Fractals in nature and applications

Fractals are not just complex shapes and pretty pictures generated by computers. Anything that appears random and irregular can be a fractal. Fractals permeate our lives, appearing in places as tiny as the membrane of a cell and as majestic as the solar system. Fractals are the unique, irregular patterns left behind by the unpredictable movements of the chaotic world at work.

In theory, one can argue that everything existent on this world is a fractal:

- the branching of tracheal tubes,
- the leaves in trees,
- the veins in a hand,
- water swirling and twisting out of a tap,
- a puffy cumulus cloud,
- tiny oxygene molecule, or the DNA molecule,
- the stock market

All of these are fractals. From people of ancient civilizations to the makers of Star Trek II: The Wrath of Khan, scientists, mathematicians and artists alike have been captivated by fractals and have utilized them in their work.

Fractals have always been associated with the term chaos. One author elegantly describes fractals as "the patterns of chaos." Fractals depict chaotic behaviour, yet if one looks closely enough, it is always possible to spot glimpses of self-similarity within a fractal.

To many chaologists, the study of chaos and fractals is more than just a new field in science that unifies mathematics, theoretical physics, art, and computer science - it is a revolution. It is the discovery of a new geometry, one that describes the boundless universe we live in; one that is in constant motion, not as static images in textbooks. Today, many scientists are trying to find applications for fractal geometry, from predicting stock market prices to making new discoveries in theoretical physics.

Fractals have more and more applications in science. The main reason is that they very often describe the real world better than traditional mathematics and physics.

Astronomy

> Fractals will maybe 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. If this new theory is proved to be correct, even the big bang models should be adapted. Some years ago we proposed a new approach for the analysis of galaxy and cluster correlations based on the concepts and methods of modern Statistical Physics. This led to the surprising result that galaxy correlations are fractal and not homogeneous up to the limits of the available catalogues. In the meantime many more redshifts have been measured and we have extended our methods also to the analysis of number counts and angular catalogues.The result is

that galaxy structures are highly irregular and self-similar. The usual statistical methods, based on the assumption of homogeneity, are therefore inconsistent for all the length scales probed until now. A new, more general, conceptual framework is necessary to identify the real physical properties of these structures. But at present, cosmologists need more data about the matter distribution in the universe to prove (or not) that we are living in a fractal universe.

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. A system is a set of things,- an area of study -A set of equations is a system, as well as more tangible things such as cloud formations, the changing weather, the movement of water currents, or animal migration patterns. Weather is a favorite example for many people. Forecasts are never totally accurate, and long-term forecasts, even for one week, can be totally wrong. This is due to minor disturbances in airflow, solar heating, etc. Each disturbance may be minor, but the change it create will increase geometrically with time. Soon, the weather will be far different than what was expected. With fractal geometry we can visually model much of what we witness in nature, the most recognized being coastlines and mountains. 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

Actually, the most useful use 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). An other 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.

Telecommunications

A new application is fractal-shaped antennae that reduce greatly the size and the weight of the antennas . Fractenna is the company which sells these antennae. The benefits depend on the fractal applied, frequency of interest, and so on. In general the fractal parts produces 'fractal loading' and makes the antenna smaller for a given frequency of use. Practical shrinkage of 2-4 times are realizable for acceptable performance. Surprisingly high performance is attained.

Surface physics

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

Medicine

Biosensor interactions can be studied by using fractals.

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