

Enlarging Satellite Images based on Fractal Techniques

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Abstract: In this work, a very brief definition and history of Fractals were presented. Fractals are commonly found in nature; which implies that they should be good candidates for modeling different types of real world signals. Fractal-based techniques have found many applications in the field of Remote Sensing by using special computer algorithms. This paper describes the usage of fractal techniques in the enlargement of satellite imageries in order to get more information from them with approximately no distortion (zooming into the image many times). In order to have a practical experience, this research has also analyzed successful implementation of Fractal techniques on a satellite image.

Keywords: Remote Sensing, Fractals, Image Processing, Dimension, Computer Graphics

1. Introduction

Fractals are recent synthesis of old mathematical constructs. Mandelbrot's fractal geometry has proved a new qualitative and quantitative approach for understanding the complex shapes of nature (Mandelbrot, 1983). In this work, fractals were used for the enlargement of real digitized satellite images in order to get more details from them. This approach is of great importance in remote sensing applications. An algorithm called "FFC algorithm" has been used to develop Pascal computer programs for synthesizing topographic surfaces (Fournier, Fussell & Carpenter, 1982; Fournier & Milligan, 1985). The computer programs of this work can be executed on any Personal Computer (PC) or Laptop. A LANDSAT Thematic Mapper digital image (band 4) is used in the implementation of the algorithms utilizing fractal techniques to Zoom into any satellite image (Thabet, 1990).

The concept and the word "FRACTAL" were introduced by Benoit B. Mandelbrot in 1975 (Mandelbrot, 1983; Jacquin, 1994). He made an important observation that "many objects in the natural world are neither continuous nor smooth or measurable by using the traditional standards of applied mathematics but require the use of more general methods and constructs of pure mathematics" (Feder, 1989). Mandelbrot coined the term "FRACTAL" in 1975 to describe a class of functions first discovered by Cantor, 1874; Peano, 1890; and Koch, 1904. He pointed how these functions yield to a valuable insight into the creation of models for natural objects such as coastlines

and mountains (Thabet, 1990; Paszto et al., 2011). Mandelbrot popularized the notion of the fractal geometry for these types of subjects. His famous and pioneering work with fractal geometry and his introduction of many new concepts including "fractal dimension", "self-similarity", "non-standard scaling" and "fractional Brownian motion" have a great effect on most branches of sciences (Thabet, 1990). Depending on Mandelbrot's results and new concepts; Fournier, Fussell and Carpenter (FFC) created terrains by taking a parametric patch and adding a stochastic element to it by applying their FFC algorithm (Thabet, 1990).

2. Implementing the Task

A digital remotely sensed image, as any image, is typically composed of picture elements (pixels) located at the intersection of each row i and column j in each band of imagery as shown in figure (1).

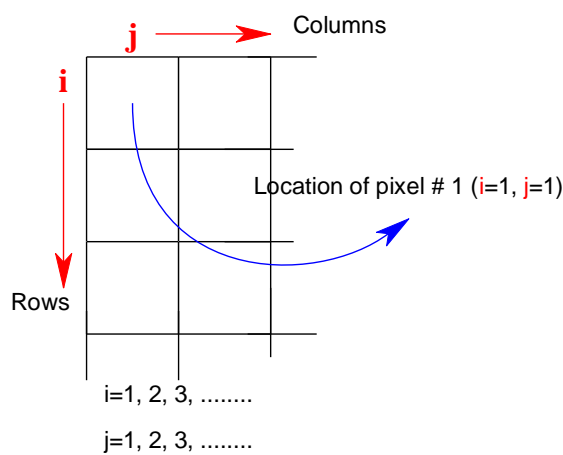


Fig. 1: Pixels manipulation

These data should be in perfect geometric registration. The brightness value at each pixel location and its color are usually represented by numbers.

To implement the FFC algorithm to remote sensing imageries (Thabet, 1990), consider the image shown in figure (2-a) as a 5 by 5 matrix, each element of this array is known as "pixel" which is in fact a set of digital numbers representing the color and the intensity of that point.

