download one of the Trial Versions of the Fractal

Imaginator (FI) software :

32-bit computer: Fractal Imaginator 32-bit trial

64-bit computer: Fractal Imaginator 64-bit trial

or to buy for $40.00:

32-bit computer: Fractal Imaginator 32-bit to buy

64-bit computer: Fractal Imaginator 64-bit to buy

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9.1. 3D fractal printed objects

9.2. 3D fractal printed objects

Fractal Shops Jules Ruis

http://www.shapeways.com/shops/fractal-shop

http://i.materialise.com/shop/designer/jules-ruis

http://gallery.fractal.org

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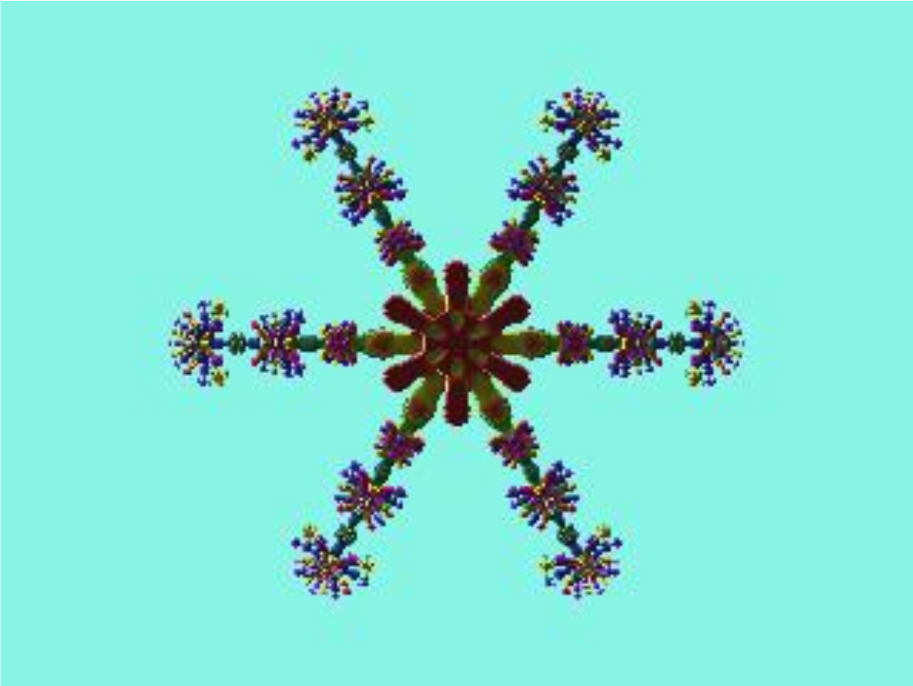
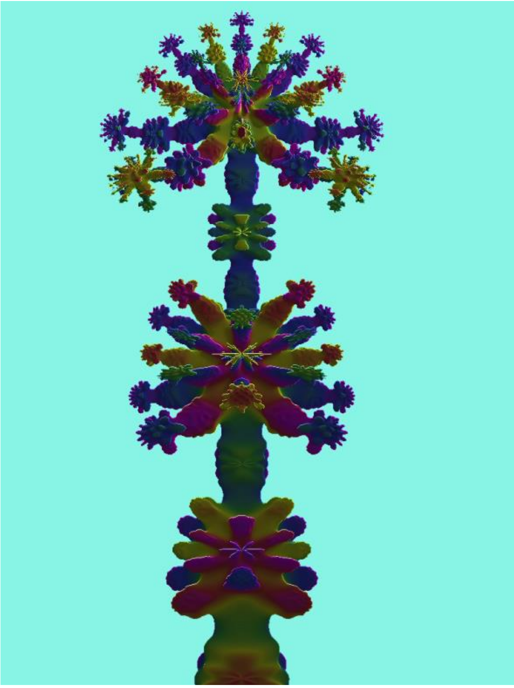
9.3. 3D fractal printed objects

