ALKINDI
Society of Engineers
جمعية الكندي للمهندسين

Complex Systems Webinar Series

Nonlinearity, Chaos and Complexity in Science, Technology and Life

Presenter: Dr Ali AlBadri

ASME SETTING THE STANDARD
UNITED KINGDOM

The Complex Systems Special Interest Group of Al-Kindi Society of Engineers, in collaboration with the UK section of the American Society of Mechanical Engineers (ASME-UK) are pleased to invite you to this webinar on Nonlinearity, Chaos and Complexity in Science, Technology and Life.

In this introductory lecture to the Complex Systems webinar series, Dr Ali Albadri will introduce the building blocks and history of this new science to show how it has evolved to the maturity we see now.

Dr Ali Albadri

- Ali has a PhD and MPhil in Materials Science from UMIST and Sheffield University respectively. A BSc in Nuclear Engineering and another in Mechanical Engineering from Baghdad University and Technology University, respectively.

- He worked for UMIST, Brunel University, Oxford University, then he moved to work for various companies. He worked as a Materials Scientist for Cookson Group, Design Engineer for ABB, Senior Design Engineer for Olympus Ltd and Hydronix Ltd, Lead Engineer for Tube Lines Ltd and JNP, then Chief Engineer for London Underground Ltd.

- He invented and patented numerous products including the concrete strength device, the smart step and the smart test rig.

- He has published more than 30 technical papers in various subjects, such as Materials Science, Nuclear Radiation, Condition Monitoring for Infrastructures, Interaction between Microwaves and Materials Moisture Contents.

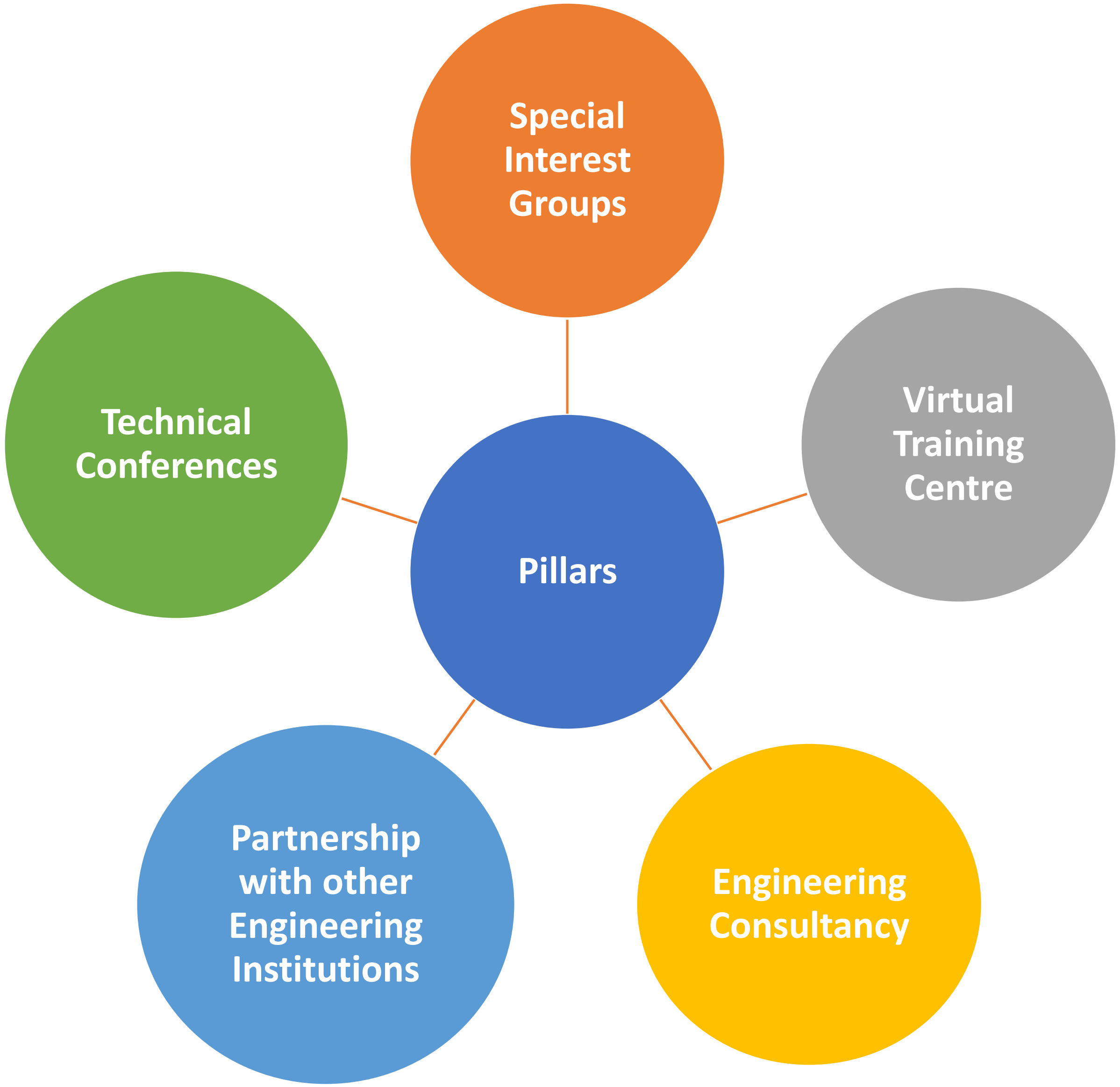
- In recent years, he published more than 20 articles in the subject of using the fractal dimension concept in understanding and maintaining machines.

ALKINDI
Society of Engineers
جمعية الكندي للمهندسين

Founded in 1994, and incorporated June 2014, as a Not-for-Profit company limited by guarantee based in London-UK.

Our purpose:

“To promote for the public benefit, the art and science of engineering in all its applications and to advance education in engineering, and technology.”



SETTING THE STANDARD

- Founded in 1880 as the American Society of Mechanical Engineers, ASME is a not-for-profit professional organization.

- ASME enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society.

- At ASME, members are a part of a network of over 100,000 members representing 140+ countries.

- Within the sections you can engage professionally through courses, activities, networking and meetings.

ALKINDI Society of Engineers
جمعية الكندي للمهندسين

ASME SETTING THE STANDARD
UNITED KINGDOM

Complexity, Nonlinearity and Chaos in Science Technology and Life

Dr. Ali Albadri

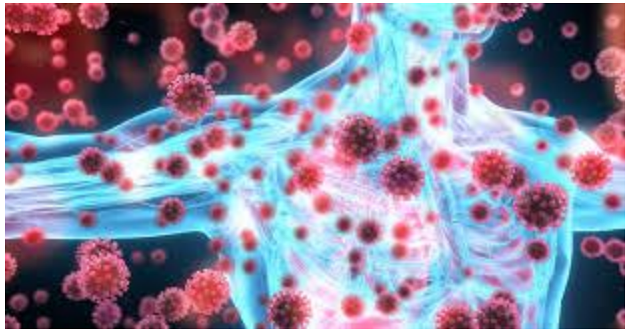
17 Feb 2020

Complex Systems

Insect colonies

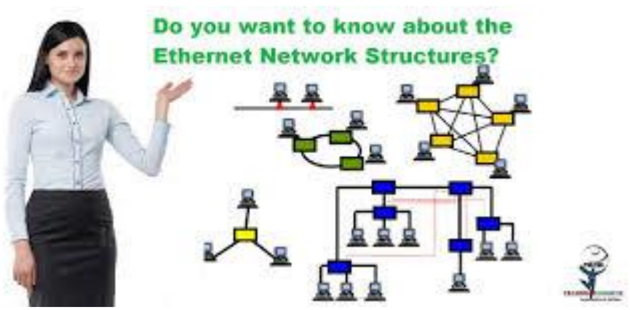
The Brain

The immune System



Economies

Network Structure



Ingredients

- Items, particles, members, components, agents.
- Dynamism.
- Adaptiveness.
- Self - organization.
- Local rules.
- Hieratical progression.

Complex Systems

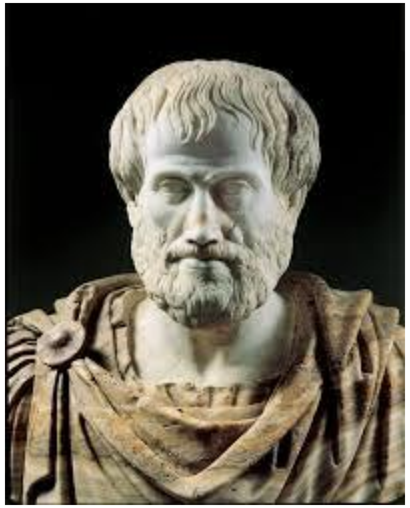
1. Information. 2. Computation. 3. Dynamics. 4. Chaos. 5. Evolution.

Large networks of components with no central control & simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution (self organize).

Brief History

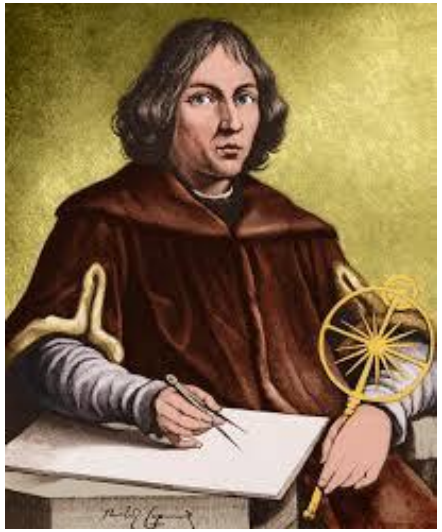
Aristotle

The author of theories of motions about 1500 years ago



Galileo/ Kepler/Copernicus

In 1600s (motion of the plant is not circular but rather elliptical)



Isaac Newton

Classic mechanics, calculus, Universal gravity

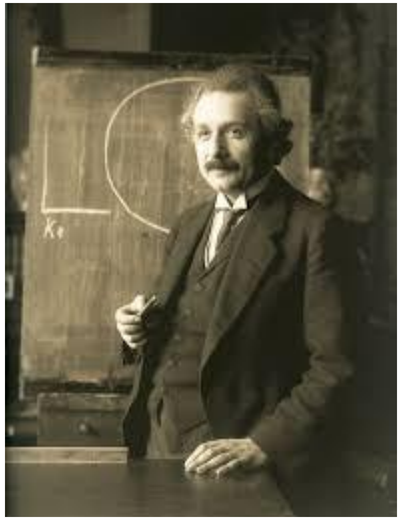
Brief History

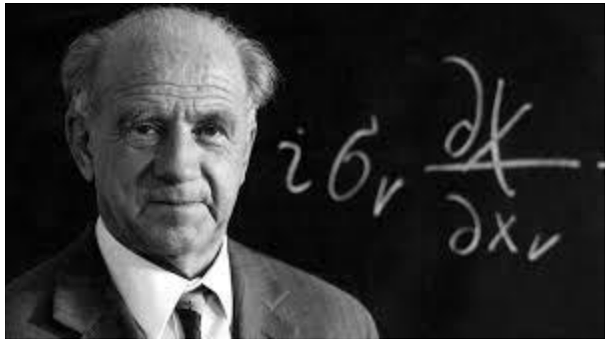
La Laplace

In 1814 Indorse the prediction concept

Einstein/ Werner Heisenberg

Relativity/Uncertainty principles in quantum mechanics





We cannot measure the exact values, positions, and momentum (mass times velocity) of a particle at the same time.

Brief History

Chaos systems theory was born. Minuscule uncertainties in measurements of initial position and momentum can result in huge errors on long term predictions of these quantities, which is known as sensitive dependance on initial conditions.

Astronomers can live with uncertainty, but Hurricane is different. A small error will produce large immediate impact on the behavior of winds.

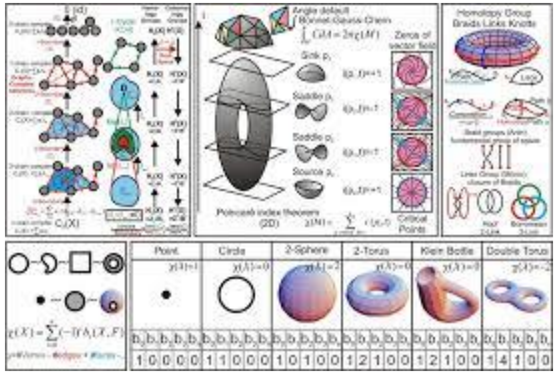
James Clerk Maxwell (1873) said; “Influences whose physical magnitude is too small to be taken account of by a finite being, may produce results of the highest impact”

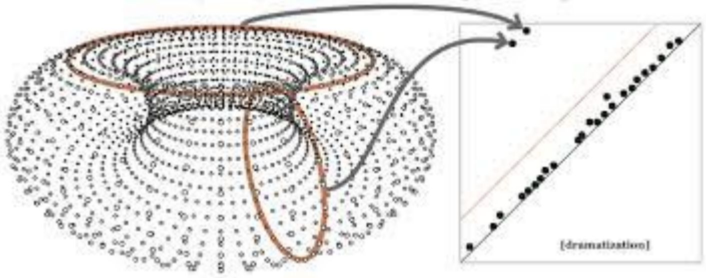
Brief History

Henri Poincare

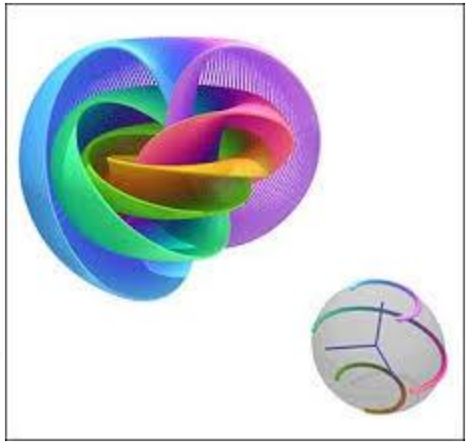
The father of modern dynamic systems 1887, who tried to solve the three body problem (predicating the future positions of arbitrarily many masses (like plants) attracting one another.

