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FRACTAL GEOMETRY THEORY IN PERFORMING AUTOMATED MAP GENERALIZATION OPERATIONS

Byron Nakos
Cartography Laboratory
National Technical University of Athens
9, Heroon Polytechniou STR.
Zographos GR-157 80
Greece
FAX: +30-1-7722 670
Email: bnakos@central.ntua.gr

Automated map generalization has been conceived by researchers as a two fold cartographic operation transforming digital objects, which represent real world entities. The "bright side" of generalization focuses on visualization issues (cartographic / graphic generalization), while the "dark side" on the design and development of multi-scale data models (model / non-graphic generalization). In addition, research has been directed towards creating sets of rules, which represent the cartographic knowledge of the generalization domain. It will be an interesting approach to develop appropriate models that can be applied both to cartographic and model generalization. Fractal geometry theory could provide such a unified approach for several generalization operations.

Fractal geometry theory could be used to realize generalization operation as an analytical transformation invariant to similarity or affinity. More specifically, generalization may be assumed as a self-similar or self-affine transformation. The self-similar transformation could be applied to 2-D cartographic objects (i.e. coastlines, contour lines, rivers), while the self-affine transformation to 3-D cartographic objects (i.e. Digital Elevation Model or any other analytical surface model). These pure geometric transformations could be statistically applied to vector or raster structured data.

Fractal geometry has been used in the past as a generalization model mainly for the development of line simplification algorithms. Their basic advantage concerns their capability to quantify subjective characteristics of cartographic objects, like complexity or roughness, by their fractal dimension. After self-similar or self-affine transformation, the fractal dimension of cartographic objects remains unchanged. Fractal geometry may provide a conceptual framework for both cartographic and model generalization. Statistical self-similarity could be determined by: (a) the length of a linear cartographic objects versus the measuring step and (b) the area of closed linear cartographic objects (polygons) versus their perimeter. Statistical self-affinity could be determined by: (a) variance function of analytical surfaces versus correlation distance and (b) power spectrum of analytical surfaces versus wavelength. These four relationships are graphically expressed on double-logarithmic diagrams by straight lines, the parameters of which are estimated by performing linear regression.

The fractal generalization methodology, proposed in this paper, is based on a three step procedure:
- verification of fractal character,
- determination of fractal dimension and
- application of fractal simplification algorithm (cartographic generalization) or fractal interpolation algorithm (model generalization).

The verification of the fractal character of the cartographic objects could be accomplished by applying three statistical tests at a high confidence level (95% or 99%). The first statistical test is checking the significance of the correlation coefficient. The second statistical test is checking the value of fractal dimension against the Euclidean dimension of the object (Euclidean shapes are not fractal). The last statistical test is checking the significance of the estimated line slope. The fractal dimension is determined as a function of slope depending on the self-similar or self-affine relationships. A fractal simplification algorithm can be designed by applying points elimination of linear cartographic objects. A fractal interpolation algorithm can be designed to enrich linear interpolated analytical surfaces with random fractal noise by keeping the variance at a level which retains their fractal dimension.

Finally, a few fractal generalization algorithms applied to the coastline of the island of Ithaka from scale 1:100.000 to scales 1:250.000, 1:500.000 and 1:1.000.000 and characteristic examples of DTM enhancement applied to the area of South Pindos Mountain are given and discussed.