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Texture Analysis in Images with Differential Box Counting Algorithm

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Abstract— Fractal dimension is a one of the vital parameters in fractal geometry that find applications in the area of image processing. Image analysis is a high-level image processing technique which includes texture analysis. Texture analysis characterizes the regions in an image, based on their texture content. It categorizes texture qualities as roughness, smoothness, silkiness, bumpiness, etc. The image intensities are transformed to fractal dimension domain to carry out texture analysis. In this paper, determining the texture for two images- smooth image and coarse image is considered.
Differential Box Counting algorithm is applied in the considered two images with different textures. The performance metrics considered are, fractal dimension average, fractal dimension standard deviation and lacunarity. The differential box counting algorithm with different pixels from different regions of the same image is implemented and the obtained results are analyzed.

Keywords— Image processing, Box-Counting, Texture Analysis, Fractal Dimension, Lacunarity

I. INTRODUCTION

The Fractal Dimension (FD) image is generated by considering each pixel in the original image as a single fractal dimension estimated from its n*n neighbors, where ‘n’ is a small positive odd integer greater than 1. Several texture analysis functions are available, that filter an image using standard statistical measures. Since these statistics provide information about the local variability of the intensity values of pixels in an image, they can characterize the texture of an image. The range of values in the neighborhood around a pixel is a small value in areas with smooth texture. The range is larger in areas of rough texture. Similarly, calculating the standard deviation of pixels in a neighborhood can indicate the degree of variability of pixel values in the region.

The differential box counting method is frequently used to estimate fractal dimension of a 2D gray-level image. The method is a well-recognized and commonly used technique for texture analysis.

1.1. Fractal Dimension

Fractals are termed as geometric primitives that are self-similar and irregular shape in nature. Fractal geometry was introduced by Mandelbrot in 1982. Fractal analysis is an approach that is applied to study the feature of an image object. Fractal dimension has got information about their geometric structure. The topological dimension of an object would not change even if transformation is applied to the object. The fractal dimension need not be an integer number always.

1.2. Texture Analysis

Texture analysis is the characterization of regions in an image by their texture. Texture analysis can be used to find the texture boundary, called texture segmentation. Texture of the image arranges the spatial color or intensities in an image or selected region of an image. Image textures are one of the way is segmentation or classification of the images.

1.3. Box Counting Method

Box counting refers to the method of gathering data for analyzing complex patterns. This method breaks an object image into smaller and smaller box shaped pieces and analyzes these pieces at each smaller scale. The box counting algorithms has been applied to the patterns in 1D, 2D and 3D spaces.

1.4. Differential Box Counting Method

For an input image using the differential box counting algorithm to calculate in Fractal Dimension, each pixel has its own FD. The user can select any region of interest in the generated FD image to estimate corresponding mean, standard deviation and lacunarity. This algorithm is applied only for binary images and gray scale images.

II. RELATED WORK

In the paper [1], the authors P. Shanmugavadivu & V. Sivakumar present a review article on increasing number of noise in the image, to calculate then fractal dimension. The original image and noise added image are compared using fractal dimension.

In the paper [2], the author Haiyan Zhang Xingke Tao present a study of recognition of plant leaf images by extracting the texture feature of leaf images. Wavelet transformation is applied and fractal dimensions are calculated.

In the paper [3], the authors Omar s. al-kadi and d. Watson, illustrates a study of fractal dimension of lung tumor. The fractal dimension is calculated using differential box counting method. The average and lacunarity are compared in the lung image. The texture analysis is based on fractal dimension of the considered lung image.

In the paper[4], Mehmet Bayirli,salami selvi and ugur cakilcioglu presents a review article on increasing number of application of fractal theory in the environmental sciences. In this paper, various algorithms that estimate the fractal dimension of natural phenomena such as landscape soils, paths of foraging animals, plant root systems are discussed.

In the paper[5], the author N. S. Nikolaidis and I. N. Nikolaidis presents a review of an image analysis method which is based on the box counting algorithm to characterize grapevine leaves. Although vine leaves lack the self similarity of the theoretical fractals, because of their highly complex structure, characterization using fractal analysis is done.

The method of differential box counting is presented by Sarkar and Chaudhuri in [6]. The program transforms an input image using the differential box counting algorithm to a fractal dimensional imager. There are each pixel has its own fractal dimension. Then the user can select any region of interest in the generated fractal dimension image to estimate the corresponding mean, standard deviation and lacunarity.

In the paper [7], the author S. Mancuso present a method known as differential box counting to compute fractal dimension using box counting technique. Leaf of the images calculates in different parameters of differential box counting algorithm for the fractal dimensional value. The degree of roughness change in the images and then grid size is based on scale of boxes.