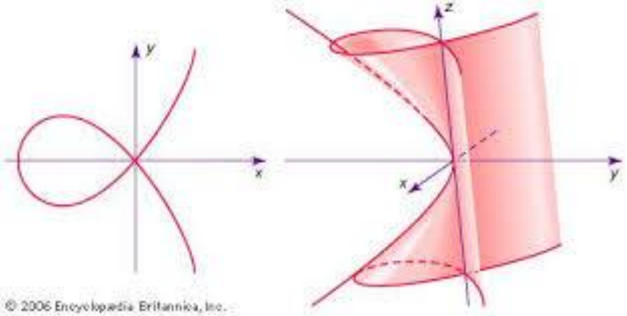
He also invented the Algebraic topography



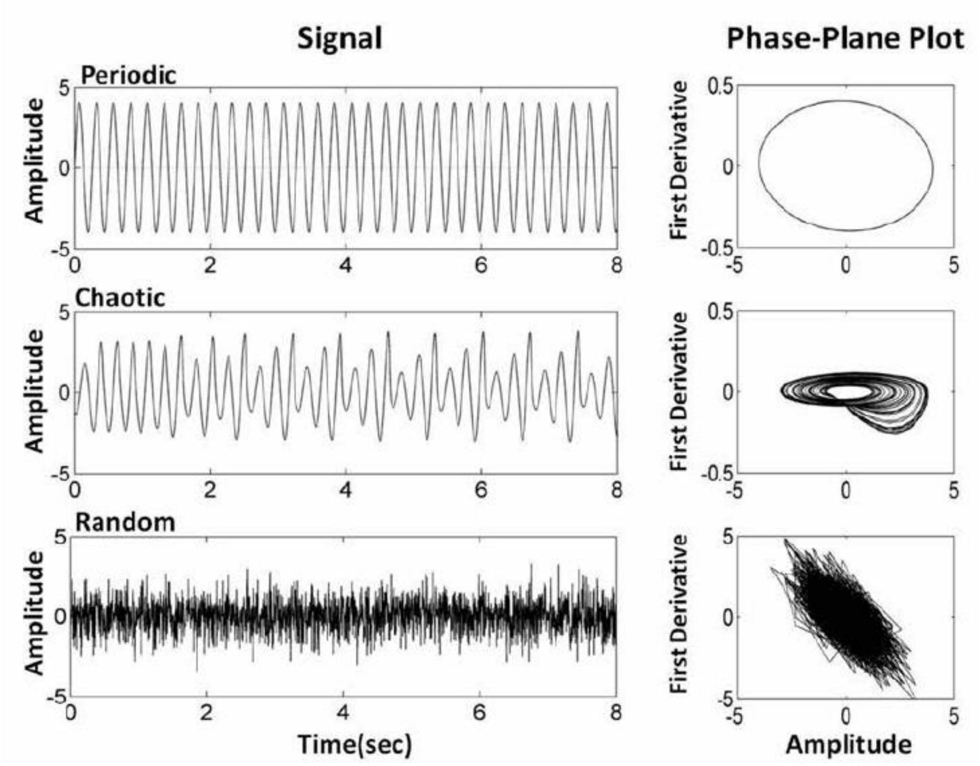


Phase Space and Poincare Section

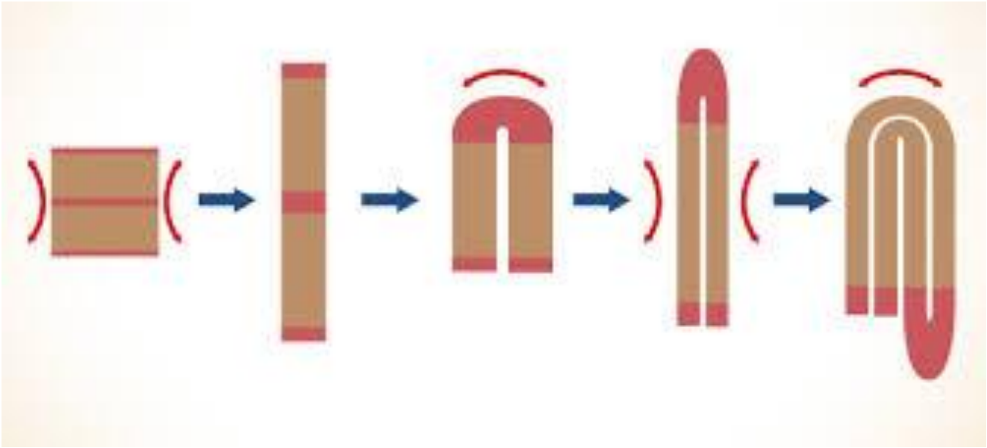




Brief History

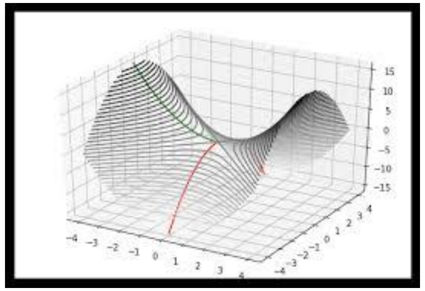


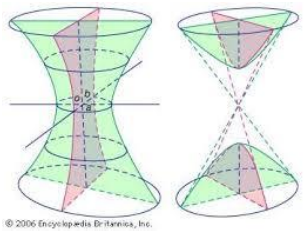
Stephen Smale Horseshoe



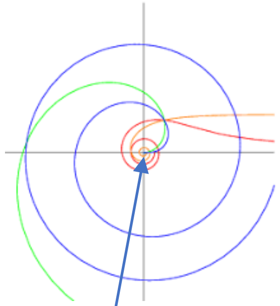
Brief History

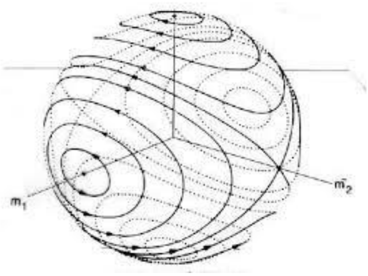
Algebraic topography





Saddle point

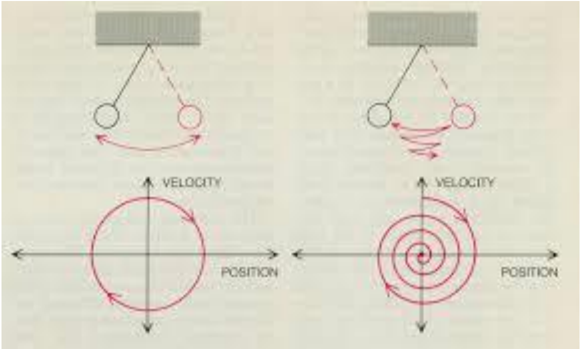




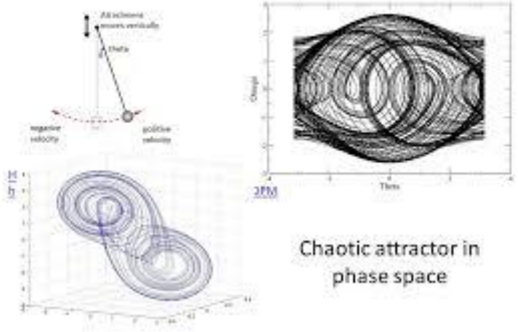
Spiral point

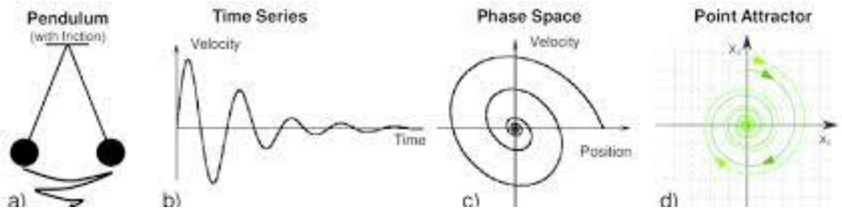
Stable point

Pendulum Application

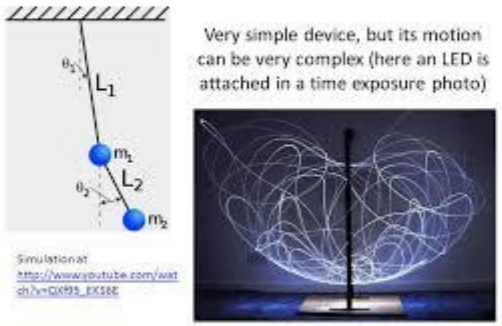


Driven Pendulum with friction





Double Pendulum



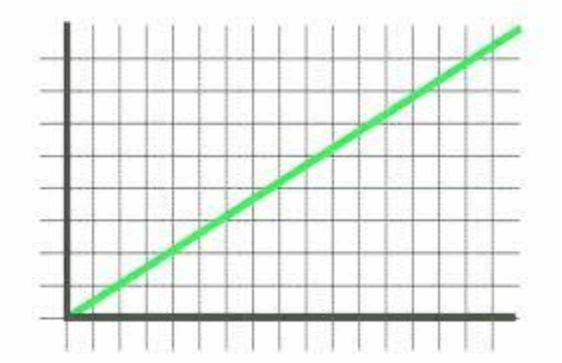
Brief History

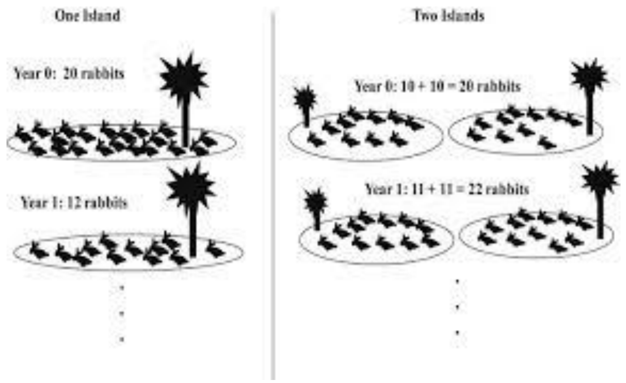
Complexity , chaos with nonlinearity

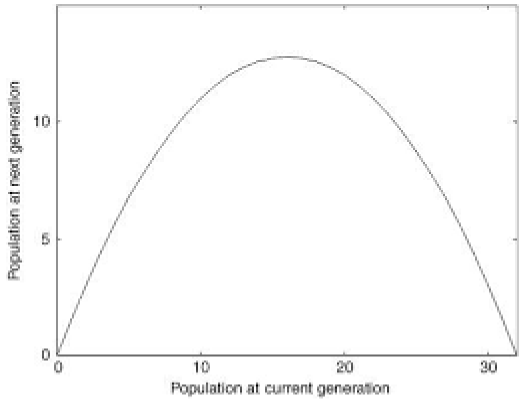
One cup of sugar + two cups of flour = 3 cups in total   (in as linear system)

Two cups of soda + two cups of vinegar = explosive with a lot of carbon dioxide (in nonlinear system)