Layering 3D printing





http://gallery.fractal.org/#!album-32-13

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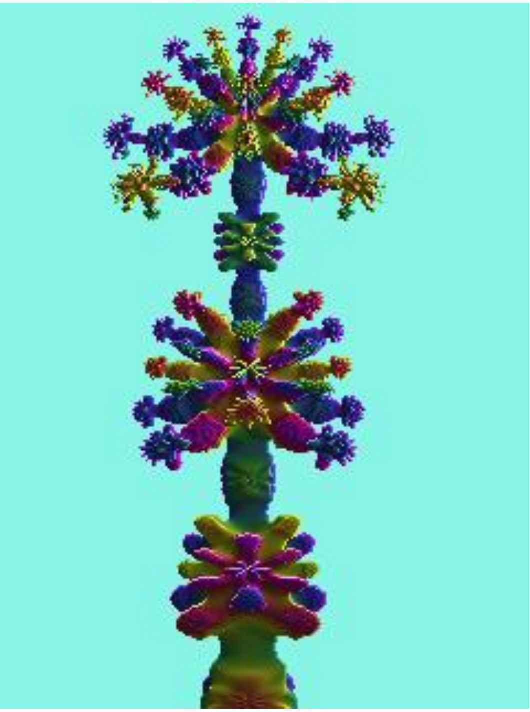
10. Applications



Antenna's

Solar Cells

Artificial Human Organs

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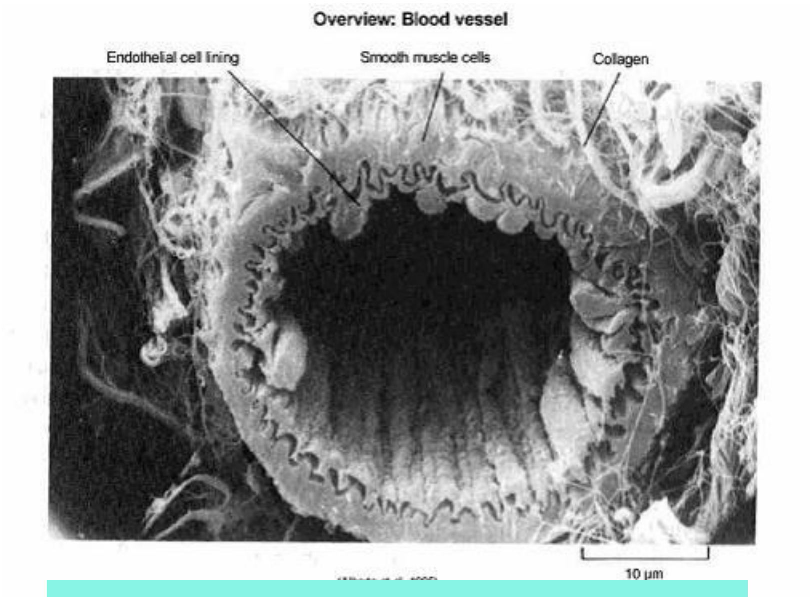
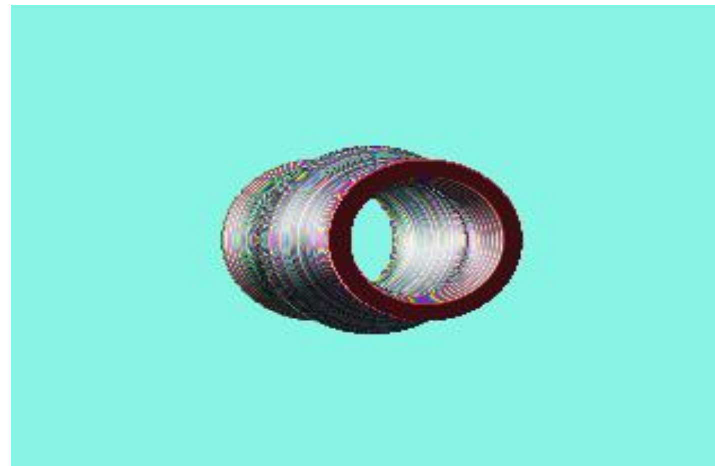
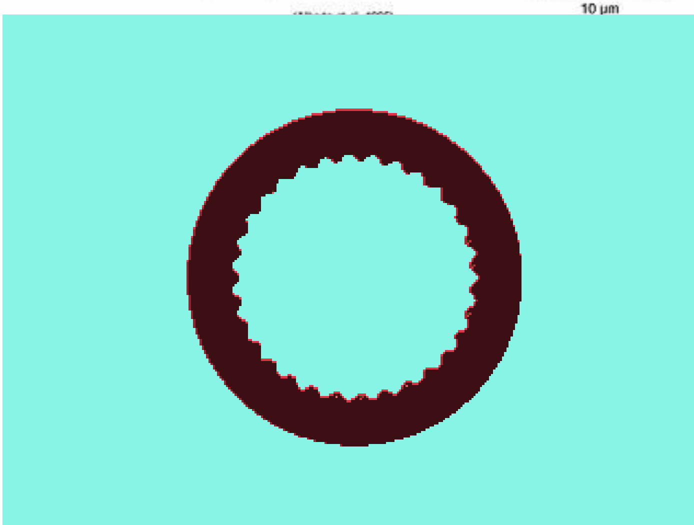
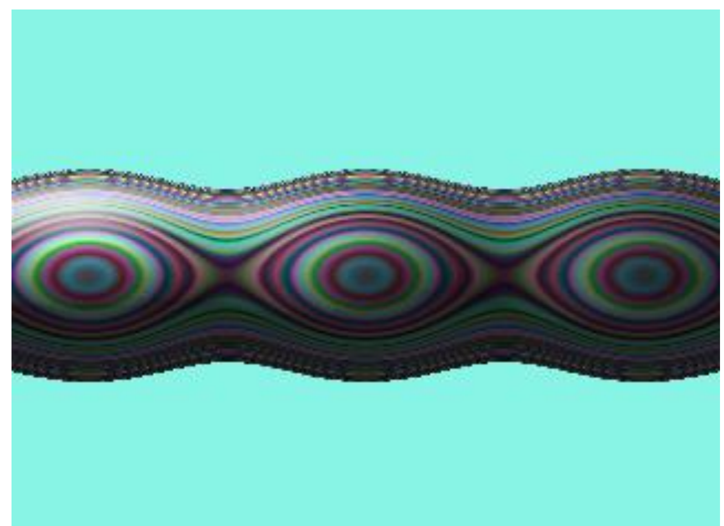
11. Artificial bloodvessel









