FRACTALS -HIDDEN DIMENSIONS OF NATURE…

A.A.C.A. Jayathilake
Board of Study in Statistics and Computer Science

The French mathematician Benoit B. Mandelbrot first coined the term fractal in 1975. He derived the word from the Latin fractus, which means "broken", or "irregular and fragmented". In fact, the birth of fractal geometry is usually traced to Mandelbrot and the 1977 publication of his seminal book The Fractal Geometry of Nature (Fractal Geometry, 2014). Mandelbrot claimed that classical Euclidean geometry was inadequate at describing many natural objects such as clouds, mountains, coastlines and trees. So he conceived and developed fractal geometry. There are two main groups of fractals: linear and nonlinear. The latter are typified by the popular Mandelbrot set and Julia sets, which are fractals of the complex plane.

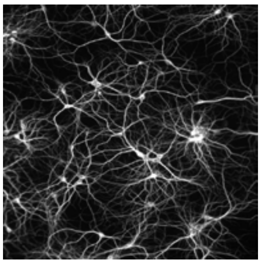

Figure 01: Neurons

A fractal is a never-ending pattern. Fractals are infinitely complex patterns that are self-similar across different scales. They are created by repeating a simple process over and over in an ongoing feedback loop. Driven by recursion, fractals are images of dynamic systems – the pictures of Chaos (Figure 02).

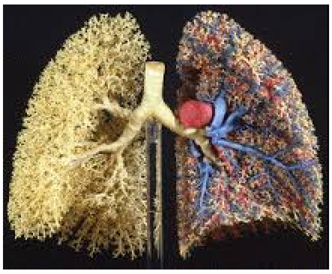

Figure 02: Fractals in Physiology

Geometrically, they exist in between our familiar dimensions. Fractal patterns are extremely familiar, since nature is full of fractals. For instance: trees, rivers, coastlines, mountains, clouds, seashells, hurricanes, etc. Abstract fractals – such as the Mandelbrot Set – can be generated by a computer calculating a simple equation over and over.

Fractals are found all over nature, spanning a huge range of scales. We find the same patterns again and again, from the tiny branching of our blood vessels and neurons (Figure 01) to the branching of trees, lightning bolts, and river networks. Regardless of scale, these patterns are all formed by repeating a simple branching process. A fractal is a picture that tells the story of the process that created it.

Figure 03: Nautilus shells

The spiral (Figure 03) is another extremely common fractal in nature, found over a huge range of scales. Biological spirals are found in the plant and animal kingdoms, and non-living spirals are found in the turbulent swirling of fluids and in the pattern of star formation in galaxies.

All fractals are formed by simple repetition, and combining expansion and rotation is enough to generate the spiral.

Figure 04: The Sierpinski Triangle

Purely geometric fractals can be made by repeating a simple process.

Figure 05: The extended Sierpinski Triangle

The Sierpinski Triangle (Serpinski Triangle (2014)) is made by repeatedly removing the middle triangle from the prior generation. The number of coloured triangles increases by a factor of 3 each step, 1,3,9,27,81,243,729, etc.(Figure 04 and 05)

The Koch Curve (Koch curve, 2014) is made by repeatedly replacing each segment of a generator shape with a smaller copy of the generator(Figure 06). At each step, or iteration, the total length of the curve gets longer, eventually approaching infinity. Much like a coastline, the length of the curve increases the more closely you measure it.

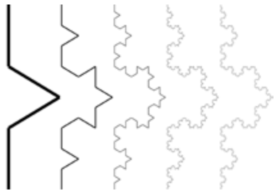

Figure 06: The Koch Curve

Fractals have more and more applications in science.

Astronomy-Fractals may be revolutionize the way that the universe is seen. Cosmologists usually assume that matter is spread uniformly across space. But observation shows that this is not true. Astronomers agree with that assumption on "small" scales, but most of them think that the universe is smooth at very large scales. However, a dissident group of scientists claims that the structure of the universe is fractal at all scales. This led to the surprising result that galaxy correlations are fractal and not homogeneous up to the limits of the available catalogues.

Nature-Take a tree, for example. Pick a particular branch and study it closely. Choose a bundle of leaves on that branch. To chaologists, all three of the objects described the tree, the branch, and the leaves are identical. To many, the word chaos suggests randomness, unpredictability and perhaps even messiness. Chaos is actually very organized and follows certain patterns. The problem arises in finding these elusive and intricate patterns. One purpose of studying chaos through fractals is to predict patterns in dynamical systems that on the surface seem unpredictable. Fractals are used to model soil erosion and to analyze seismic patterns as well. Seeing that so many facets of mother nature exhibit fractal properties, maybe the whole world around us is a fractal after all!

Computer science-The most useful usage of fractals in computer science is the fractal image compression. This kind of compression uses the fact that the real world is well described by fractal geometry. By this way, images are compressed much more than by usual ways (eg: JPEG or GIF file formats). Another advantage of fractal compression is that when the picture is enlarged, there is no pixelisation. The picture seems very often better when its size is increased.

Fluid mechanics-The study of turbulence in flows is very adapted to fractals. Turbulent flows are chaotic and very difficult to model correctly. A fractal representation of them helps engineers and physicists to better understand complex flows. Flames can also be simulated. Porous media have a very complex geometry and are well represented by fractal.This is actually used in petroleum science.

Figure 07: Fractal-shaped antennae

Telecommunications-A new application is fractal-shaped antennae (Figure 07) that reduce greatly the size and the weight of the antennas . The benefits depend on the fractal applied, frequency of interest, and so on.

Surface physics- Fractals are used to describe the roughness of surfaces. A rough surface is characterized by a combination of two different fractals.

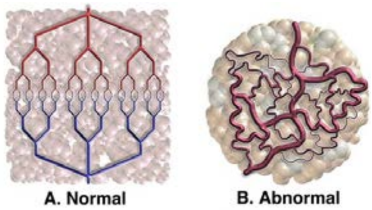

Figure 08: Biosensor interactions

Medicine- Biosensor interactions (Figure 08) can be studied by using fractals.

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