Rabbits on Islands



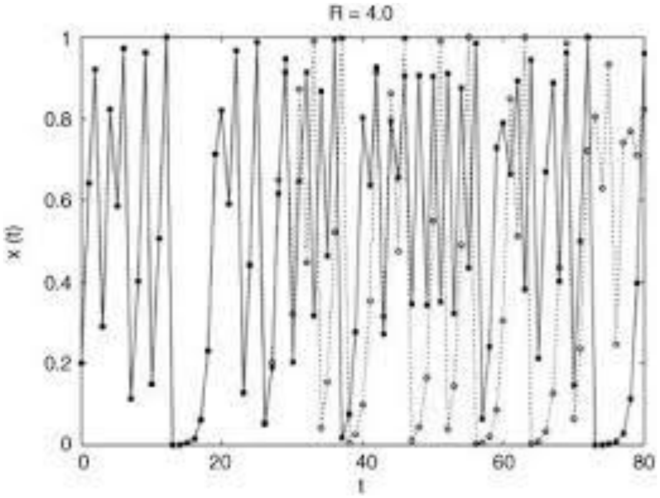


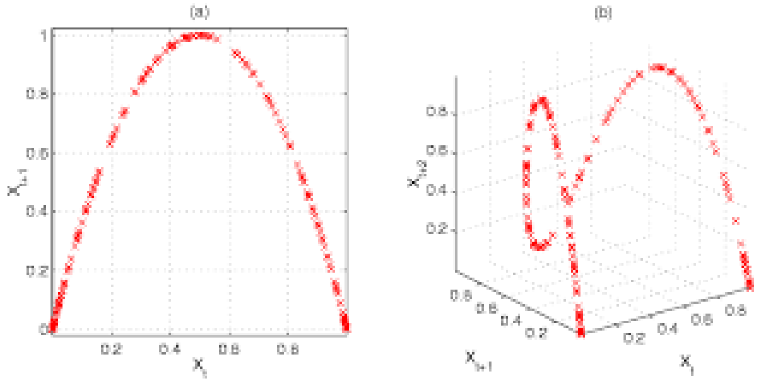


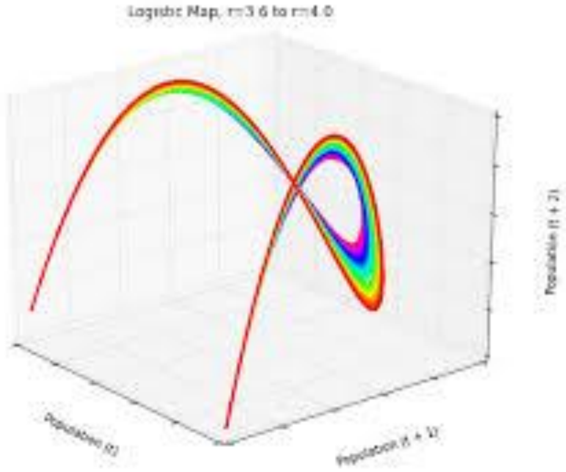
Brief History

Logistic Equation By Robert May 1976

$$x_{t+1} = rx_t(1 - x_t)$$



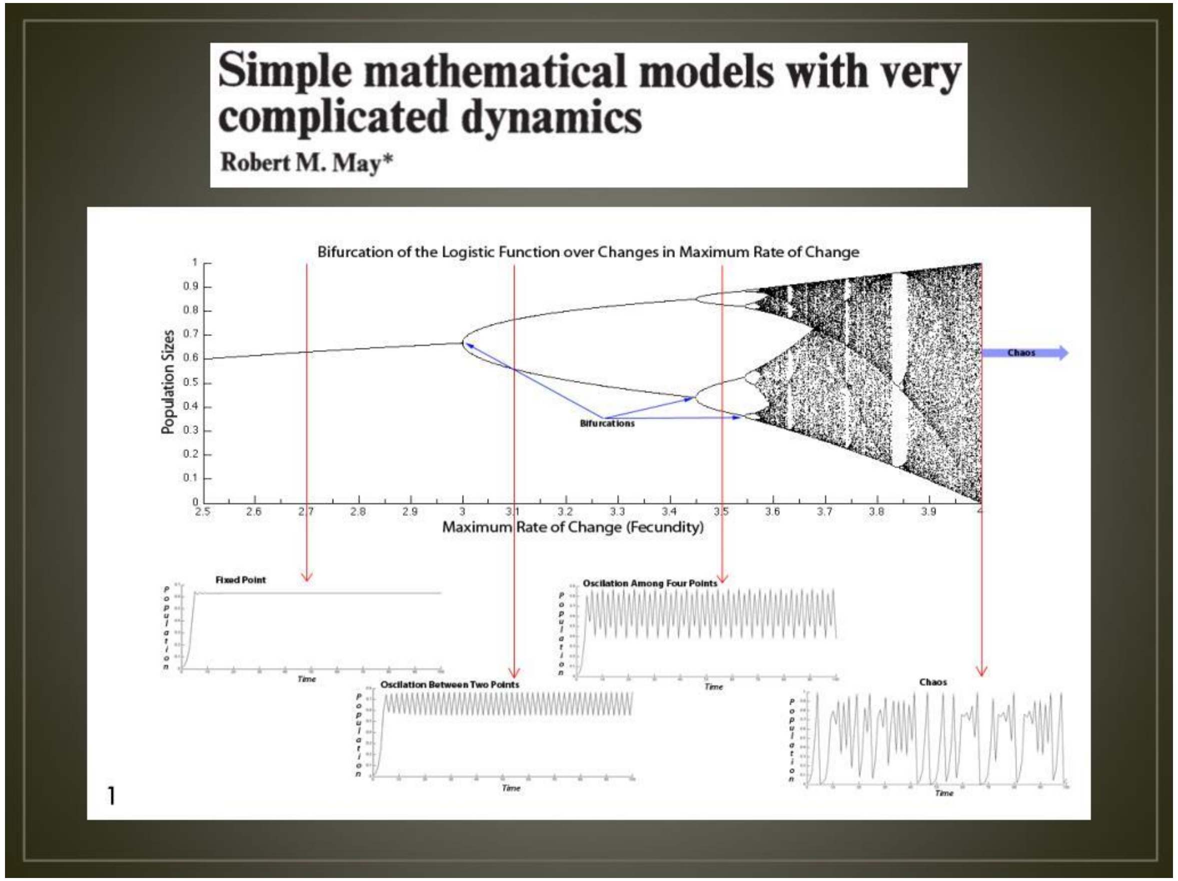




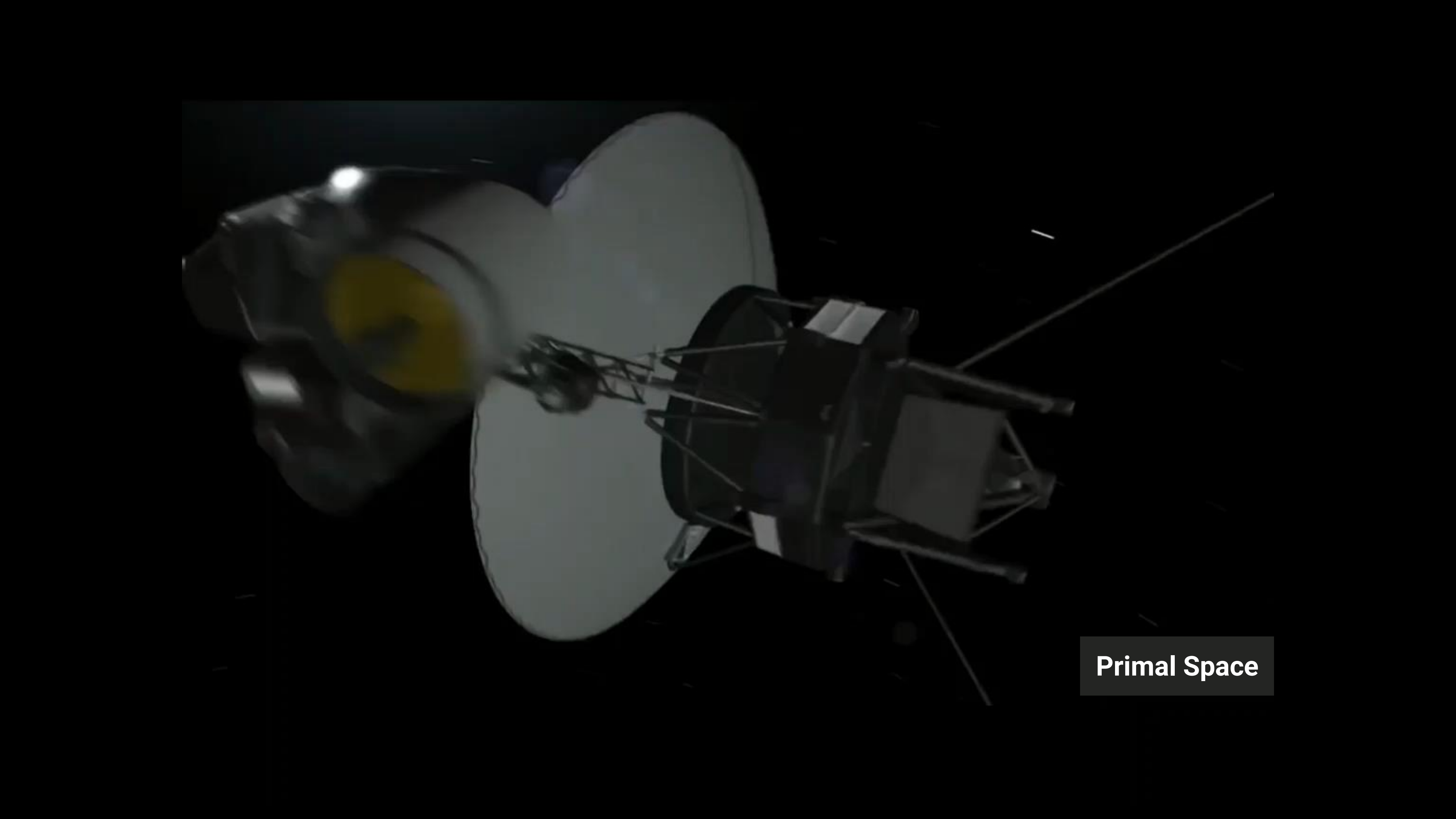
Brief History

Bifurcation and Universality By Mitchell Feigenbaum 1978

$$x_{t+1} = rx_t\,(1 - x_t)$$



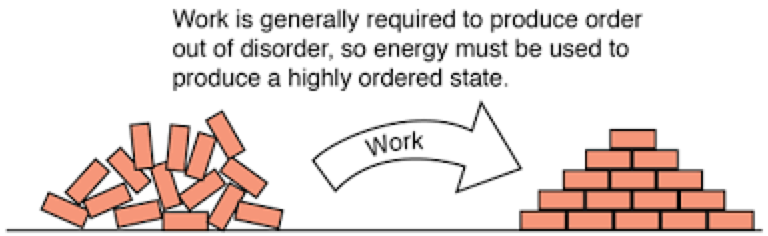
Universal number = 4.6692016


Primal Space

Brief History

Complex Systems

1. Information.

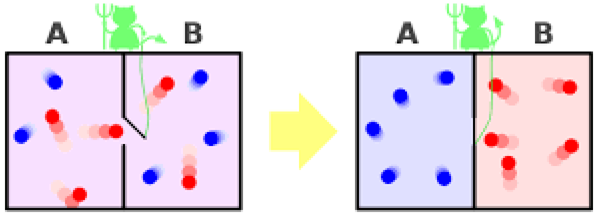


Energy, work, and entropy

Decrease entropy

Maxwell Demon (1871)

Hinge is frictionless thus the demon does not do any work

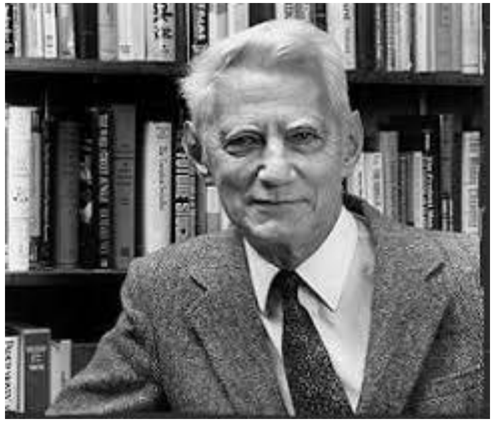


Yes/NO

Cool side becomes cooler
And hot side becomes hotter

Leo Szilard (1964)

Claude Shannon (1948)



Information Theory;
A source that sends messages to a receiver

Brief History

Complex Systems

2. Computation.

David Hilbert Question (1862-1943)

Is there a definite procedure that can be applied to every statement that will tell us in finite time whether or not the statement is true or false?

YES

Alan Turing (1912-1954)

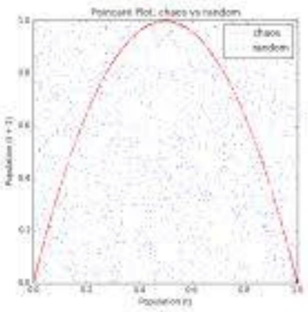
Definite procedure = a powerful calculating machine – one that could not only perform arithmetic but also could manipulate symbols in order to prove mathematical statements.