In the paper [8], the authors Elio Conte and Maria pieralice presents studies of fractal dimensions of leaves are calculated in different leaf images. The values are compared by those obtained from box counting method and the exponent values of density correlation function. There is a relationship between a fractal dimension of the leaf and a surface density of the image and was concluded that together with other measures. The fractal dimensions, with surface density function are used as a new approach in taxonomical study of plants.

In the paper [9], the authors Michael J. Ostwald and Josephine Vaughan presents details about Fractal objects that indicate their scale-invariant structure and hence referred to as self similar. The length of the fractal objects depends on the length scale used to measure it, which is the common characteristic of the fractal object. Fractal dimension tells us the precise nature of the dependence. The authors estimated fractal dimension of different kinds of leaves.

In [10] Nirupam Sarkar et al. present a method of forward differential box counting to calculate fractal dimension. The number of boxes is based on the calculated in fractal dimension of images. In this paper, differential box counting algorithm based on the issues of over-covering boxes and under-covering boxes of images are considered.

III. PROBLEM SPECIFICATION

This work presents a detailed analysis determining the texture of the image applying box counting algorithm for different selected regions of input images.

3.1. Methodology

Gray Scale: Each pixel is a shade of gray normally from 0 to 255. The different images that can be considered are, DICOM images, Figure, jpeg, bmp, png, tiff, gif. In this work two jpeg images with different texture are considered.

Algorithm:
To determine the texture of an image by calculating FD using Differential Box counting.
Input:
Two Images with different texture.
Output:
Average (FD_{avg}), Standard Deviation (FD_{sd}) and Lacunarity.

Step 1: *Read the image.*
Step 2: *Convert to gray scale image.*
Step 3: *Apply Column Filter function in gray image.*
Step 4: *Assign the number of boxes to 5.*
Step 5: *Select the multiple regions in image as boxes.*
Step 6: *Find the Fractal Dimension in different regions of image applying box counting method.*
Step 7: *Find the FD Average, FD Standard Deviation and lacunarity of different regions.*

Column filter function is *colfilt (A, [m n], block-type, fun)* processes the image *A* by rearranging each *m-by-n* block of *A* into a column of a temporary matrix. The block-type is a string; block-type can be of type *distinct* or *sliding*. Sliding is used in this algorithm. The sliding rearranges each m-by-n sliding neighborhood of A into a column, in a temporary matrix and then applies the function *fun* to this matrix. The *fun* must be a function handle and then return a row vector containing a single value for each column in the temporary matrix. *Colfilt* then rearranges the vector returned by fun into a matrix the same size of *A*. This colfilt function is available in MATLAB tool. Differential box counting algorithm [3] is applied and the results are obtained for five different box regions.

FD_{avg}, FD_{sd} and lacunarity are found applying this algorithm. FD_{avg} is an average fractal dimension value for the particular area. The amount of variation or dispersion of a set of data values is quantified by a measure FD_{sd}. If FD_{sd} is low it indicates that the data points are closer and high FDsd value indicates that the data points are spread out over a wider range of values. Lacunarity which means “gap” or “lake” in Latin, refers to a measure of how patterns or texture fill space. Patterns having more or large gaps generally have higher lacunarity.

IV. RESULT AND DISCUSSION

Using differential box counting algorithm, FD_{avg}, FD_{sd} and lacunarity are calculated for smooth and coarse images.

Input Images:

Fig. xx (Smooth image)

Fig. xy(Coarse image)

Five different regions are selected from the chosen images for performing Box counting. The calculated values of FD_{avg}, FD_{sd} and lacunarity for the considered images (Fig. xx & Fig. xy) are tabulated in table 1.

Table: 1

	Image Texture	**FD_{Avg}**	**FD_{sd}**	**Lacunarity**
	Smooth	1.7503	0.3491	0.0398
size1	Coarse	1.7920	0.3632	0.0410
	Smooth	1.7207	0.3588	0.0435
size2	Coarse	1.8061	0.4452	0.0607
	Smooth	1.7171	0.3727	0.0471
size3	Coarse	1.9036	0.4301	0.0510
	Smooth	1.7300	0.3665	0.0449
size4	Coarse	1.8703	0.3719	0.0395
	Smooth	1.7029	0.3820	0.0503
size5	Coarse	1.8646	0.3643	0.0382

The FD average values are plotted for smooth and coarse image. In fig:1 ‘x’ axis depicts the different box sizes (number of pixels) chosen are s1, s2, s3, s4 and s5. ‘y’ axis depicts the FD_{Avg} values obtained.

