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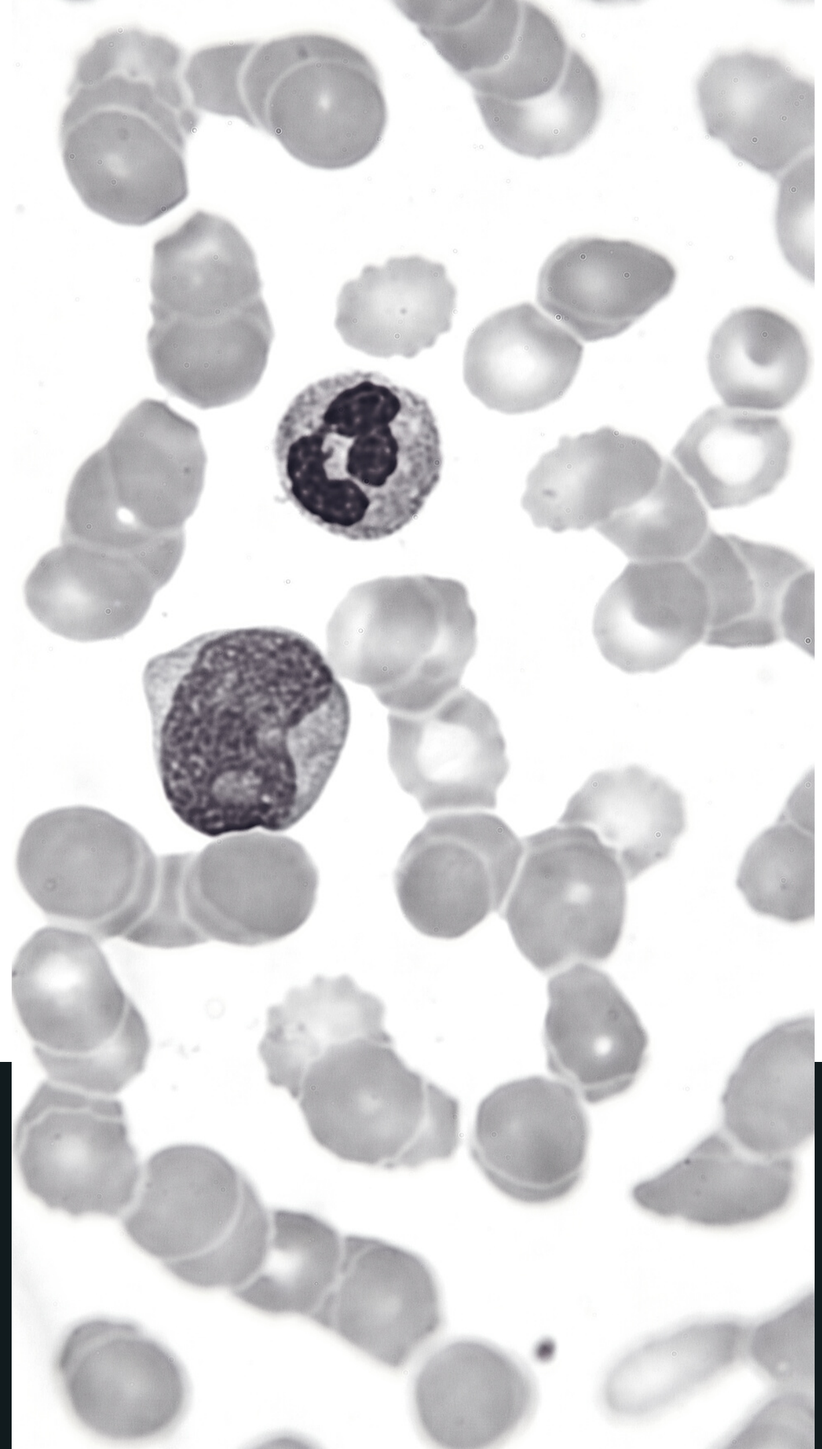
Biomedical imaging with fractals spaces



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Course link :

/IhabBendidi/biomedical-imaging-with-fractals

ihab.png

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The Presenter

IHAB BENDIDI

Deep Learning Engineer

RESEARCH & INDUSTRY

Artificial Intelligence

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RULE BASED

Expert Systems
Multi-agent systems
Knowledge bases
Ontologies

CONSTRAINT BASED

Linear Systems
Constraint Domains
Operational Research

CONNECTIONIST APPROACH

Machine Learning
Deep Learning
Reinforcement Learning
Genetic Algorithms

DOMAIN SPECIFIC APPROACHES

Fractal Spaces
Segmentation Algorithms
Optical Reconstruction
.....