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12. Patent Application

Jules Ruis filed end 2006 a patent application on a procedure using fractal geometry for the design and manufacturing of artificial human and/or animal organs, more specifically human blood vessels. The designed structures can be presented in a two-dimensional as well as a three-dimensional way.

The patent pending also emphasizes the use of fractal geometry for the direction of print- and injectionheads in equipment used for the application of materials (inkjet printing and methods of direct writing), and equipment that directs laserbeams and electronic beams (electron microscopes).

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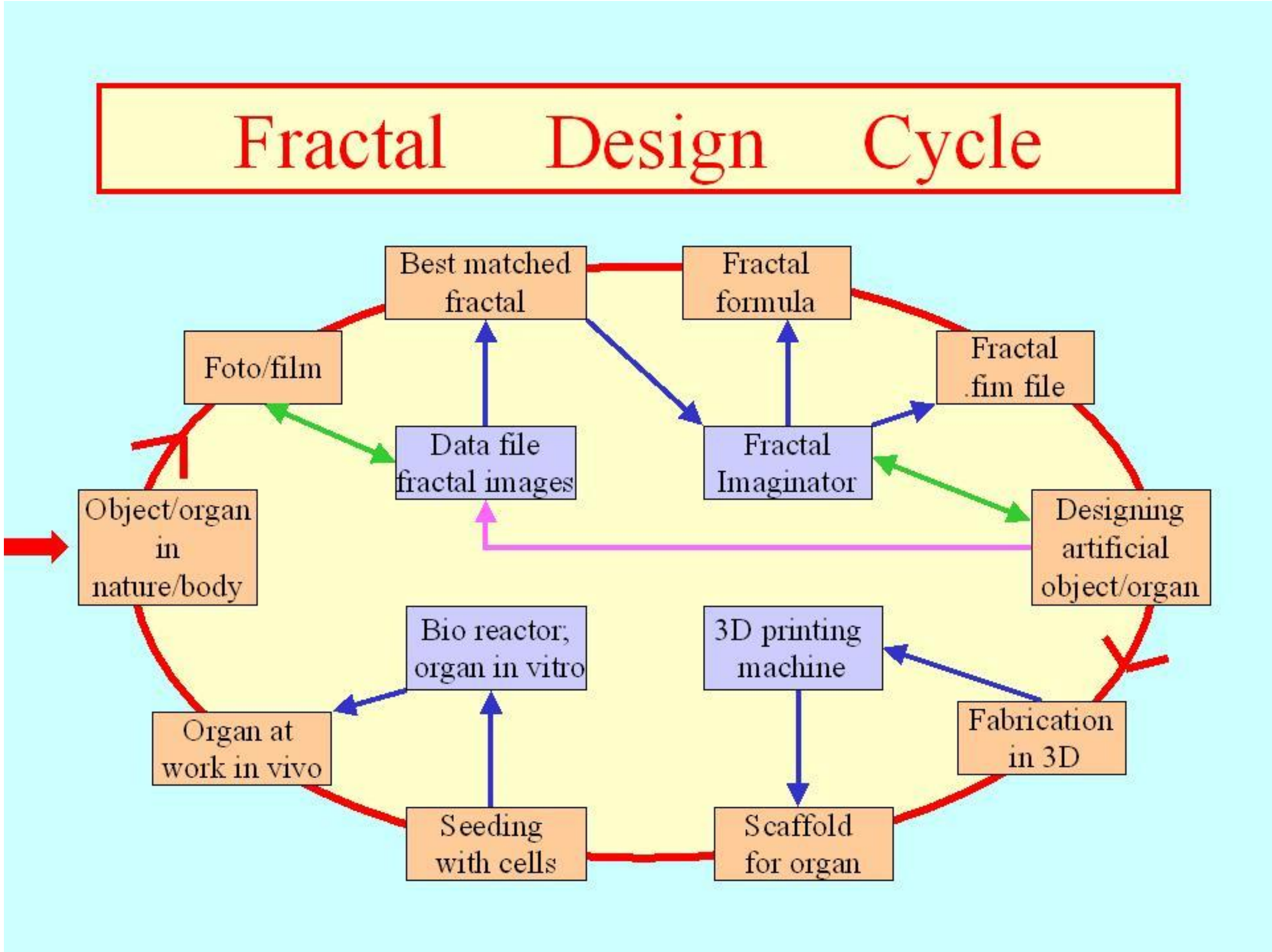
13. Fractal Design Cycle