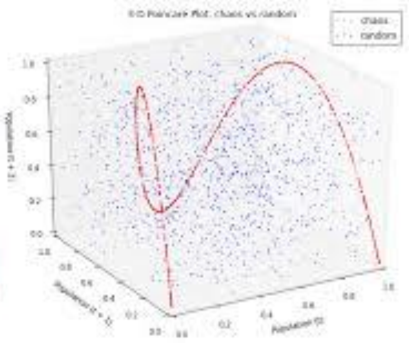
COMPUTERS AND PROGRAMMING WERE BORN

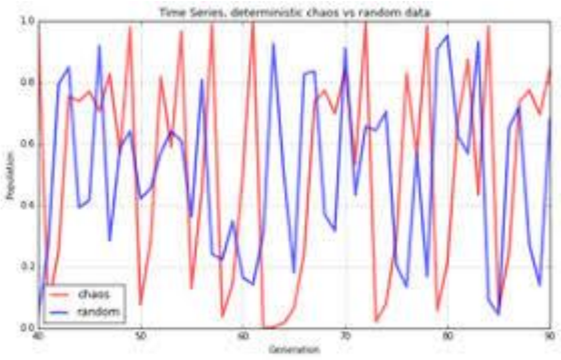
Brief History

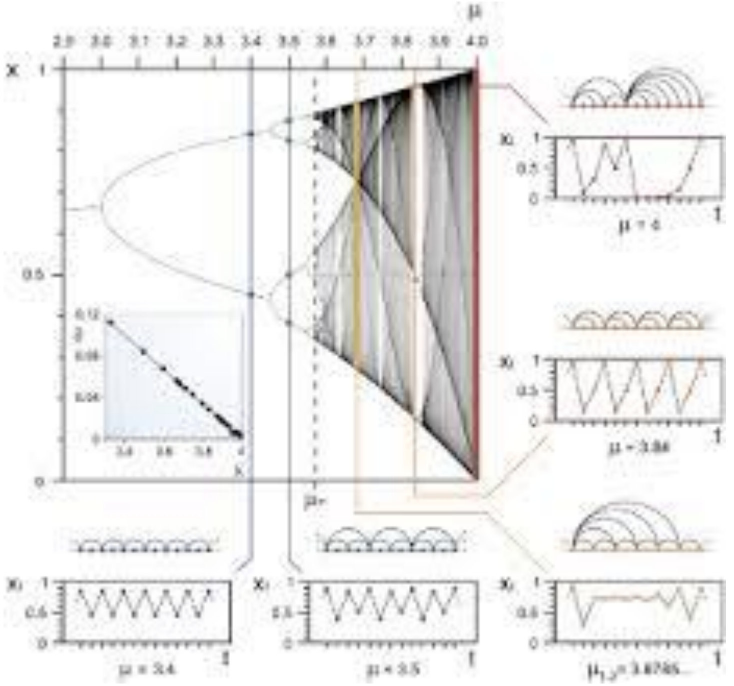
Complex Systems

3. Dynamics
4. Chaos.









Dynamics; variables changing against a reference such as time.

Chaos; complex output that mimic random behavior that is generated by a simple, deterministic system.

Brief History

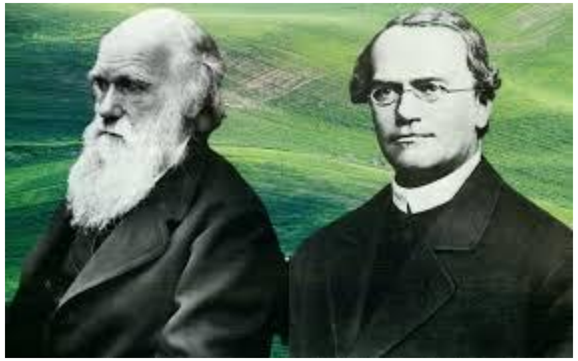
Complex Systems

5. Evolution (Gradual Change)

In Thermodynamics, total entropy of an isolated system will always increase until it reaches its maximum value. But living systems ae complex, they exist somewhere in the middle ground between order and disorder.

Charles Darwin (1809-1836), Evolution by natural selection

Gregor Mendel (1822-1884), Evolution by natural selection



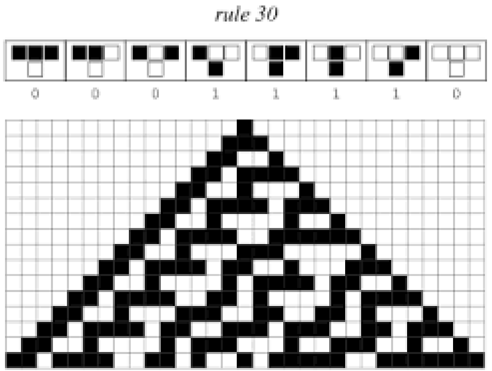
Collections of individual acting in self interested ways produce global benefit. Life seems to allow almost infinite variation, and species particular traits seem designed for the very environment in which the species lives. Species branch out from common ancestor.

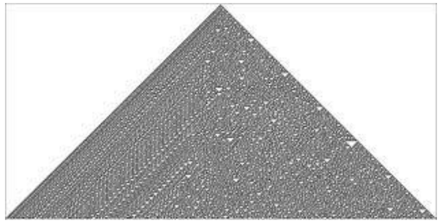
John Holland (1975), Genetic algorithms

Adaptation in Natural and Artificial Systems

Stephen Wolfram (1980), Genetic algorithms

Cellular automation

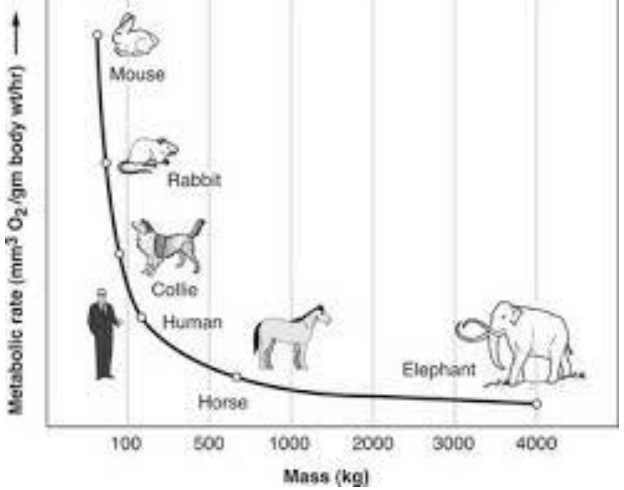


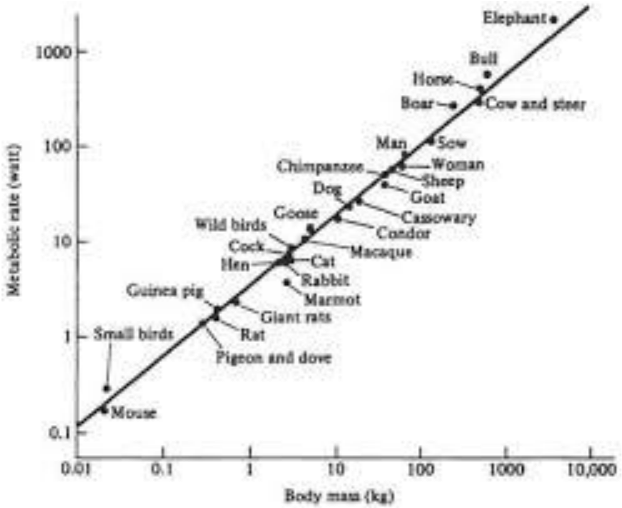


Brief History

Complex Systems

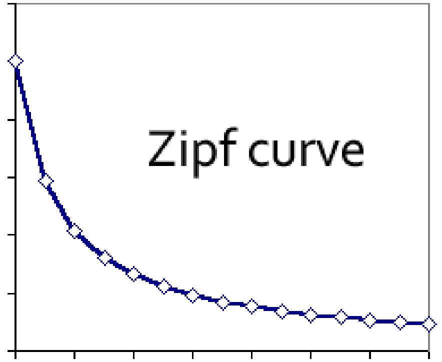
2. Evolution (Gradual Change)

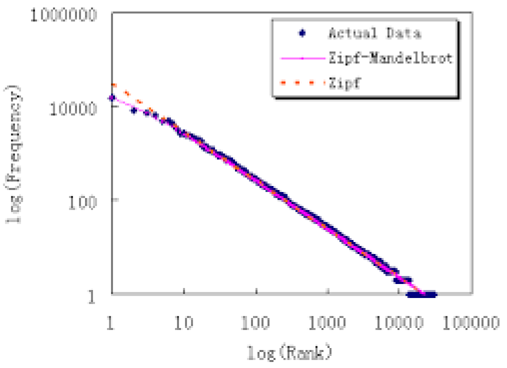




George Kingsley Zipf (1930), Ziplfs law

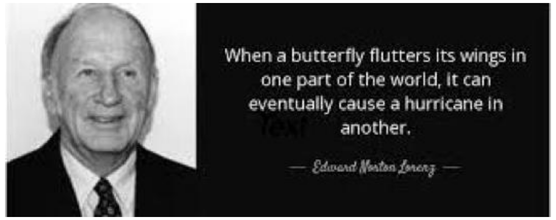
Frequency of occurrence of words is inversely proportional to the rank in this frequency occurrence

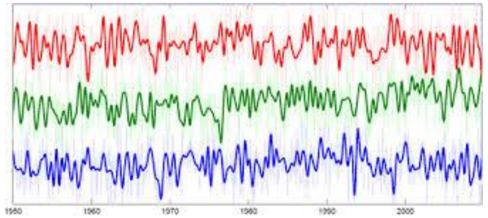


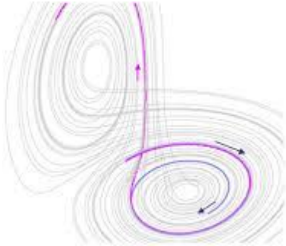


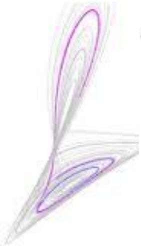
Applications & Examples

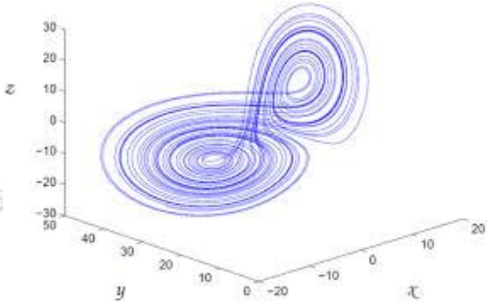
Lorenz Attractor (Weather System)