From the obtained results, it is clear that there is a distinct variation in the FD_{Avg} values. These values are lower for smooth image and are higher for coarse image, irrespective of the box size.

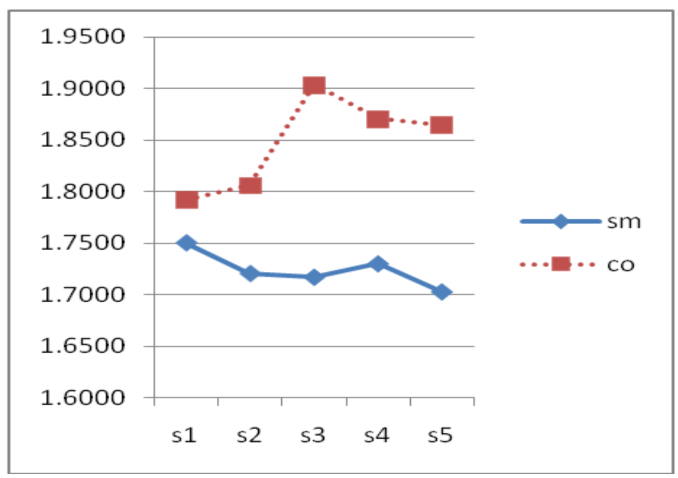

Fig. 1 (FD Average)

Similarly, the FD standard deviation values are plotted for the considered smooth and coarse image for the different box sizes. Fig.2 from the obtained results, it is clear that there is a distinct variation in the FD_{sd} values. These values are lower for smooth image and are higher for coarse image, irrespective of the box size.

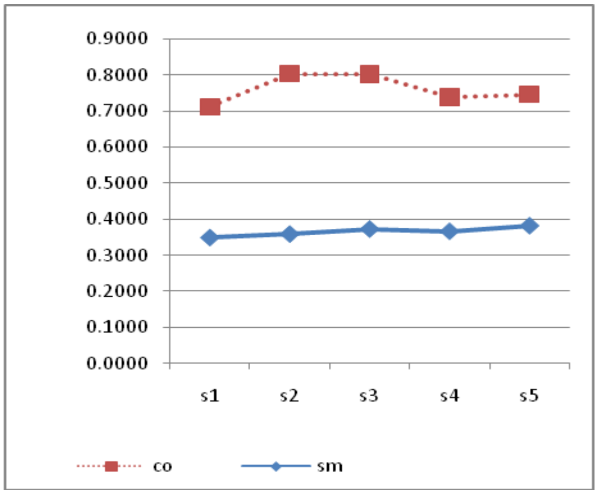

Fig: 2 (FD Standard Deviation)

In similar line, the lacunarity values are also plotted. Like, FD_{Avg} and FD_{sd}, it is evident that there is a distinct variation in the lacunarity values too. These values are low for smooth image and high for coarse image, irrespective of the box size.

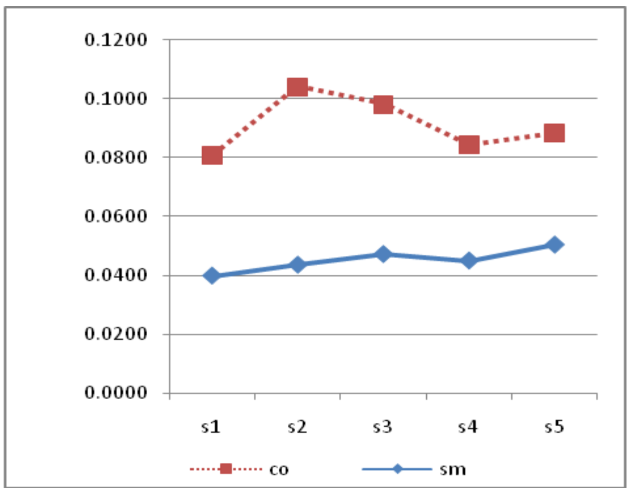

Fig. 3 (Lacunarity)

From the observed results, we conclude that the Fractal dimension can be used in analyzing the texture of an image.

V. CONCLUSION

Fractal dimension of an image has a correlation with its texture. Fractal dimension serves as a vital component to measure the texture of an image. The $FD_{avg,}$ FD_{sd} and lacunarity of two images with different texture are calculated. From the obtained results, it has been observed that smooth image has low $FD_{avg,}$ FD_{sd} and lacunarity when comparing with coarse image. This result clearly indicates that FD technique can be applied for determining the texture of an image. In future, images with different texture like roughness, silkiness etc., can also be considered and tested.

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