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14. Artificial Human Organs

- Human body and organs
- Brain/eye/ear/
- Heart/blood vessel/lungs
- Digestion/intestines/liver
- Stomach/colon/kidneys
- Bladder/trabecular bone

- Cell/neuron/mitochondrium
- Bacterium/virus

- DNA/RNA/protein
- Dendrimer
- Molecule/atom/particle
- Unparticles

15.1 Print me a heart and a set of arteries

publication d.d. April 2006

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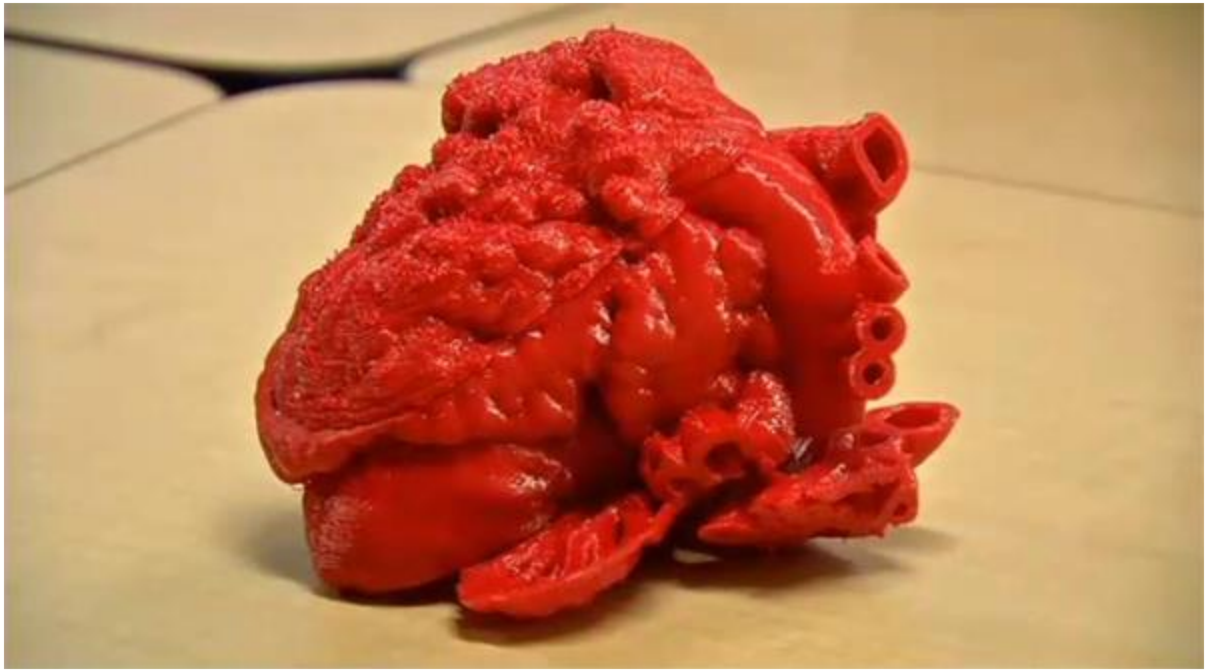
15.2 Print me a heart and a set of arteries