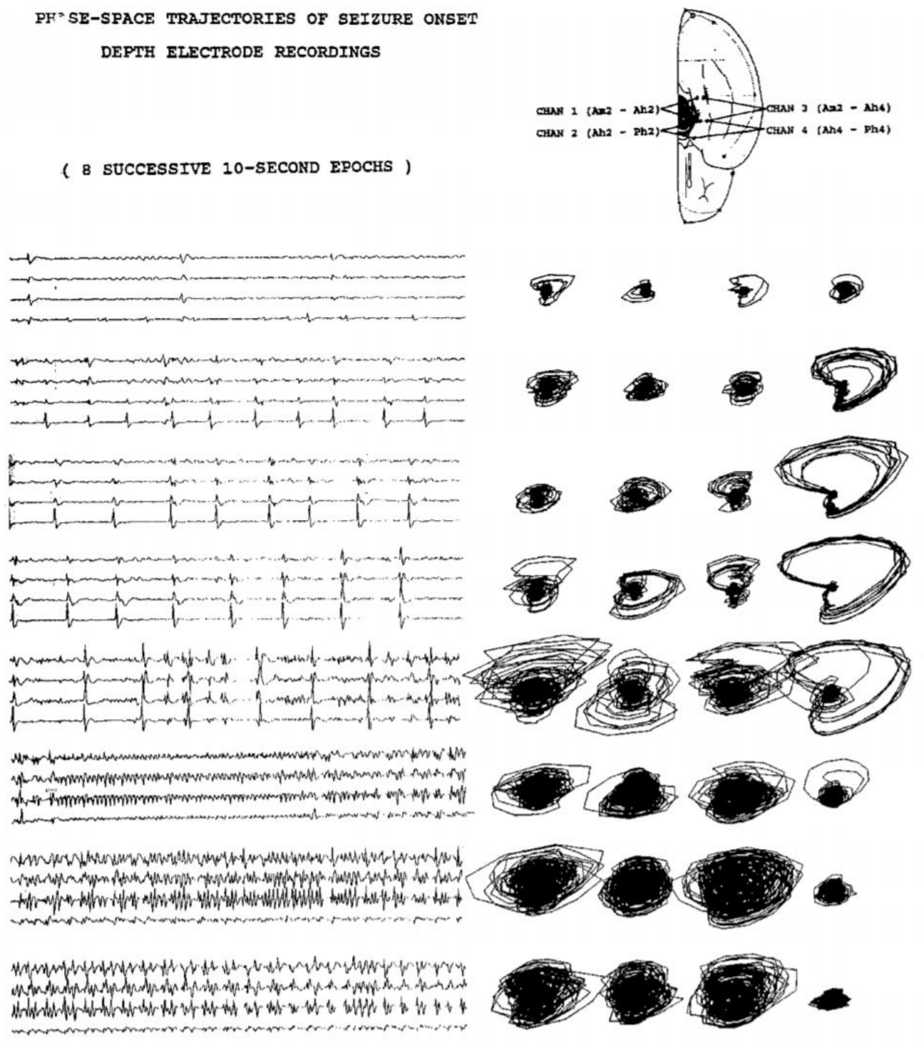






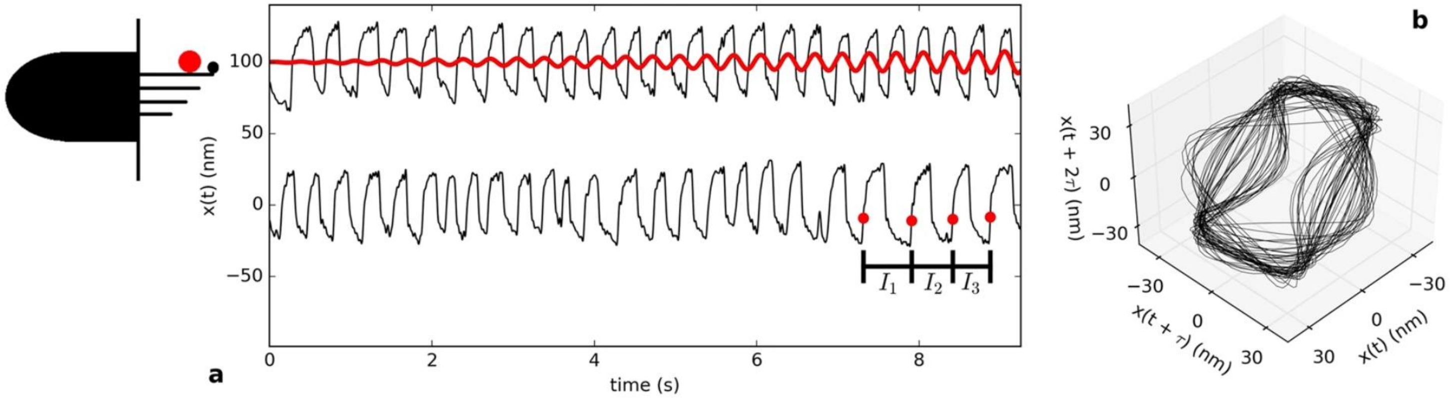


Seizure Patterns in Epilepsy

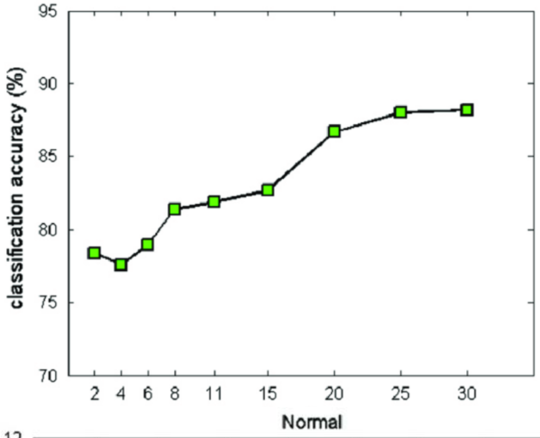


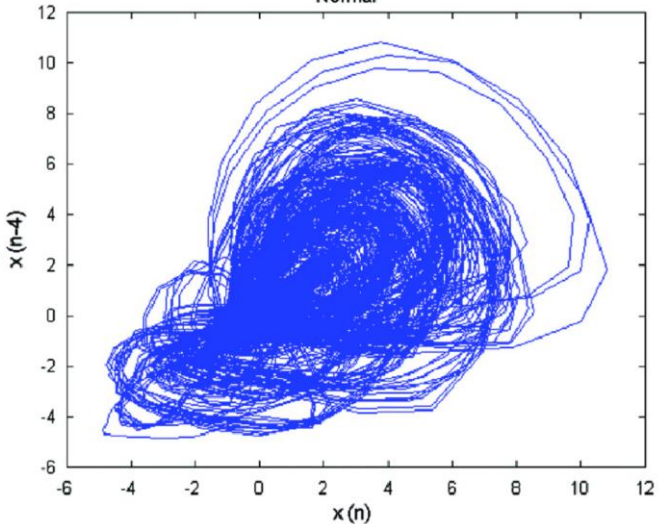
Applications & Examples

Chaotic Dynamics of Inner Ear Hair Cells

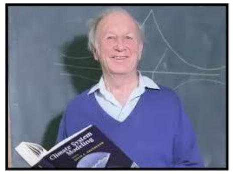


Chaos in Human Heart Beat

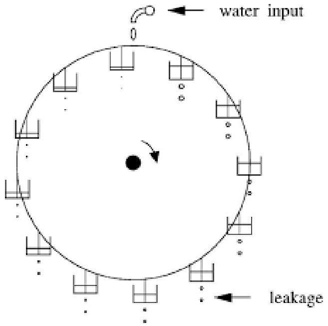


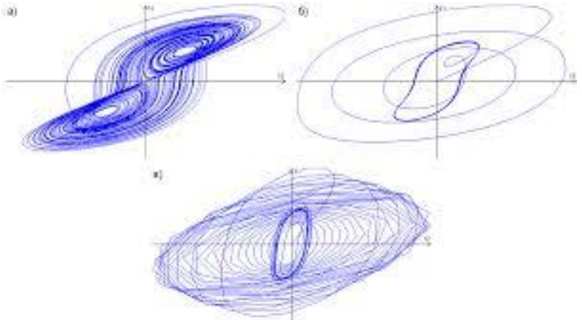


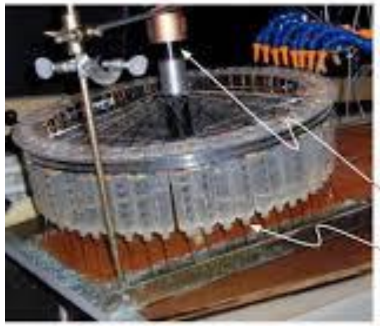
Applications & Examples

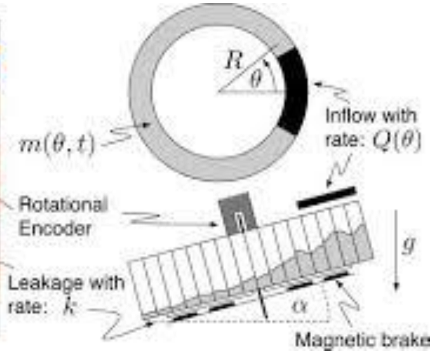


Lorenz Water Wheel



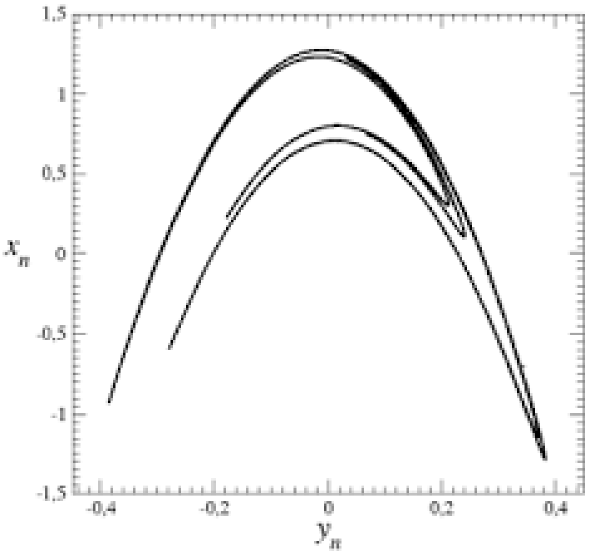


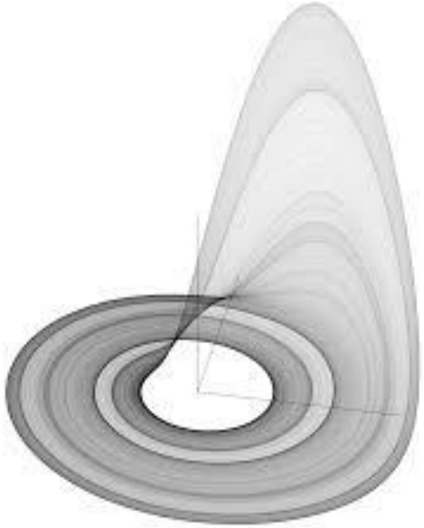




Michel Henon

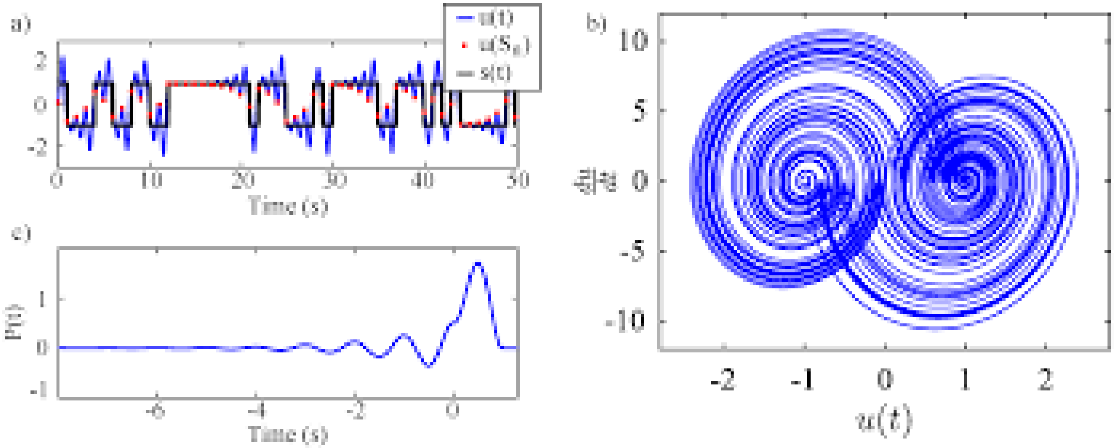
Trajectories of the stars



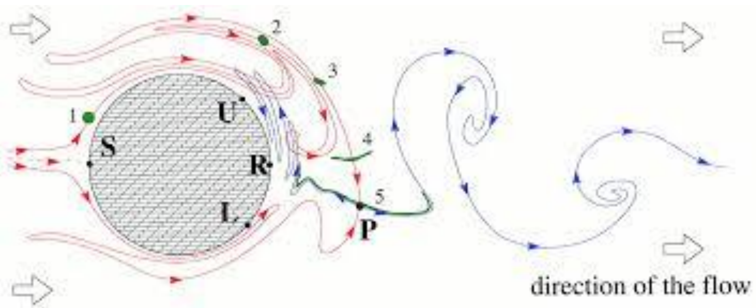


Applications & Examples

Radio Frequency

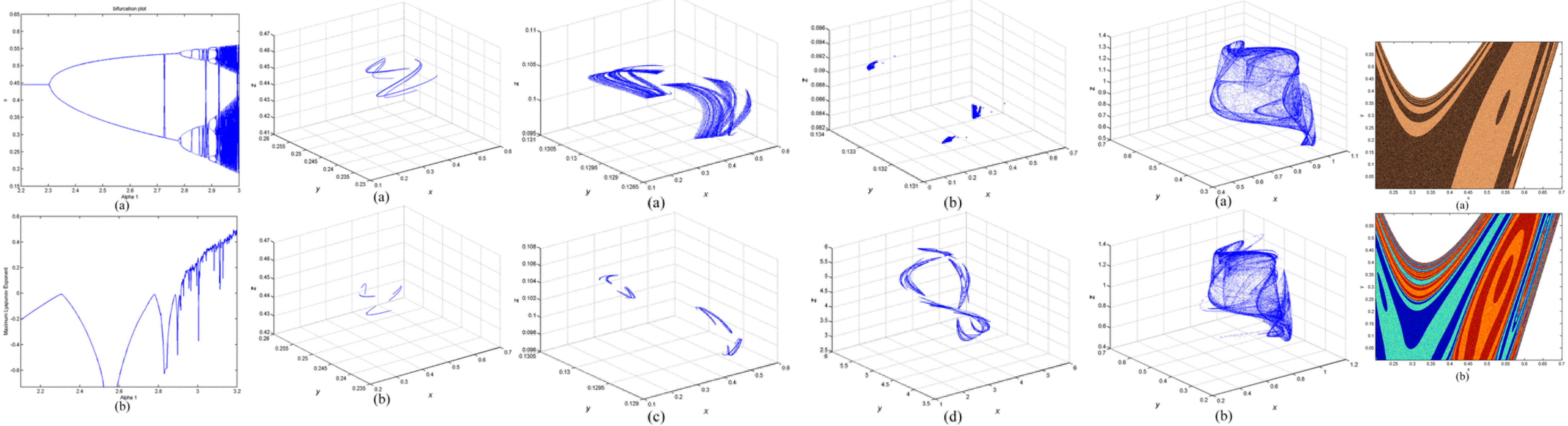


Chaotic Flow



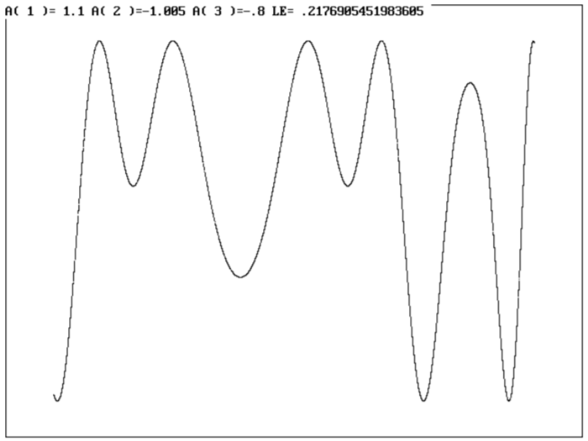
Applications & Examples

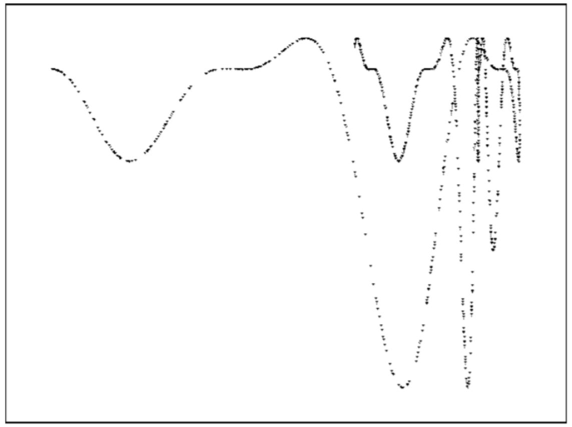