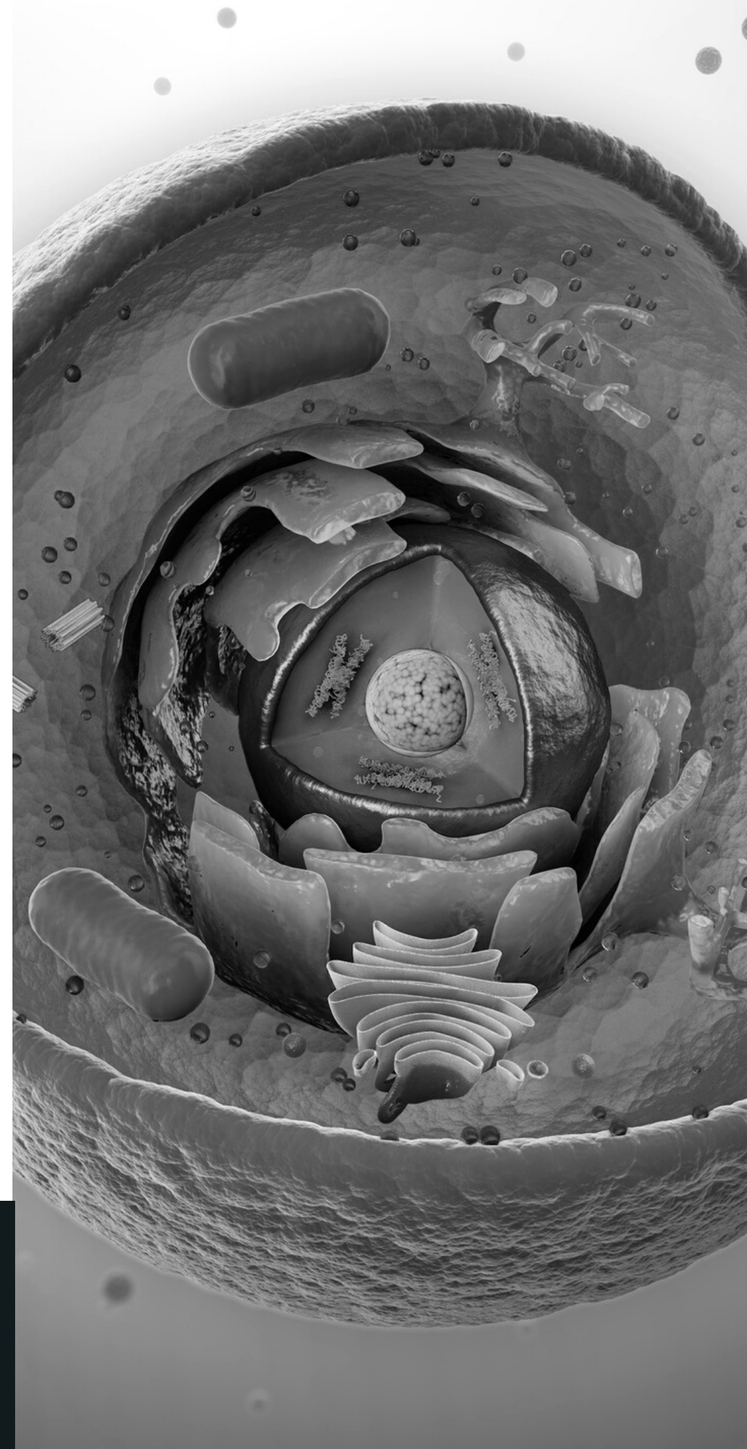
Why not use Deep Learning if it has better results ?

Data Intensive

MODELS NEED HUGE AMOUNTS OF DATA FOR TRAINING

Expertise Necessity

DATA CAN ONLY BE LABELLED BY EXPERTS



Fractals' Definitions

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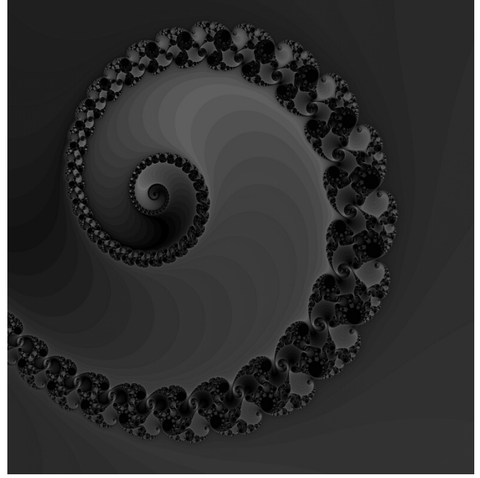

SELF SIMILAR

Every part of a fractal curve is similar to the whole curve.

HIGHER DIMENSIONS

The dimension of a fractal always exceeds the dimension of a similar but non-fractal curve.

REPRESENTS NATURE

Fractals are always naturally in everyday sights of our life, only unnoticed by most.

WHAT MAKES A FRACTAL... A FRACTAL...

Auto similarity, or how we can theorically and iteratively create one.

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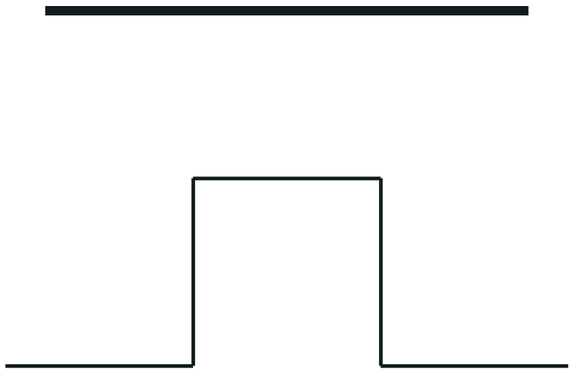

