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MULTI-RESOLUTION PROCESSING FOR FRACTAL ANALYSIS OF AIRBORNE REMOTELY SENSED DATA

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Fractal geometry is increasingly becoming a useful tool for modeling natural phenomenon. As an alternative to Euclidean concepts, fractals allow for a more accurate representation of the nature of complexity in natural boundaries and surfaces. Since they are characterized by self-similarity, an ideal fractal surface is scale-independent; i.e at different scales a fractal surface looks the same. This is not exactly true for natural surfaces. When viewed at different spatial resolutions parts of natural surfaces look alike in a statistical manner and only for a limited range of scales.

In this paper, images acquired by NASA's Thermal Infrared Multispectral Scanner are used to compute the fractal dimension as a function of spatial resolution. Three methods are used to determine the fractal dimension - Shelberg's line-divider method, the variogram method and the triangular prism method. A description of these methods and the result of applying these methods to a remotely-sensed image is also presented.

Five flights were flown in succession at altitudes of 2 km (low), 6 km (mid), 12 km (high), and then back again at 6 km and 2 km. The area selected was the Ross Barnett reservoir near Jackson, Mississippi. The mission was flown during the predawn hours of Feb. 1, 1992. Radiosonde data was collected for that duration to profile the characteristics of the atmosphere. This corresponds to 3 different pixel sizes - 5m , 15m and 30m. After, simulating different spatial sampling intervals within the same image for each of the 3 image sets, the results are cross-correlated to compare the extent of detail and complexity that is obtained when data is taken at lower spatial intervals.

Introduction

The advent of fractal analysis measures has been alluded to as one of the four most significant scientific concepts of the 20th century, with a scientific impact similar to that created by quantum mechanics, the general theory of relativity, and the development of the double-helix model in DNA structure. (Clarke et al. 1991) Since the development of the fractal concept by Mandelbrot (Mandelbrot 1967, Mandelbrot 1977), a number of methods for calculating fractal dimensions have been developed and applied to various spatial problems. (Goodchild 1980, Goodchild 1982, Burrough 1981, Mark et al. 1984, Goodchild et al. 1987, Krummel et al. 1987, Milne 1991, Lam et al. 1992) Fractals, however, have seen only limited employment for analysis of remote sensing data. (DeCola 1989, Lam 1990) As noted in Lam (1990), fractals offers significant potential for improvement of measurement and analysis of spatially and spectrally complex remote sensing images. The fractal dimension of remote sensing data could yield quantitative insight on the spatial complexity and information content. Thus, remote sensing data acquired from different sensors and at differing spatial and spectral resolutions could be compared and evaluated based on fractal measurements. The fractal dimensions derived from remote sensing data could also be compared with other measures of spatial complexity to better understand the significance of the spatial interrelationships present within image data. Moreover, if fractal dimensions are shown to be unique to different types of remote sensing data, these values could be used as control for the simulation of fractal surface generation of remotely sensed images.

Outside of the potential offered by fractal analysis, the only other method for measuring the spatial frequency as an index of variability and complexity within a remote sensing image has been the two-dimensional Fourier transform technique (2D-FFT). In spite of being computationally intensive, the 2D-FFT technique has been successfully used for spatial processing of image data, such as filtering. (Moik 1980) The only information that a 2D-FFT can provide to classify data in a spatial manner is the spectrum of the data. For example, urban areas have a higher spatial frequency than rural areas. The information is very qualitative and does not readily lend itself to quantitative interpretation. With the emergence of fractals, it may be possible to lend that quantitative analysis of these spatial variations.

This paper describes the adaptation and implementation of three methods that have been successfully applied to compute fractal dimensions from multiple scaled remote sensing data. These are the Shelberg or line-divider method, (Shelberg et al. 1982, Shelberg et al. 1983) the triangular prism method, (Clarke et al. 1991), and the variogram method. (Mark et al. 1984) These techniques have been implemented on a self-contained menu-driven PC-compatible image interpretation software package (Note: This package is also available for the UNIX workstation environment, without the menu structure, as a set of routines). This interactive program, written in 'C', allows the user to analyze their results without having to spend considerable effort in programming these methods for fractal computation. The results are accessible to the user on the screen as well as from an ASCII file for future use in graphing and more intensive interpretation. Also, this PC-compatible software utilizes almost no special purpose hardware (except for a VGA monitor), which permits wide distribution to other users.

On entering the program, the user encounters an image on the screen with a menu adjacent to it. The menu allows the user to perform analyses using either of the three fractal computation methods. The fractal dimension is computed for a user-specified region within the image. This region is outlined as a rectangular box on the image. The user can then interactively move the box anywhere or change the size of the box. Also, some of these methods allow for analysis to be performed using different values for specific internal parameters. These parameters can also be changed interactively or can be preset by the user. The following is a discussion of the three fractal computation methods, their implementation using the program, and a description of the results obtained from each fractal calculation method.

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