Economy and Stock Market

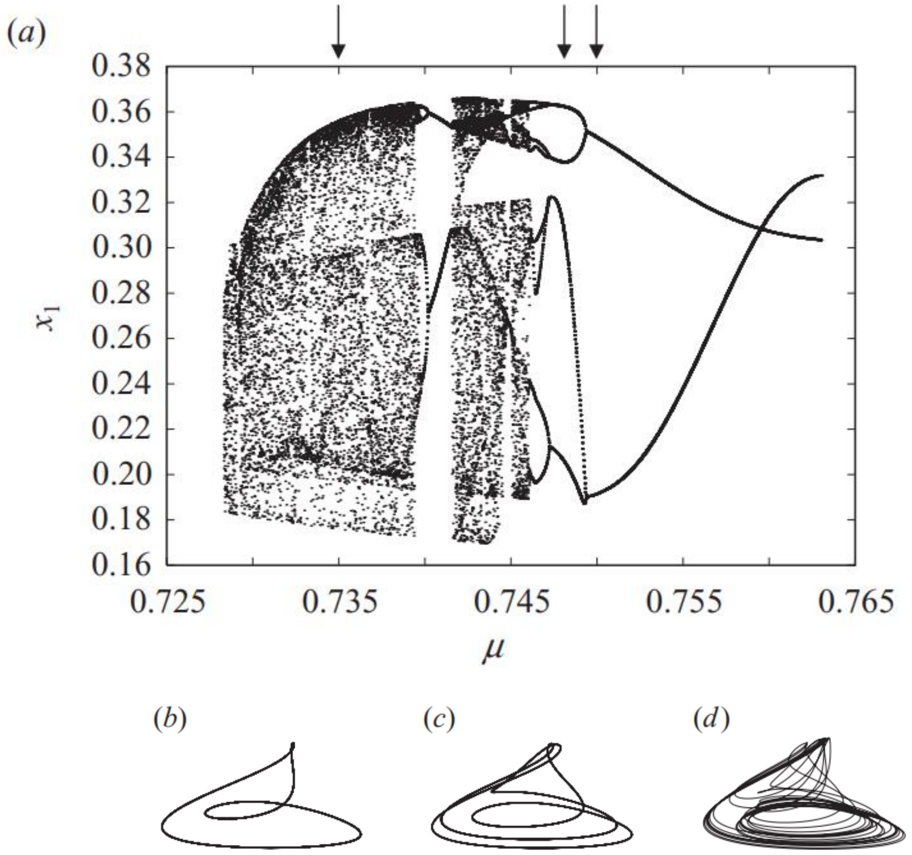


Applications & Examples

Language (Structure and Way of Speech)



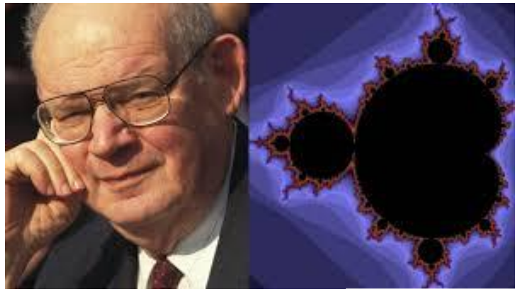


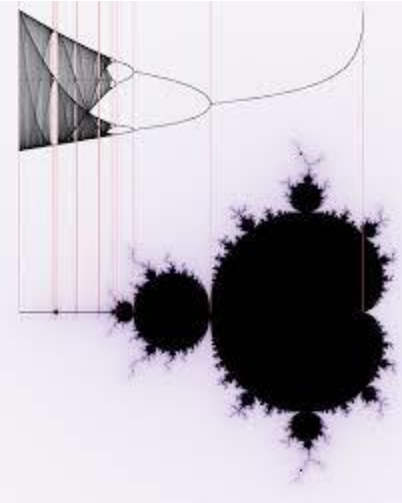


Tool to Measure (The Fractal)

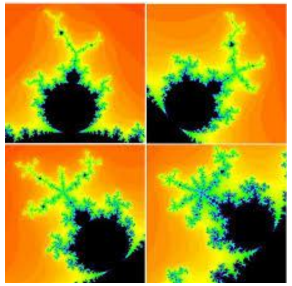
Fractal is a patter that repeats the same design & detail or definition over a broad range of scale.

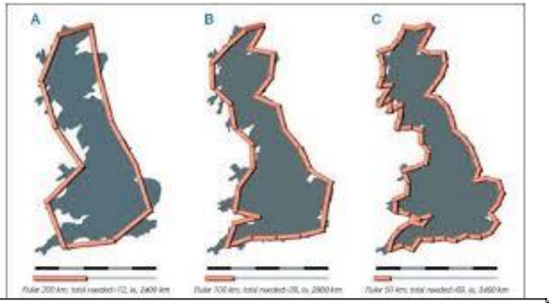
Benoit Mandelbrot (1924-2010)

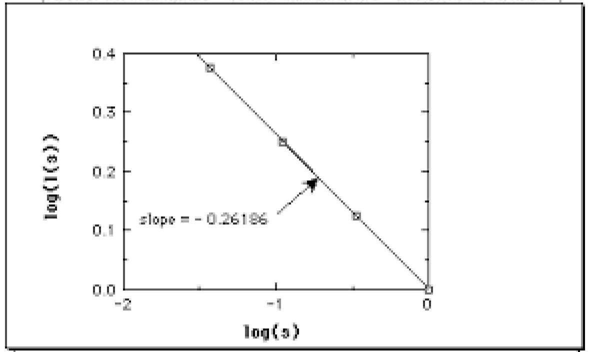


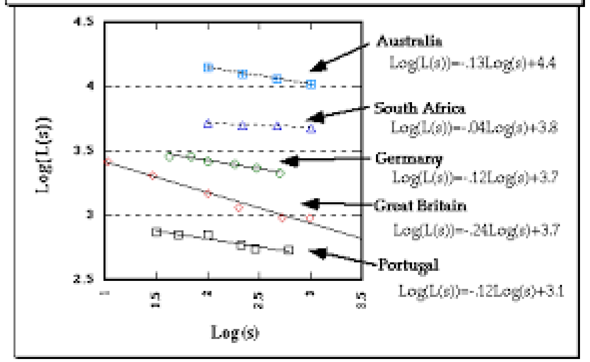


$$z_{n+1} = z_n^2 + c$$

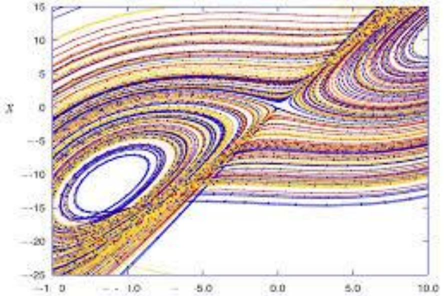




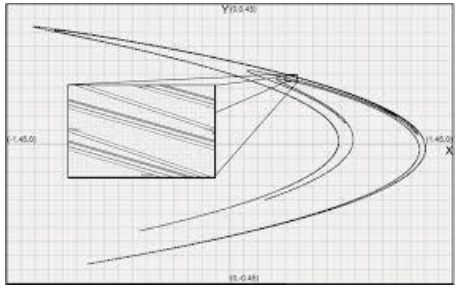




Lorenz Attractor

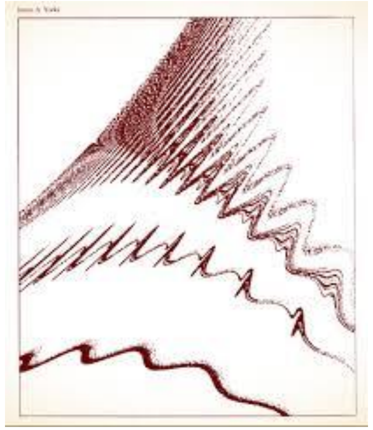


Michel Henon Attractor



Flow Attractor

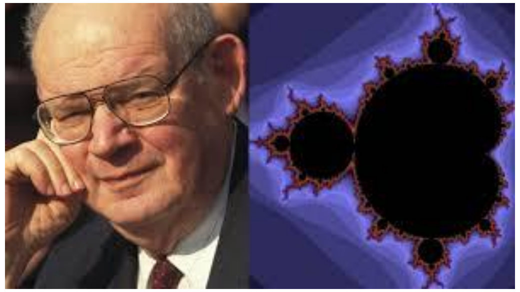
Radio Attractor



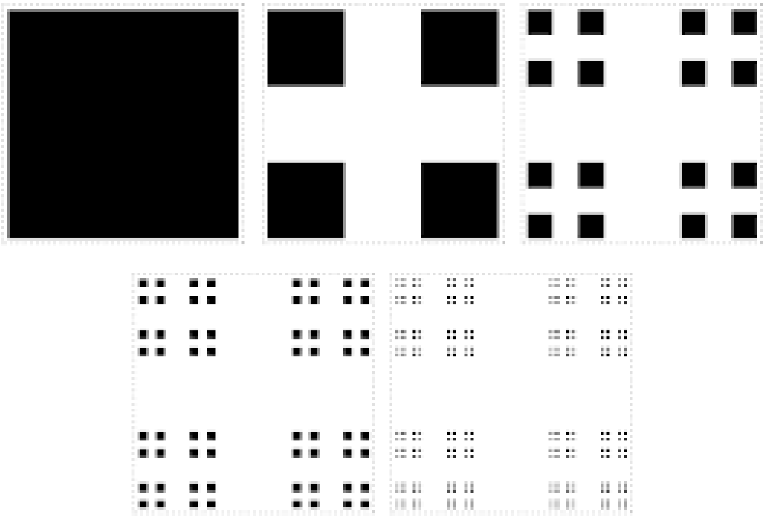
Tool to Measure (The Fractal)

Fractal is a patter that repeats the same design & detail or definition over a broad range of scale.