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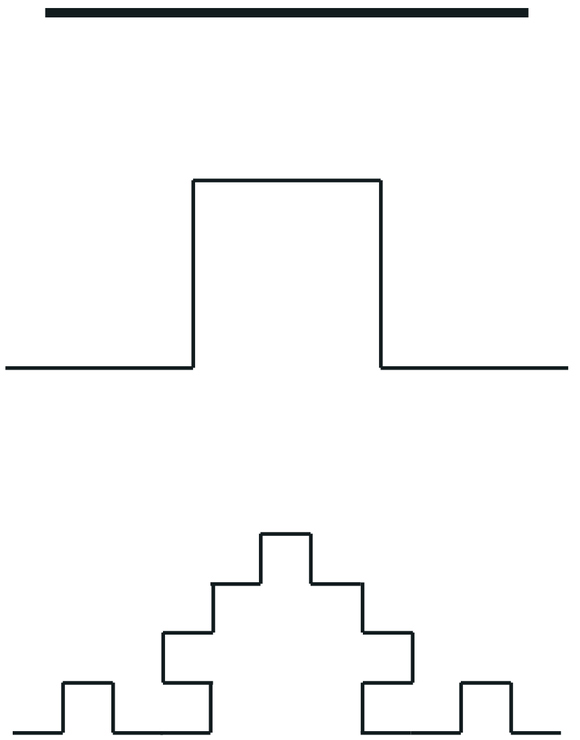

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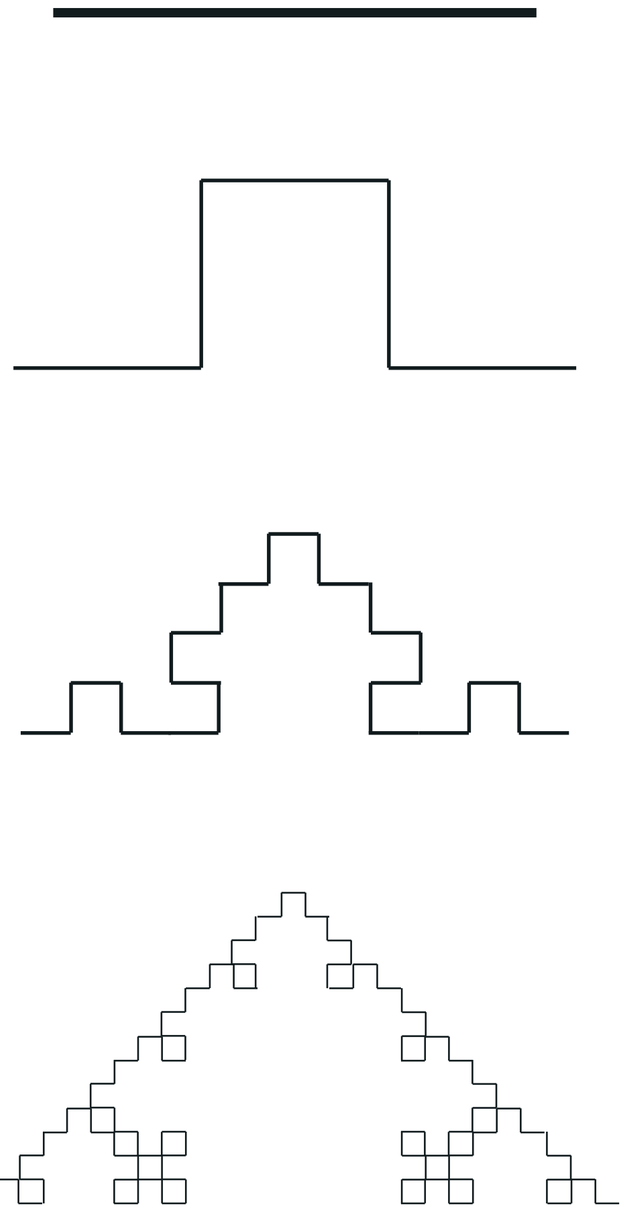
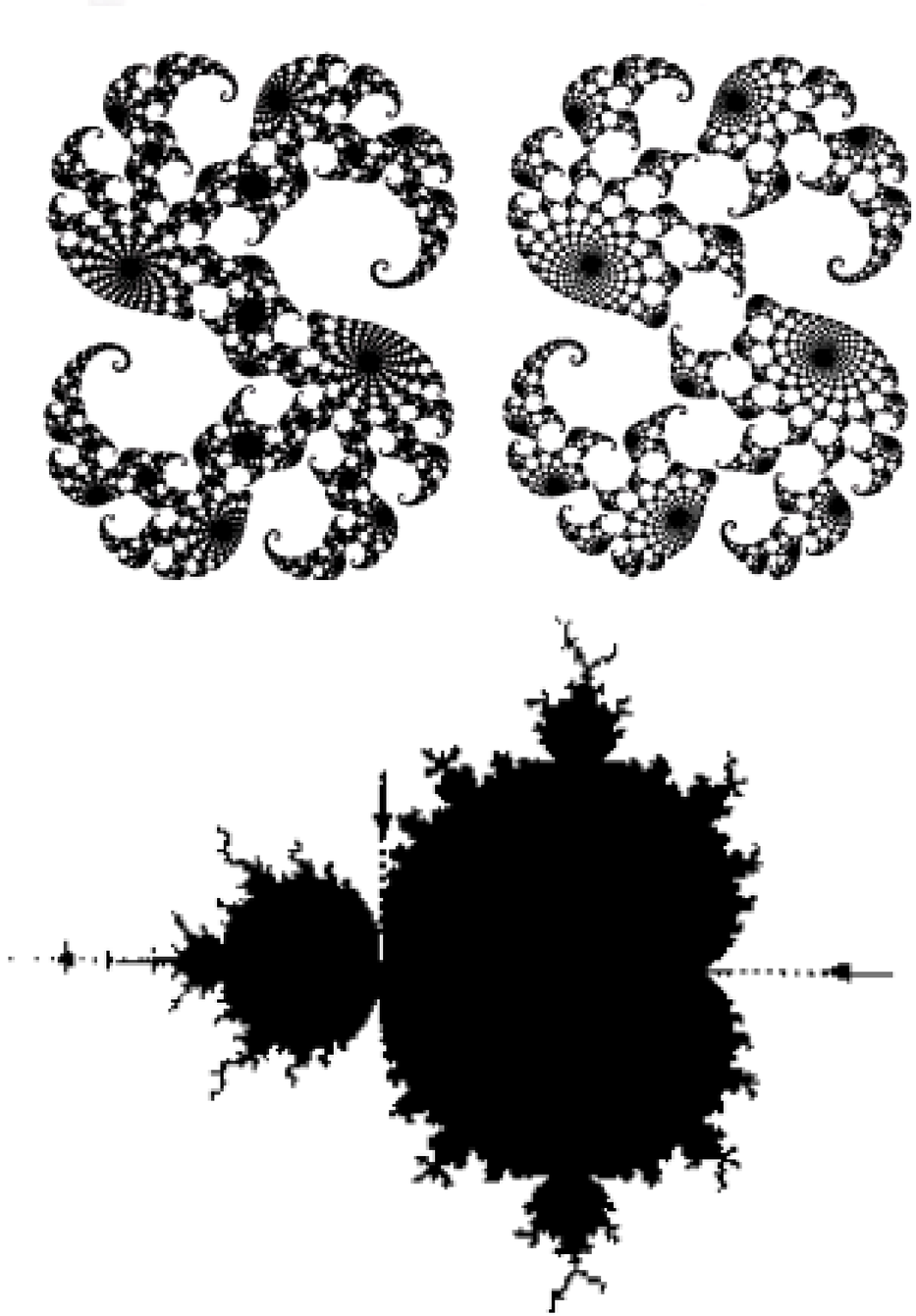


