GEOMORFOLOGY, LANDSCAPE PAINTING, POWER LAW, AND FRACTAL MUSIC

Yevina Anna

Moscow State University, Geography Department, Uchtomskaya, 15-34, Moscow 111020 Russia

Natural landscapes are prime examples of complex open non-equilibrium systems. Although landscapes may appear as static, the crust of Earth has organized itself through earthquakes, landslides and so on, working through millions of years and any landscape can be considered as snapshots of a dynamic process.

What are the general principles governing the formation of landscapes? Mathematical models in geomorfology using the theory of self-organized criticality explain fractal features of natural landscapes. All the variability of Earth landscapes (including mountscapes) can be regarded as an self-organized critical phenomenon[1].

In sandpile model of self-organized criticality, critical state comes from a combination of two processes: energy is supplied by adding sand and energy is dissipated by topping of the grains of sand. A.Rinaldo and his colleagues from Padova University (Italy) assumed that landscape formation occurs by a similar process, in which energy is supplied by an uplifting processes (by plate tectonic, volcanic activity or some other geological process) and dissipated through erosion by wind and water.

Figure 1. All natural landscapes (including mountains, coastlines, clouds, trees and so on) are fractals

Computer simulation of landscape formation, carried out by A.Rinaldo, is quite simple: Starting from a given landscape with a river network, the stress on a riverbank from the water flow is calculated. The sites where the stress exceeds the critical value are identified. Erosion is simulated by removing one unit of material at each of those sites. The landscape settles into stationary state, with a fractal network of rivers traversing a fractal landscape.

Mountain landscape images with lakes and rivers can be rather easily generated by computer using simple iterated procedures. One of the simplest fractal model for computer generation of realistic natural landscapes is a recursive procedure when computer draws lines to depict the major peaks and valleys and then these lines are subdivided many times.

Another way is connected with Fourier transformation of sufficiently many independent, identically distributed random samples with appropriate power spectrum. For instance, a mountain with Brownian power spectrum has a surface, whose Hausdorff dimension is D=2.5, which looks like geologically very young.

Figure 2. Computer generated mountscape with Hausdorf dimension D=2.1

R.Voss and J.Wyatt estimated fractal dimensions of early Chinese landscape painting analyzed of digital image intensities J(x,y) [2]. Space representation changed drastically during Sung dynasty (960-1279 A.D.), when landscape painting reached the highest development in Chine. It turned out that landscapes painted at the beginning of this period have fractal dimension in the range 1.3-1.4, while the later paintings have fractal dimension in the range 1.07-1.13.

Some preliminary data indicate that color palette in painting is also subordinated to power law of distribution. In a landscape painting (the following canvases were used: "Ukrainian Night" by Kuindzi and "Above Eternal Repose" by Levitan) some portions of areas painted in one color were investigated. It turned out, that the colors occupying approximately 95 per cent of pictures area and about two-thirds of its color range can be satisfactory described by power law [3].

Great many of natural curves are fractals and therefore can be used to produce "fractal music". For instance, the profile of the top of the mountain range is scaling fractal and one can generate "mountain music" by translating its fluctuating heights to tones that fluctuate in time. Well-known Brazilian composer Villa Lobos did this using mountain skyline around Rio de Janeiro (and more later – skyline by New York city). Gary Nilsen used iterated procedure for score generation of his "mountain songs".

Literature

1. Per Bak. How Nature Works. The Science of Self-Organised Criticality. New York, Copernicus, 1996
2. A.Rinaldo and others. Thermodynamics of Fractal River Networks. *Physical Review Letters* 76, 3364 (1996)
3. A.Somfai, A.Czirok, and T.Visek. Sels-Affine Roughening in a Model Experiment on Erosion in Geomorphology. *Journal of Physics A* 205 (1994) 355
4. R.Voss, J.Wyatt. Multifractals and the Local Connected Fractal Dimension: Classification of Early Chinese Landscape Paintings. In: A.J.Crilly, R.A.Earnshaw, H.Jones, eds., Applications of Fractals and Chaos. Berlin, Springier, 1993. 171
5. Yu.Orlov. Invisible Harmony. "Chislo i Mysl", N3, Moscow, Znanie, 1980 (in Russian)