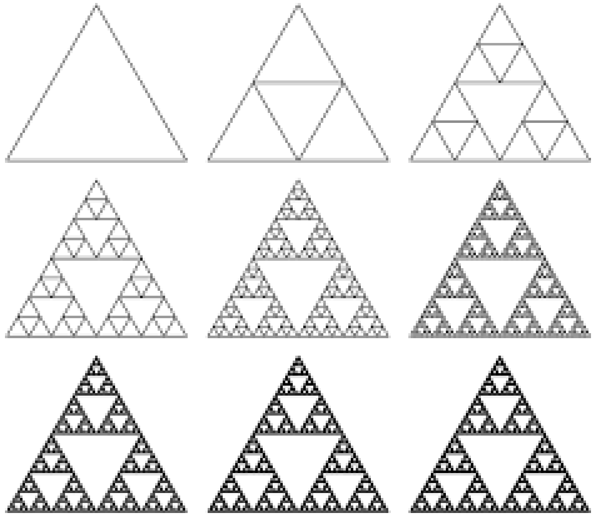
Benoit Mandelbrot (1924-2010)



Cantor Dust
Georg Cantor

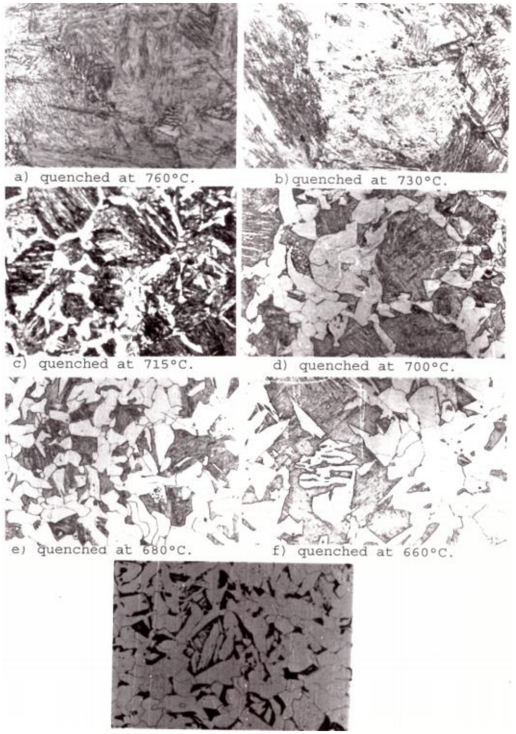


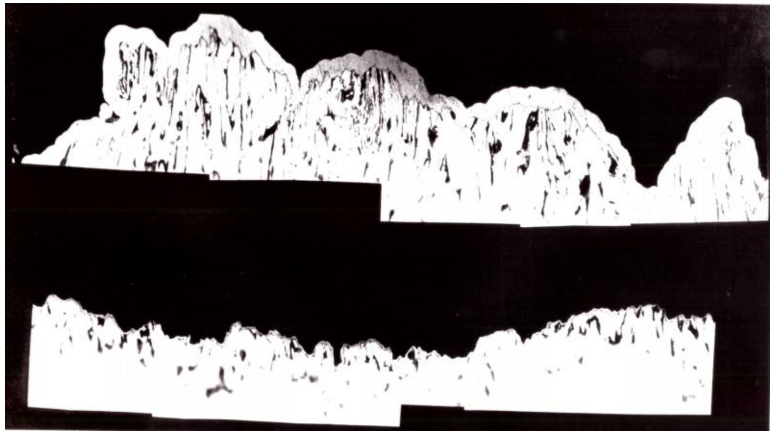
Sierpinski capet
Wacław Sierpiński

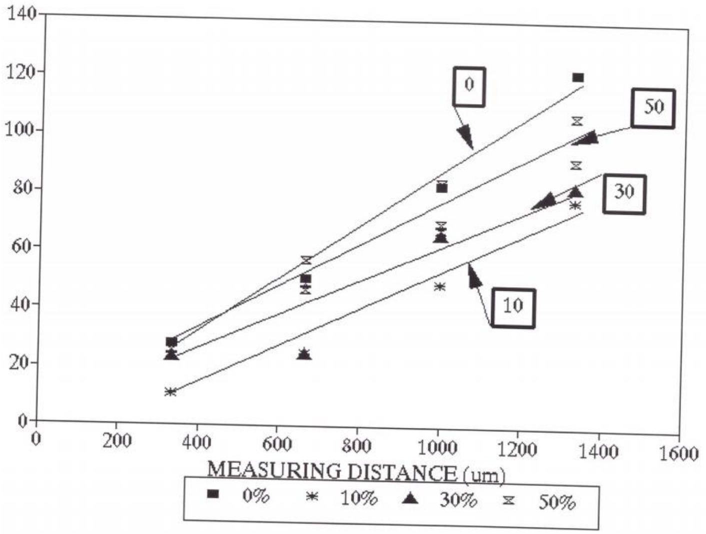


Our Projects with Fractal

Fractal & Materials Science

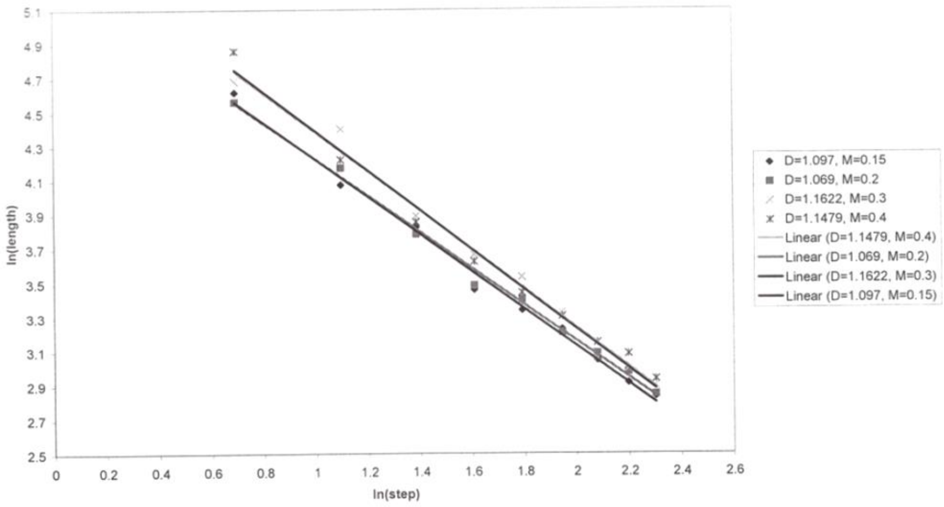


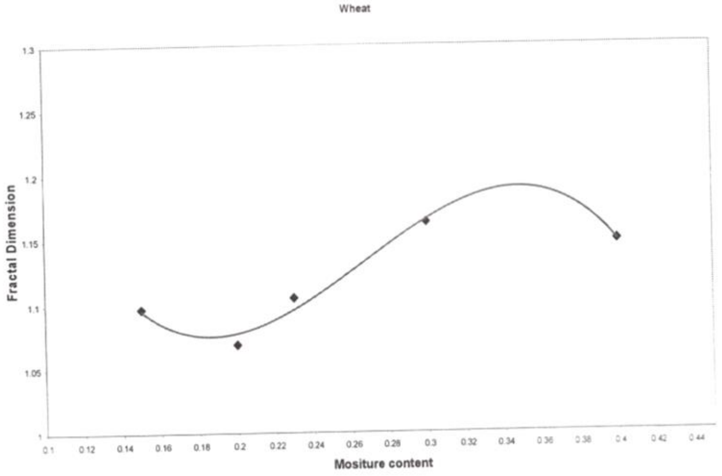




Our Projects with Fractal

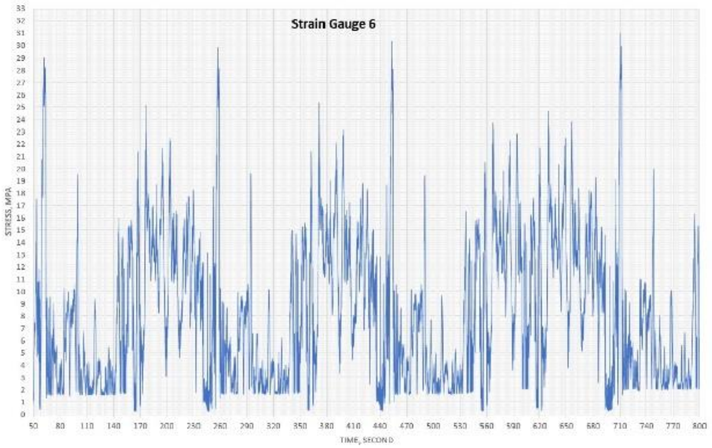
Fractal Dimension & Moisture Content in Grains Using Microware Technique