SOMETHING TO REMEMBER

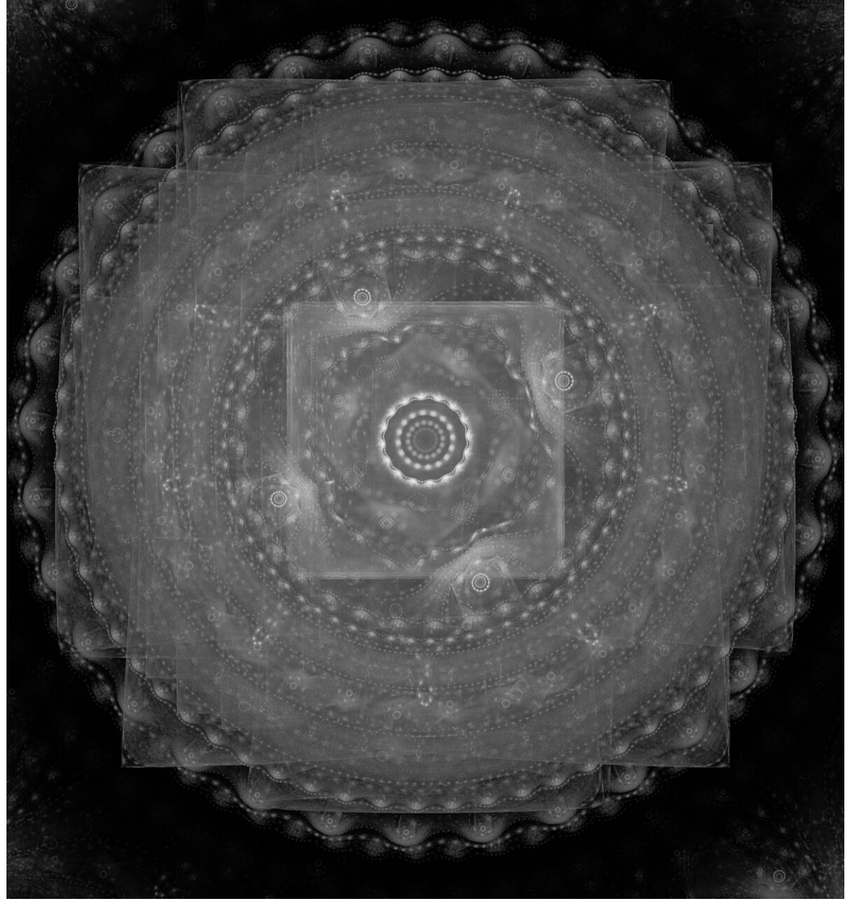
Every operation, every transformation, can be modelized into a function



Julia Set

Successive iterations can take the form of the recursive function $Z \leftarrow Z^2 + c$;
Using this function, starting from a single point, we can generate a whole fractal infinitely. And 'c' is the constant controlling its shape, connectivity and behavior as it gets close to infinity.