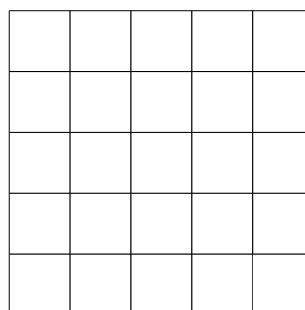


Fig. 2-a: Basic 5 by 5 matrix

This matrix can be expanded to a 9 by 9 matrix by the following equation

$$n_{i+1} = 2n_i \quad (1)$$

$i = 1, 2, 3 \dots \dots \dots$

The expanded matrix is shown in figure (2-b)

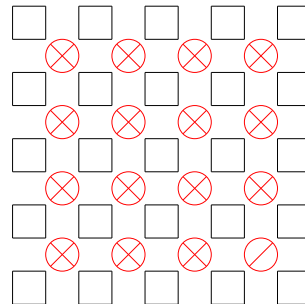


Fig. 2-b: The new expanded matrix

Intensities and colors that are generated over the center point of each square as depicted here by dots. For each small square cell, the average intensity (I_{ave}) of the corner (vertex) points is calculated. A pseudo-random number chosen from a Gaussian distribution G is used to generate the intensity of the center; I_{new} , where

$$I_{new} = I_{ave} + G.Z(3-D) \quad (2)$$

Where

Z is the distance from the center point to the vertex.

D is the fractal dimension.

3 is the dimensionality of the embedding space.

After this has been repeated for each square, the intensity will be known over a finer diagonal array containing both original intensities and the newly generated ones as shown in figure (2-c).

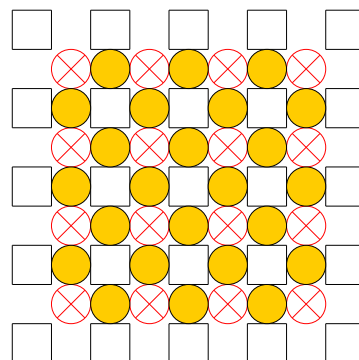


Fig. 2-c: The newly generated intensities

The procedure is repeated again for intensities of the center points of this grid with the exception that, for outer bounding edges, the average intensity is determined from only three or two points. At this stage a new enlarged image has been established as shown in figure (2-d).

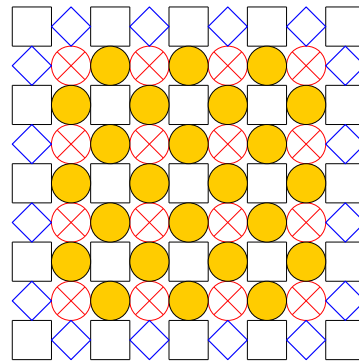


Fig. 2-d: The newly enlarged image

This image will contain three times as many points as the initial image shown in figure (2-a). The procedure can be repeated again and again by using equations (1) and (2), i.e., the new 9 by 9 matrix can be expanded to 17 by 17, 33 by 33, 65 by 65 and more until a sufficiently image is produced (Thabet, 1990).

A segment of the main computer program designed by the author describing this method is shown in figure (3).

```

( *** IMAGE ENLARGING PROGRAM ***
  IDENT.      : ENLARGEMENT
  PROGRAMMER  : HASSAN THABET
  INPUT DATA : OBTAINED FROM USER'S INPUT FILE
  OUTPUT FILE : RESULT WILL BE IN GRAPHICAL FORM
  FUNCTION    : THE PROGRAM DRAWS & ENLARGES A DIGITAL IMAGE      )
program enlargement(input,output,f);
uses graph,crt;
const seed=10;xs=1;ys=1;
type
  graydots=array[1..125,1..125] of integer;
var f,f1,f2,f7,f8:file of integer;gm,gd,i,j,x,y,n9,ff:integer;kn,g1:graydots;
    y1,x1,y2,x2,s1,s2,t:integer;ans1,ans2:char;
    pixelcolor:word;k,l,ik,jk,ig,jg,ss,no:integer;
    sum,fd,d,noise,c:real;dx,dy,m,index,q1,q2,q3:integer;
    ii,jj,il,jl,n1,m1,m3,n3,m2,xx,yy,ik1,ik2,v1,v2,th,ma:integer;
    color:word;p,s,n:integer;
( FUNCTION GAUSS : RETURNS A NORMALLY DISTRIBUTED RANDOM VARIATE      )
function gauss(seed,index:integer):real;
var g:real;i:integer;
begin
  g:=0;

```

Fig. 3: A segment of the main computer program

The program's segment in figure (3) is written in Pascal language and it shows the use of the normally distributed Gauss function because of the randomness of the input signals. This program draws the original satellite image and enlarges it as shown in figure (4).