May 2014

http://www.fractal.org/Fractal-Research-and-Products/Printable-hearts.pdf



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16. Further information

See:

http://www.fractal.org/Fractalary/Fractalary.htm

http://gallery.fractal.org

http://www.fractal.org

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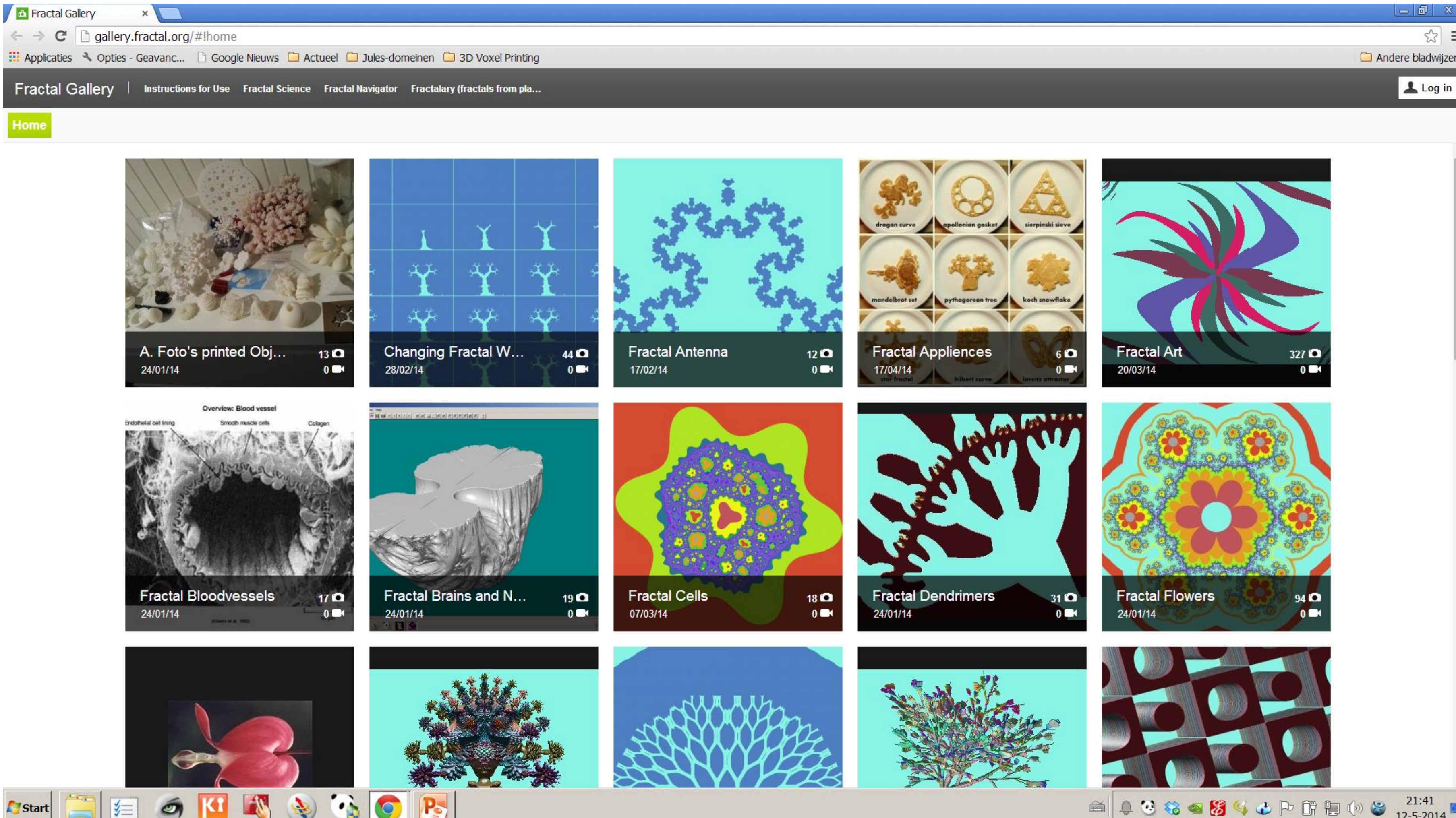
17. http://gallery.fractal.org



End: Questions and Remarks

1. .Playing wit Fractal Imaginator (FI)
2. .
3. .
4. .
5. .