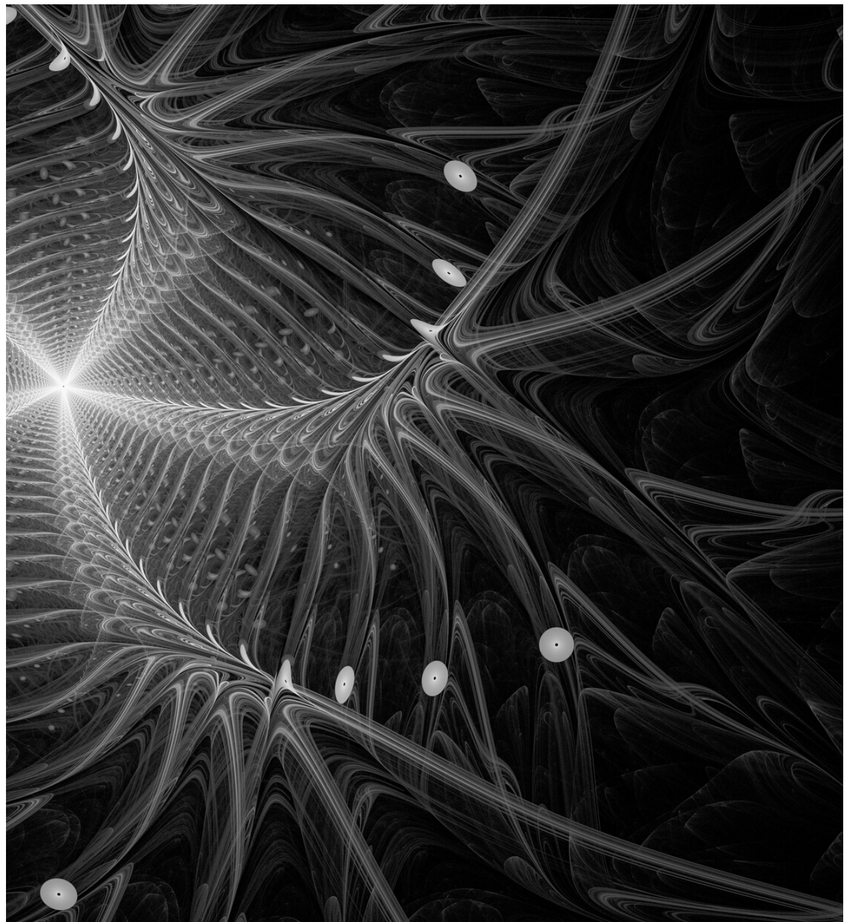
FRACTAL SPACES IN 2D SPACES



This is only one curve, fractured to Infinity

FRACTAL SPACES IN 3D SPACES

And this, is only a surface, fractured to infinity.