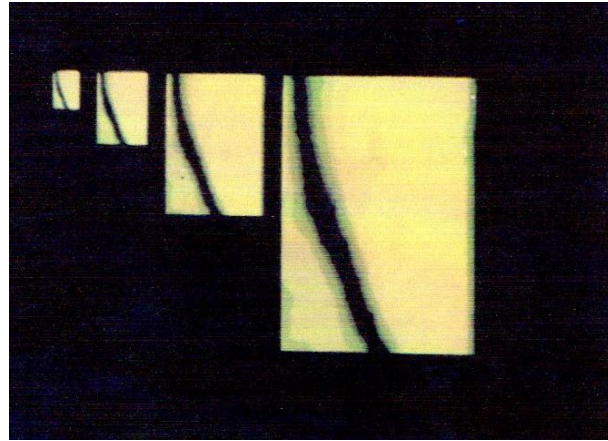


Fig. 4: Implementation of FFC algorithm

Figure (4) shows the FFC algorithm is applied to the original satellite digital image which is enlarged approximately eight times by using equations (1) and (2) three times (16 by 16 pixels is expanded to 31 by 31 then 61 by 61 then 121 by 121 pixels).

3. Results

In this work, a patch of 16 by 16 pixels is taken from a LANDSAT Thematic Mapper digital image of band 4. This image was enlarged (zoomed in) eight times by both a classical and the fractal methods, the results are shown in figure (5). It should be noted that the enlarged image by the classical method contains a very high amount of distortion, whereas the image which is enlarged by the fractal method has approximately no distortion.

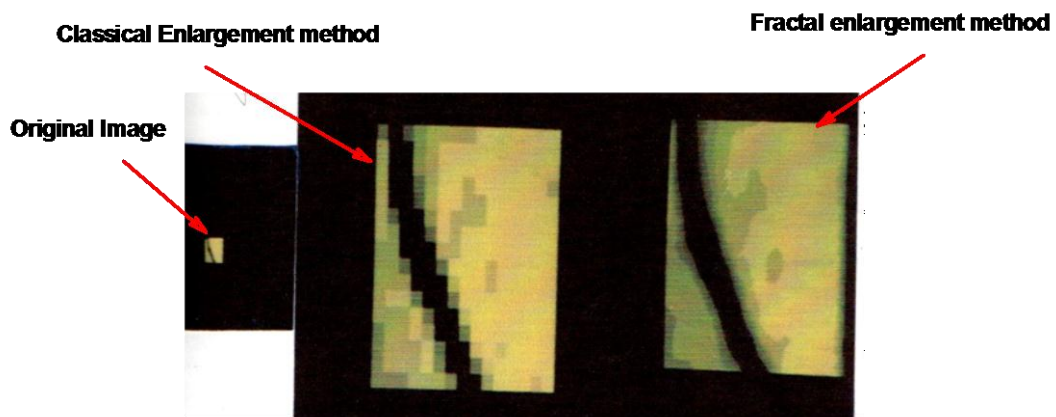


Fig. 5: An enlarged Thematic Mapper Image

4. Conclusions

The FFC algorithm has been used in this work to zoom into any digitized satellite image in order to get more details with less distortion than the previous classical methods. The FFC algorithm is found very useful and applicable in two important branches of applications in the Remote Sensing field:

- 1) It is used to compress the stored images in order to increase the storage capacity of the computer (Hard Discs and computer's memory) especially in remote sensing

applications because the MSS and the TM collect a huge amount of data which have to be stored and transmitted to earth's stations. The FFC algorithm has been used also to reconstruct the compressed stored images to their original sizes when displayed.

- 2) It is also used to measure coastlines which are mathematically fractal objects and considered as fractal interfaces between lands and seas. The main message of this paper is that; fractals are very important and useful in remote sensing applications especially in satellite imageries, computer graphics, signal image processing and many other areas; in addition to their existence as objects that are beautiful and interesting on their own.

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