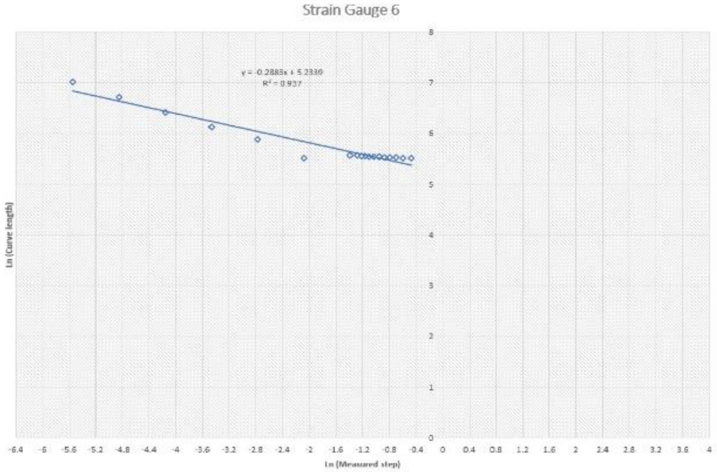


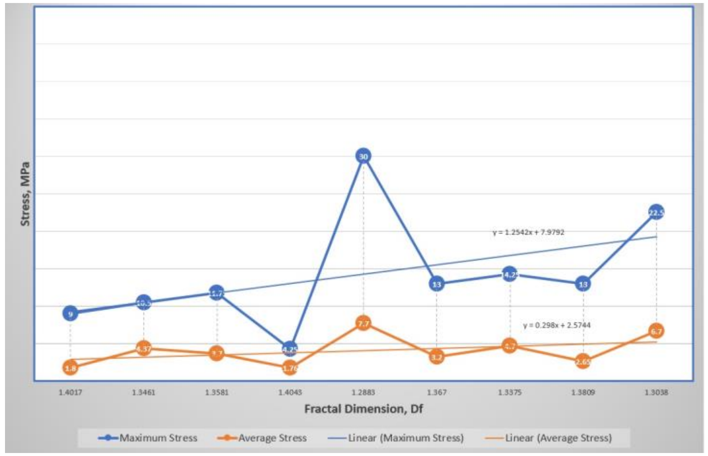


Our Projects with Fractal

Fractal & Machines Maintenance

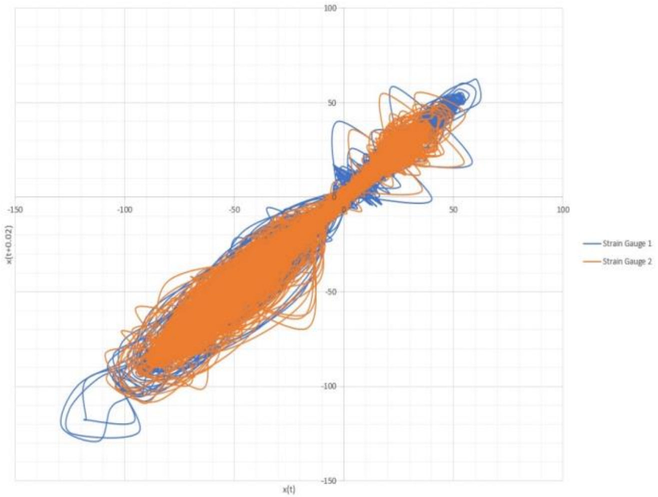


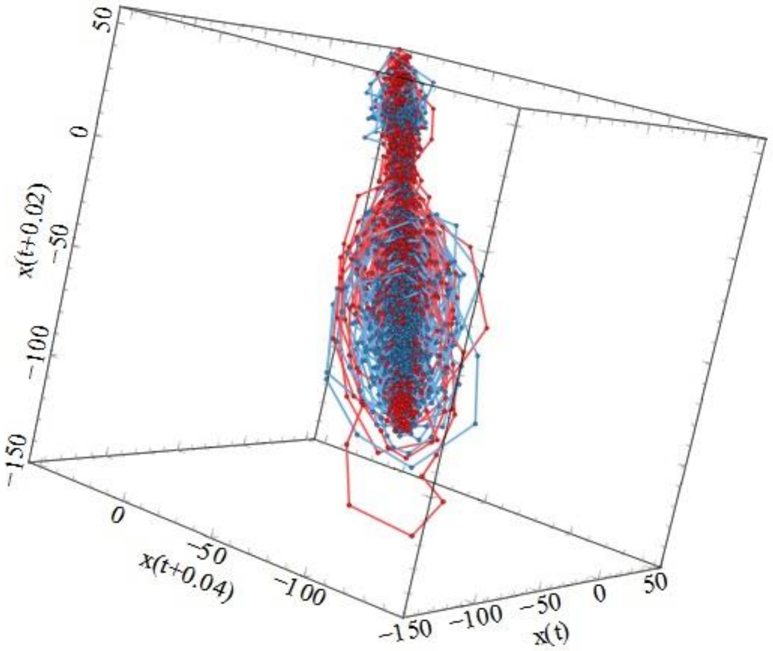


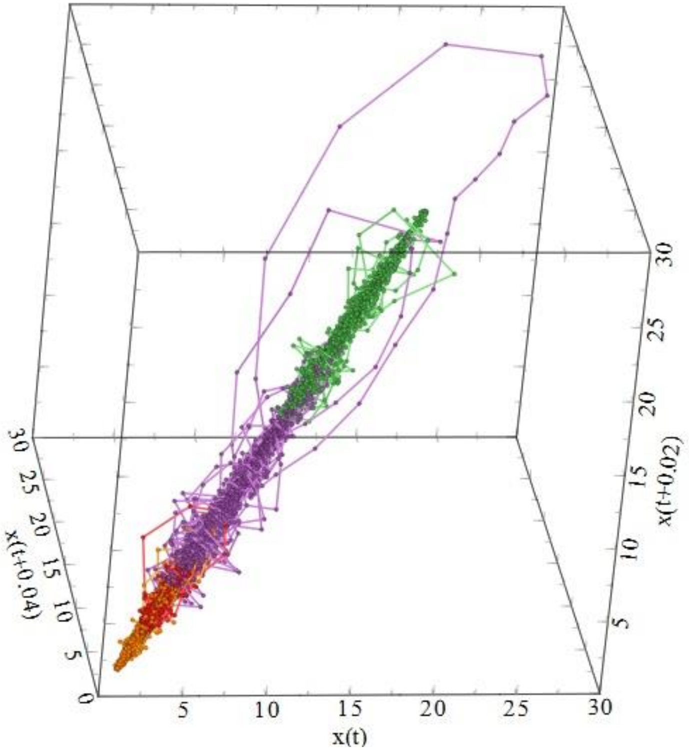


Our Projects with Fractal

Phase Plan & Machines Maintenance

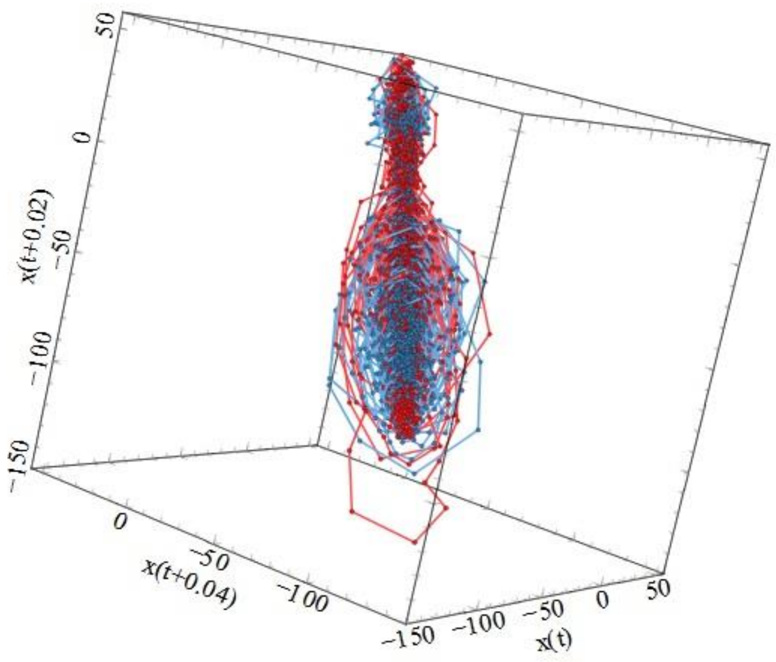




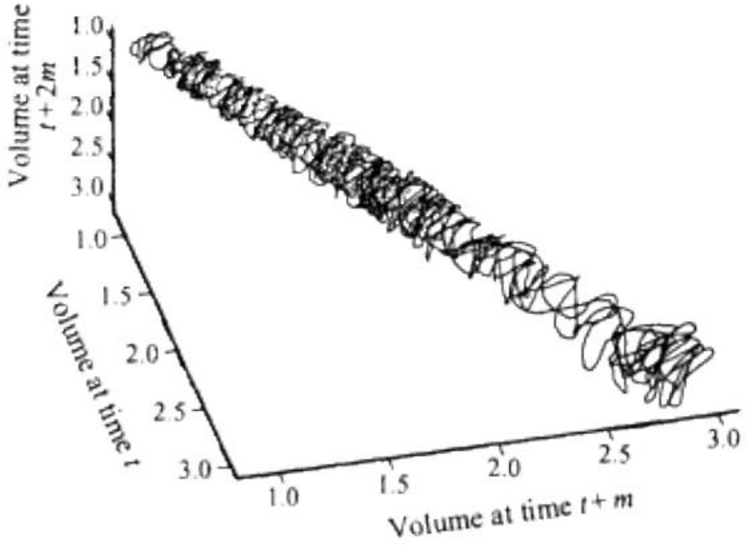


Our Projects with Fractal

Phase Plan & Machines Maintenance



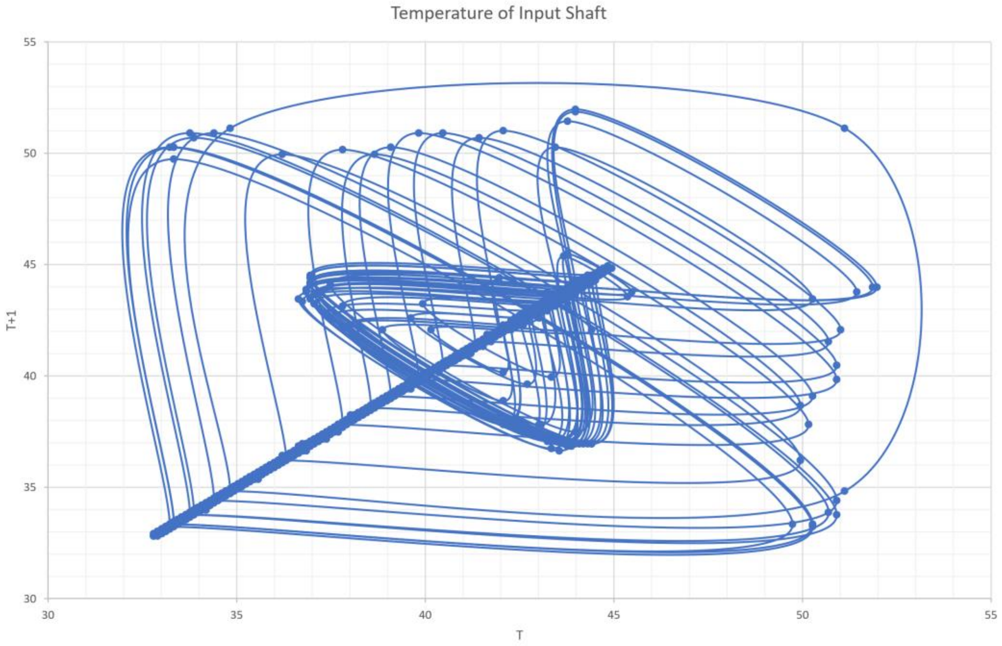
Behaviour of a machine.

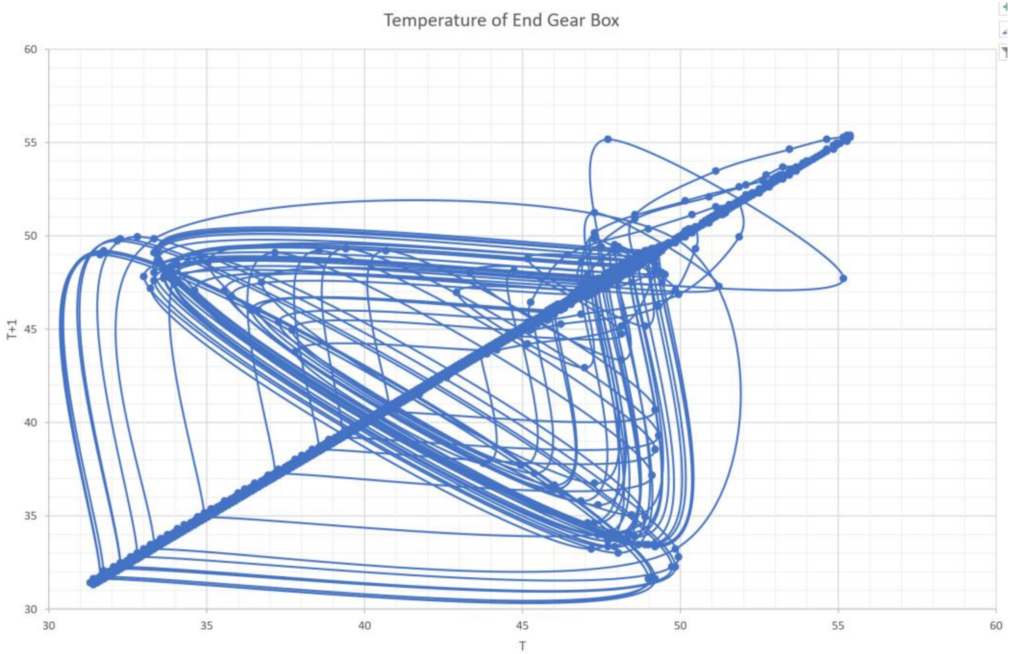


Volume of water in the Great Salt Lake, Utah, 1848-1992.

Our Projects with Fractal

Poincare Section & Machines Maintenance

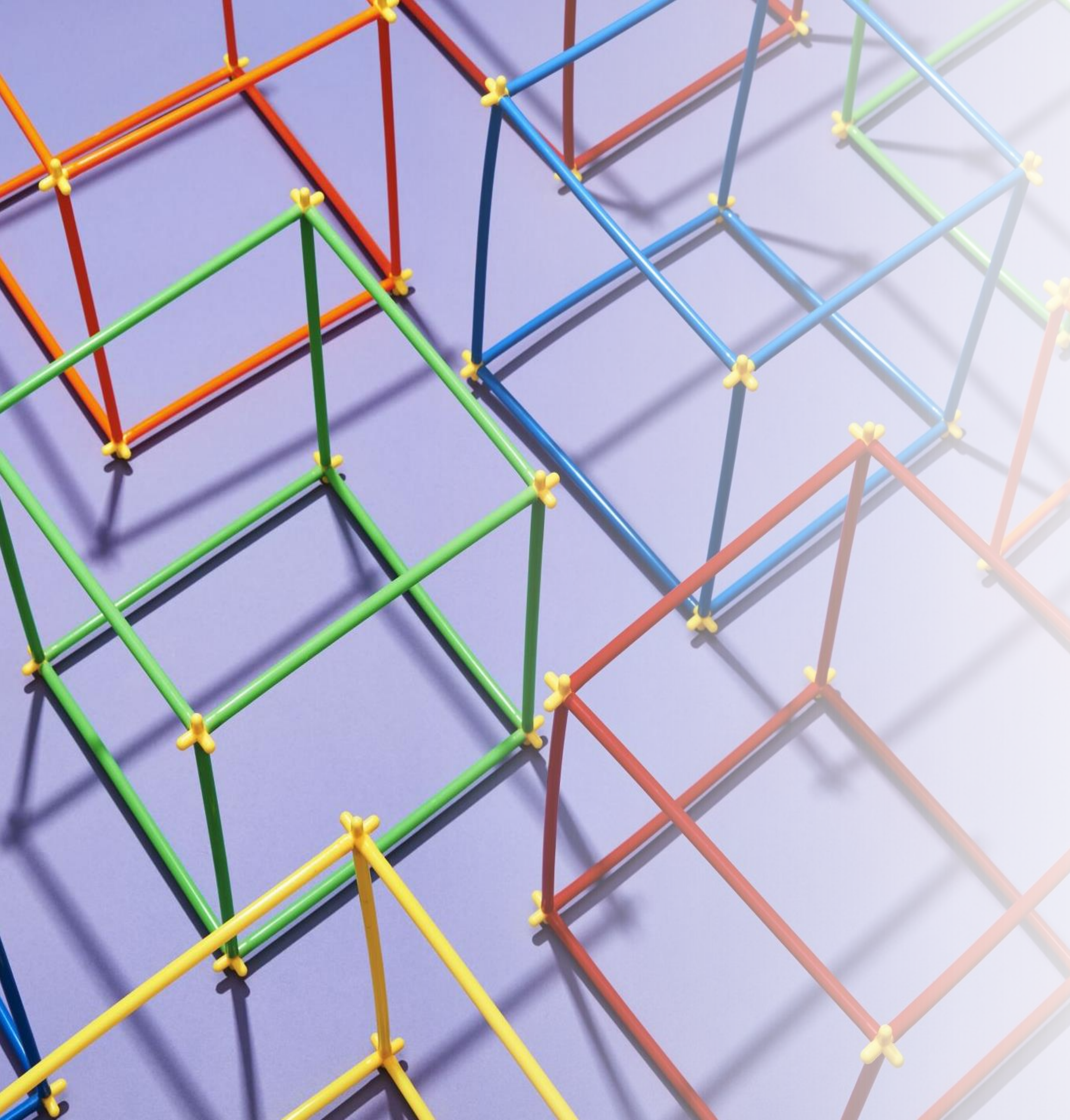




What Have We Learnt & What Can We Conclude

Complexity/Chaos/nonlinearity

- **are a new area of science, they interconnect many scientific areas.**
- **needs computer and programming knowledge.**
- **touch our scientific/technical lives as well as our private lives.**
- **still evolving.**
- **need foundations in advance mathematics.**
- **need foundations and understanding of topology.**



Never be bored of trying to discover shapes and patents of dynamical systems such as the patent of your personal behaviour and response.

It is never too late to get onboard…

…the train has not left the station yet , but it is moving, we still have the chance to catch up with the last vehicle.

ALKINDI
Society of Engineers
جمعية الكندي للمهندسين

ASME
SETTING THE STANDARD
UNITED KINGDOM

Thank you

Discussion / Q&A