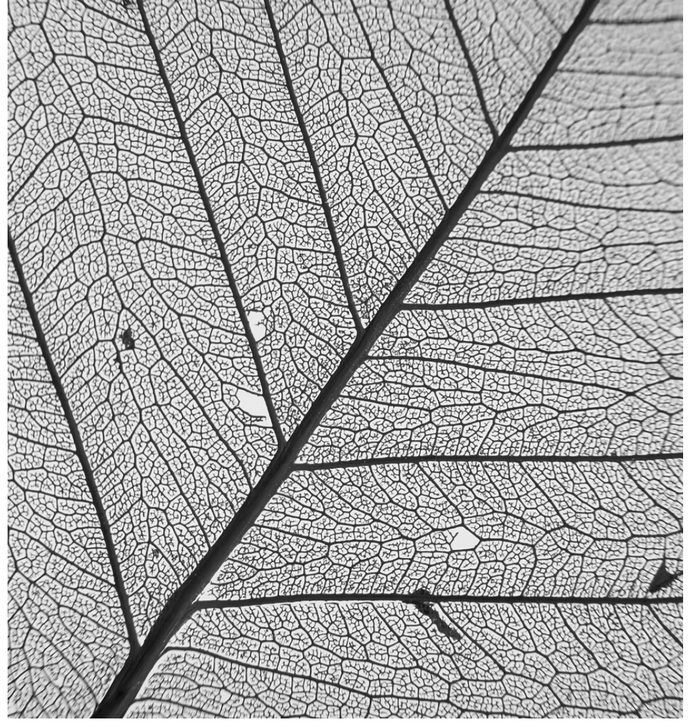


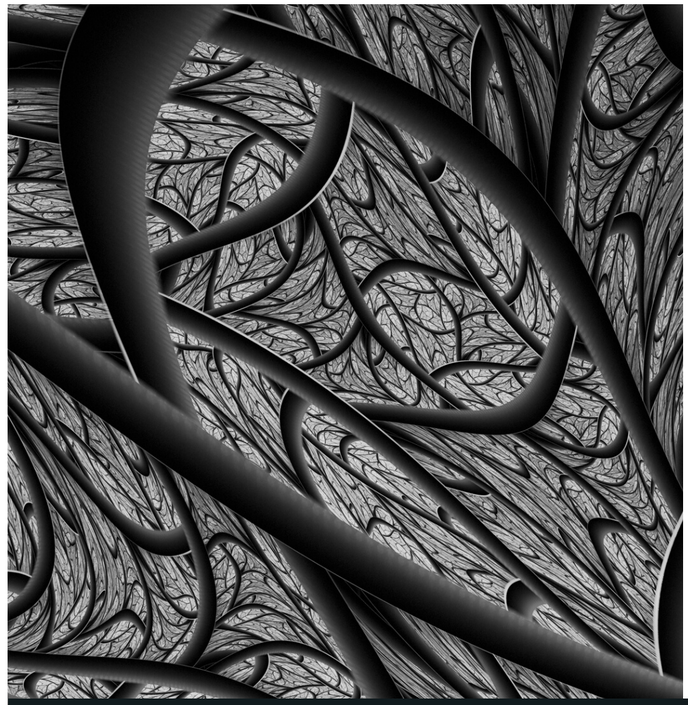
Digging deeper

https://fractal.rafgraph.dev/

FRACTALS IN NATURE

They can be found in most things if you look deep enough.
Patterns. Patterns governed by functions.





An image can fully resumed by only one function, without any loss of quality in smaller scale.

That applies to all images containing fractals.

But it can also applied with some modifications to regular everyday images.

A result of that...

Fractal Compression

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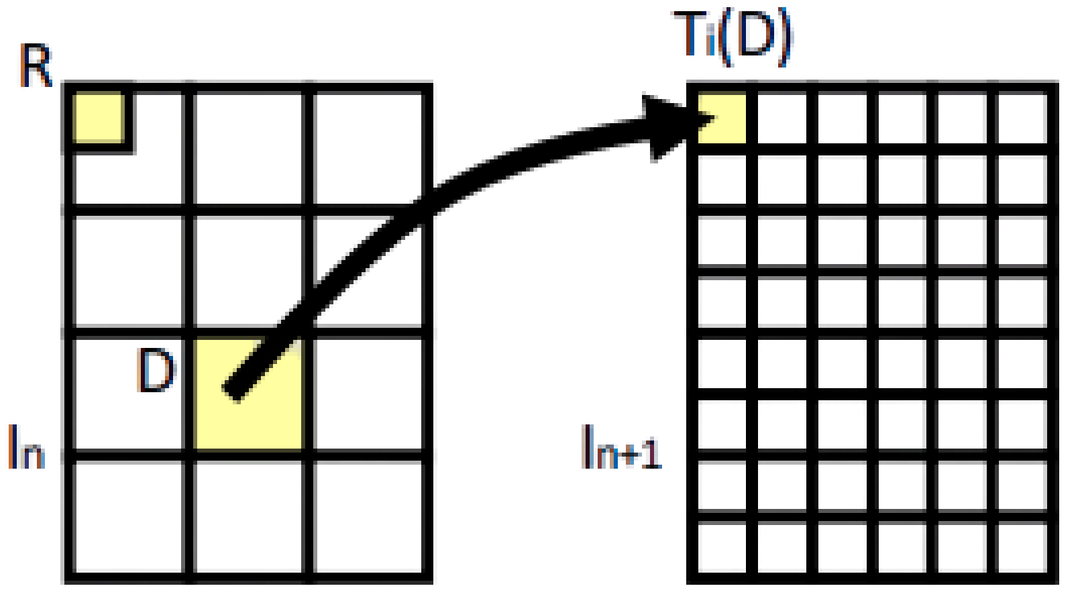
Inverse process of fractal generation. We aim to transform an image into a group of functions defining it.

We look for internal self similarity in a picture. It always exists, only in very different scales.

Each function T of the group of functions is defined by a Domain 'D', a Range 'R', and defines an autosimilarity such as
R = T(D)

Following the theorem of the fixed point, once we have a group of functions defining each region of our image, then from whatever starting image, we can get our final image.



Fractal Compression In practical terms

We divide our image into a grid of many Regions R.

Our segmentation/contour algorithms needs to finds other domains (group of regions) that are similar to the first region.

We then find a self similar function such as R = T(D), and that is for every iteration, until we get a set of functions that can generate our initial image just from a black image.

Timeline

FROM THEN TO NOW

"Beautiful, damn hard, increasingly useful, that's fractals."

"A fractal is a set for which the Hausdorf-Besicovitch dimension stricly exceeds its topological dimension."

"A fractal is a shape made of parts similar to the whole in some way."

- A point is of dimension 0
- A curve or line has a topological dimension of 1
- A surface has a topological dimension of 2

