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Research Article

Reconstruction of Satellite Remote Sensing Images using Multifractal Analysis

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A B S T R A C T

Remote Sensing Satellites are imaging the earth and providing different types of imagery in terms of volume, variety, velocity and variability. The spatial resolution is an important quality parameter and critical bottleneck in various remote sensing applications. In this work, we used multi-fractal based reconstruction to increase the spatial resolution of the remote sensing image. In multifractal analysis, image is treated as a nontrivial combination of a number of fractals. Multifractal characteristics of the low resolution image are extracted to compute the information transfer function and noise parameters. We generated an enhanced resolution image using low resolution image by a fractal based denoising and downscaling method. The reconstructed super resolution image is validated with original high resolution image through quality parameters like correlation coefficient and Structural Similarity Index (SSIM).

Keywords: Image Reconstruction, Multifractal Analysis, Information Transfer Function, Downscaling, Super Resolution

Introduction

Satellite Remote Sensing is an important source to observe the earth, providing various types of imagery in terms of volume, variety, velocity and variability. The spatial resolution is an important quality parameter and critical bottleneck in various remote sensing applications. Super Resolution (SR) reconstruction is an important method to generate enhanced spatial resolution image from one or more Low Resolution (LR) images.[1] The super resolution reconstruction method can involve single image or multi images based on the number of low resolution images. The multi image SR reconstruction aims to combine complementary information from different images based on sub-pixel shifts. The single image SR reconstruction method focuses on extracting relationships among neighborhood pixels.[2,3] Fractal theory is very efficient method to depict chaotic, erratic, natural phenomena concertized by Mandelbrot and also considered as straightforward method to analyze extreme variability over a wide range of scales.[4] Here, we used multifractal reconstruction method to enhance the image resolution. The self similarity in the image is helpful to estimate the information in higher and lower scales.

We first search for multifractal characteristics in the images and then estimate information transfer function and noise in the low resolution image. Later, we use a fractal based denoising and downscaling method to generate a noise free enhanced resolution image. This method is useful for any images with multifractal characteristics along with remote sensing imagery.[5] A multifractal system is a generalization of a fractal system which needs continuous spectrum of exponents.

Methodology

The relation between high resolution image (H) and the low resolution image (L) is represented by

$$L = H * s + e \quad (1)$$

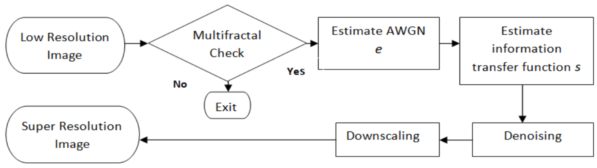

Figure 1.Flowchart of SR construction

where s is the information transfer function which describes the information transfer between different scales, e is the noise and * denotes the multiplication operator.[6] The framework of super-resolution reconstruction using multifractal analysis is shown in figure-1.

Here, we take *e* as Additive White Gaussian Noise (AWGN) and information transfer function *s* moves through H without overlap. For a given *L, s* and *e*, *H* can be estimated if the low resolution image has self-similarity characteristics. With multiracial analysis, we learn about the upscaling information transfer function *s* and compute the additive white Gaussian noise *e* in the image. Then, we construct a super resolution image from a single low resolution image by denoising and downscaling.[6]

Study and Result

An initiative to generate a database of seamless, homogeneous DEM from Cartosat-1 stereo mission, named as CartoDEM and associated ortho-image tiles at country level has been undertaken by Indian Space Research Organization (ISRO). Carto DEM generation system in National Remote Sensing Centre (NRSC) has produced the digital surface model covering India and other countries.[7] NRSC has generated and disseminated 1/3 arc-second (10m) CartoDEM covering India and surrounding countries and 1 arc-second (30m) DEM is ported on Indian EO portal Bhuvan for visualization and free download. The effectiveness of the proposed reconstruction using multifractal analysis is evaluated on a set of CartoDEM tiles covering geographical locations at latitude 38.500N, longitude 146.75E (SW corner) and latitude 19.000N, longitude 126.000E (SW corner).

Table 1.Objective Quality Parameters

Quality Parameter	Correlation Coefficient (CC)	Structural Similarity Index (SSIM)
Study area SW co-ordinates	SR vs.HR	SR vs.HR
38.500N/146.750E	0.98	0.77
19.000N/ 126.000E	0.92	0.69

We reconstructed an enhanced 1/3 arc-second resolution image from 1 arc-second image and compared it with the original 1/3 arc-second image. The reconstructed super resolution images are compared with original high resolution images in terms of visual quality and objective quality parameters like Correlation Coefficient (CC), Structural Similarity Index (SSIM). The objective quality parameters given in table-1 confirm that the reconstructed super resolution image is comparable with original high resolution image.

The visual comparison of SR image with LR image confirms that the reconstruction with multifractal analysis is resulted with better details and comparable with original HR image. The images of study area (latitude 38.500N, longitude 146.75E) are show in figure 2.