Classic Euclidian Spaces reminders

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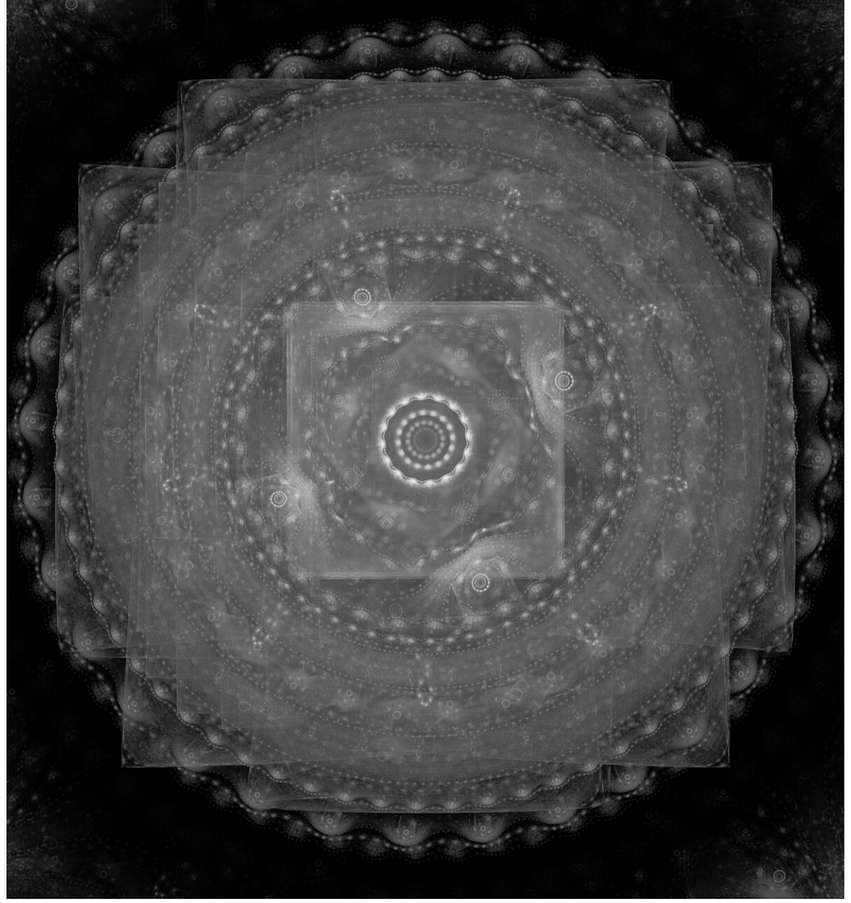
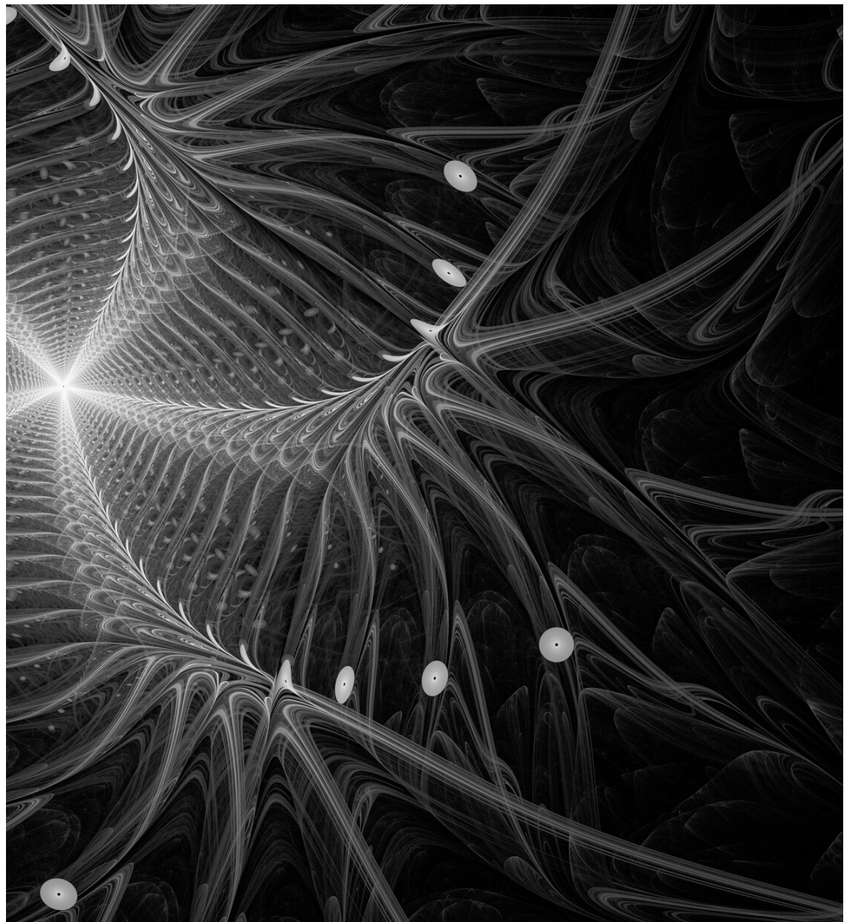
FRACTAL SPACES IN 2D SPACES



This curve's dimension exceeds 1 dimension, as it fills surface between the cracks infinitively.

FRACTAL SPACES IN 3D SPACES

This surface's dimension exceeds 2 dimensions, as it fills the volume between the fractures infinitively.



DIMENSION COMPUTING

In defnition, all dimensions can be computed the following way

$$N = \varepsilon^{-D}$$

With D as the dimension, Epsilon as the scale metric, and N the number of sticks/surfaces in the scaled curve

That is, for a fractal described by $N = 4$ when $\varepsilon = \frac{1}{3}, D = 1.2619$, a non-integer dimension

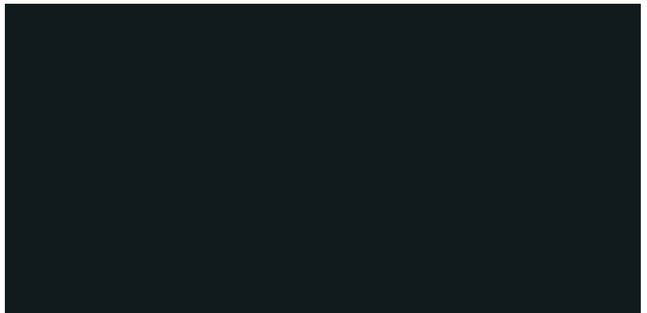
Computing the fractal dimension

Fractal Spaces in Technology

Signal and Image
compression and generation

Pathology, Enzyme detection,
and microbiology recognition

Material Engineering and fiber
reconstruction



Case Study

We'll be interested here in the results of HD Colonoscopy, to detect whether Polyps exist in the colons of the patient.

Local fractal dimension computing has proven to be an efficient way for automated detection.

A more detailed article would be found on the course's Github.

FRACTAL DIMENSIONS FOR RECOGNITION OF POLYPS

Pratically detecting Polyps

Segmentation of surfaces by depth, using Watershed algorithms

Take each segmented surface separately, divide it into regions, and compute their local fractal dimensions at different scales.

Compute an unified fractal dimension for each region, scale invariant.

Simple ML classification models can then separate the regions with very different dimensions while in the same segment.

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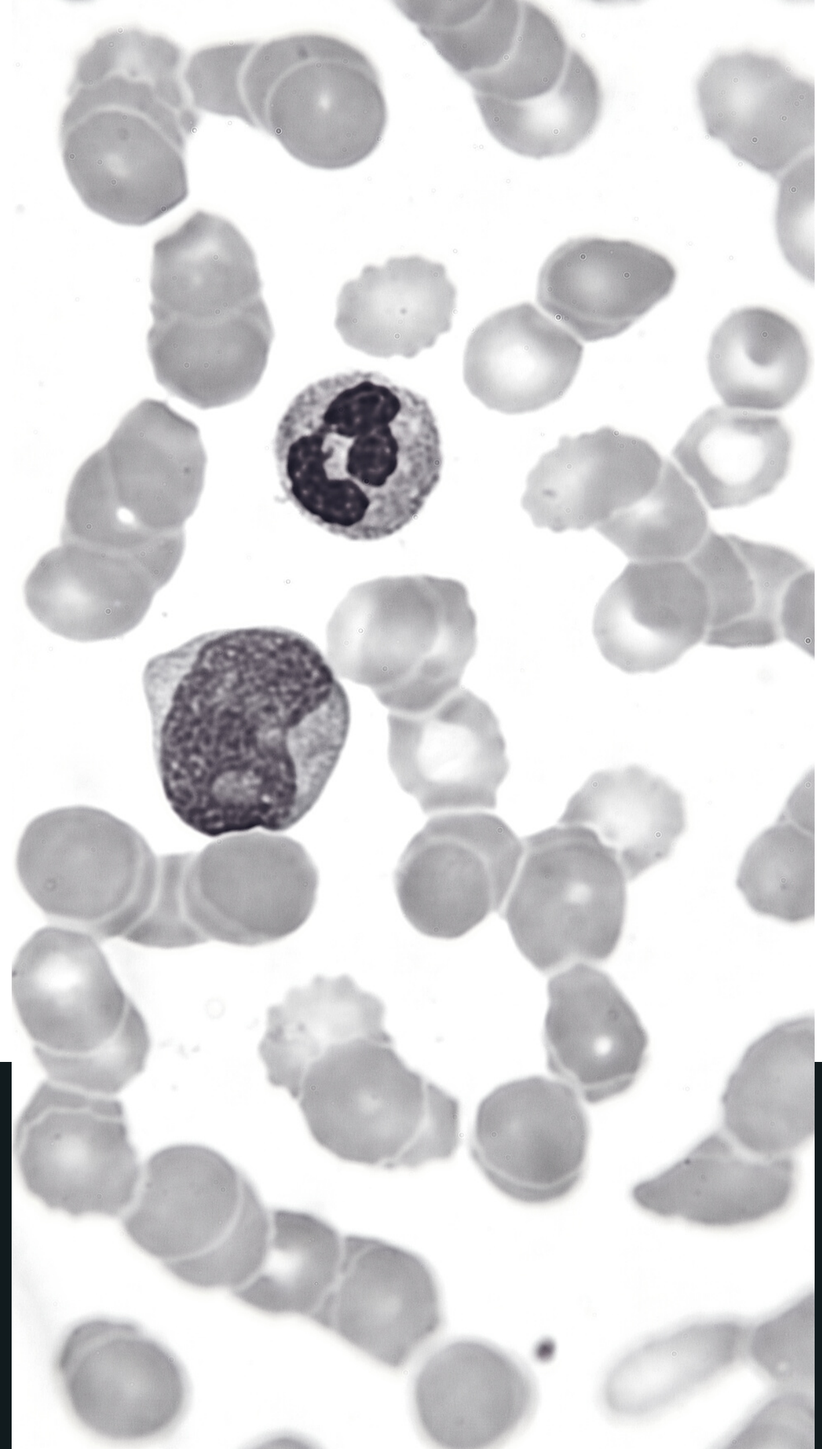

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