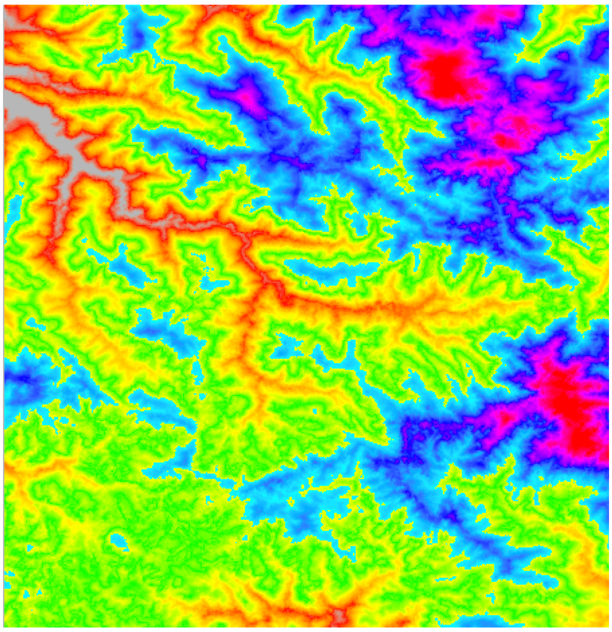

Figure 2(a).Low Resolution image (30m)

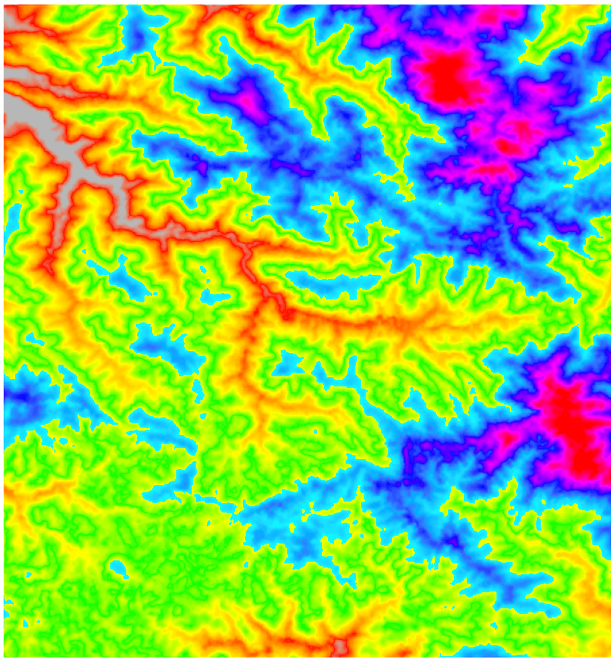

Figure 2(b).Super Resolution image (10m)

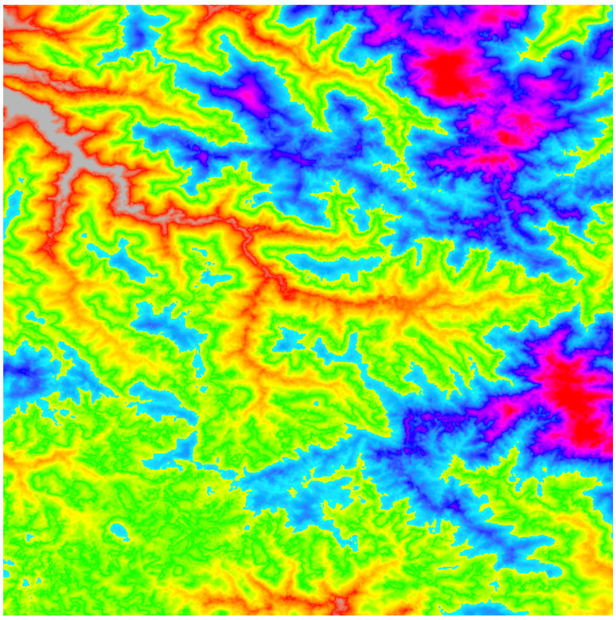

Figure 2(c).Original High Resolution image (10m)

In the SR image, many details are added compared to the LR image and shown in Figure 3. The original LR image is coarser than the SR image.

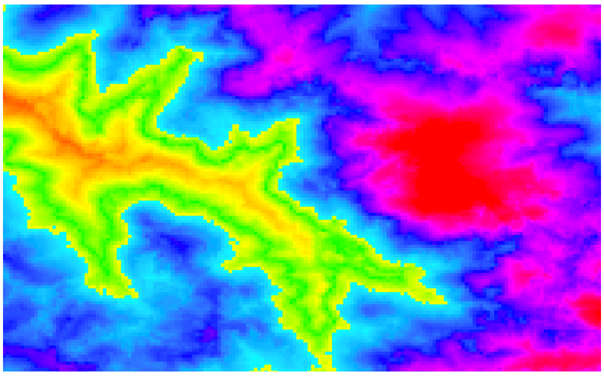

Figure 3(a).Low Resolution image (30m) zoom

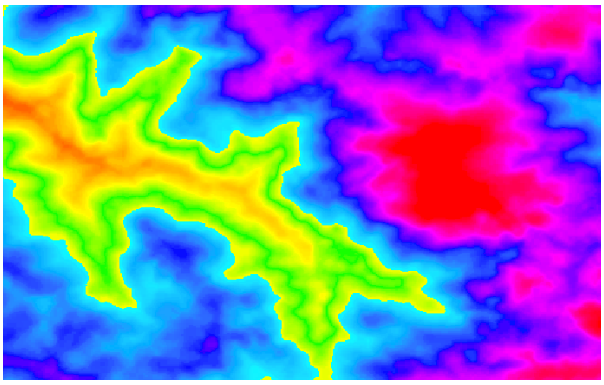

Figure 3(b).Super Resolution image (10m) zoom

Conclusions and Future Work

Remote Sensing data provides an important source to interpret the earth features but the spatial resolution is a limiting factor. In this case study, we tested a multifractal based super resolution reconstruction using self-similarity present between different scales to reconstruct details at a smaller scale than the original lower resolution image scale. The results confirm that the multifractal analysis is efficient in reconstructing super resolution image. Future planned work includes search strategy to estimate information transfer function, fractal coding and applying this method to other datasets with multifractal characteristics.

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