

SATELLITE IMAGES CLASSIFICATION BASED FRACTAL FEATURES

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Abstract

In this paper, a TM-multi-spectral satellite images is adopted in a purpose of supervised classification. The traditional method of the segmentation namely Quad tree is applied as pre processing step. For each segmented block, the fractal features (fractal dimension and lacunarity)s are determined to be used as a maximum likelihood classifier. The results showed that the fractal dimension has not certainly able to classify the segmented blocks while the lacunarity gave good classification results. In general, the fractal geometry was found an efficient parameter for describing the image. The results show that the over all classification accuracy is 85.5%.

1- Introduction

The first problem in many images processing application is to extract from the image a description in terms of a set of meaningful features. An appropriate choice of feature set is therefore a vital factor in such application. As it will determine the ease and effectiveness with which subsequent segmentation and processing tasks may be performed [1, 2].

One of the most efficient region based segmentation method is Quad tree method. This method starts by subdividing an image into a set of arbitrary disjointed regions and then merges and or split them in attempt to satisfy the conditions stated before

The segmentation by quad tree method needs to store 5 pointers, one for the father sub picture and one for each of its 4 son sub pictures. The quad tree codes for a square $2^k \times 2^k$ pixel block made by $n - k$ successive subdivision into quadrants consists of $n - k$

In the current research, the adaptation of the quad tree method with new suggested conditions for the purpose of segmentation is carried out. The algorithm of the quad tree is extracted in following: The quad tree of a $2^n \times 2^n$ picture is a rooted directed tree generated by the recursive a square sub picture of the picture, with the root representing whole picture. If the sub picture represented by a given node dose not satisfied the conditions then the node is a leaf of that root; otherwise the sub picture is divided into 4 equal sons.

2- Fractal Images

The actual benefit of satellite images strictly tied to the problem of the segmentation and classification. In the present work, we employ a classification method based on fractal geometry.

In fact, fractal geometry provides a suitable mathematical framework to study the nature irregularity shapes since it allows to easily describing such complex objects and phenomena. In particular, it has been shown that most natural surfaces are fractals and that intensity images of these surfaces are also fractal [3].

The main characteristics of fractal images are that they are continuous but not differentiable and that they show a fine detailed at any arbitrarily small scale. A fundamental concept of fractal geometry is the fractal dimension, at any fractal application, one can use the fractal dimension as a recognizable fractal feature because it is a measure of complexity in fractal patterns, the higher fractal dimension the more complex the fractal pattern. Fractal dimension can be computed by the following simple way;

If one take a single line segment of length one, and divide it into N equal parts, each will be scaled by a factor of $r = 1/N$ with respect to the original segment. Thus one can write $Nr=1$.

In two diminutions, one take a square of area one, and divide it into N equal parts, each

will be scaled by a factor of $r = 1/\sqrt{N}$, Thus one can have $Nr^2=1$.

And in three diminution, one take a square of area one, and divide it into N equal parts, each will be scaled by a factor of $r = 1/\sqrt[3]{N}$,

Thus one can have $Nr^3=1$.

So in general, if we take a set of dimension D , one would expect to say that it consists of N parts, each scaled by a factor of r . one have;

$$Nr^D = C$$

Where, C is constant, solving one get;

$$D = \frac{\log(N)}{\log(1/r)}$$

where, D is the fractal dimension.

Because D can takes non-integer (i.e., $2 < D < 3$) number, therefore it is difficult to recognize plenty of classes well. Mandelbrot suggest new fractal measure ‘‘Lacunarity’’ to handle the case of sharing two different classes with same fractal dimension [4]. Lacunarity is an accurate similarity measure to distinguish two fractal images. It is a set of points (curve) computed by the same method of computing the fractal dimension ‘‘Box counting method’’. Box counting method is an accurate one for computing the fractal dimension and the lacunarity, but it has some of complexity.

3- Box Counting Method

One can define the box dimension D of a set S contained in R^n as follows; for any $S > 0$, let $N(S)$ be the minimum number of η -dimensional cubes of sides length S needed to cover S . If there is a number D so that;

$$N(S) \approx 1/S^D \quad \text{as } S \rightarrow 0$$

Where, D is the box dimension of S .

Note that the box dimension is D if there is some positive constant K , so that,

$$\lim_{S \rightarrow 0} \frac{N(S)}{1/S^D} = K$$

Since both sides of the equation above are positive, it will still hold if one takes the logarithm of both sides to obtain;

$$\lim_{S \rightarrow 0} (\ln(N(S) + D \times \ln(S))) = \ln(K)$$

Solving for D gives

$$D = \lim_{S \rightarrow 0} \frac{\ln(K) - \ln(N(S))}{\ln(S)} = - \lim_{S \rightarrow 0} \frac{\ln(N(S))}{\ln(S)}$$

Note that $\ln(k)$ drops out, because it is constant while the denominator becomes infinite as $S \rightarrow 0$. Also, since $0 < S < 1$, $\ln(S)$ is negative, so D is positive as one would expect [5].

4- Materials and Method

In this paper, TM-multi-spectral bands (6 bands, three bands in visible and the other three infrared regions) of Ramadi-sense satellite image are adopted in purpose of classification. The different bands of the image are tested by determining the variance to find the most spectral varying band [6]. This band is used to build the lookup table necessary for classifying the image. Practically, the main task of the research is studying and analyzing the ability of the fractal features to distinguish different classes in satellite images, and then determining the performance of each feature alone. The trial image is taken at six bands contains six known training areas. Our previous knowledge about the training areas of this images help to test the classification results well.

The design and implementation of classifier software require to pass through stages present in the block diagram shown in figure (1) below;

In the following, more details about each stage;

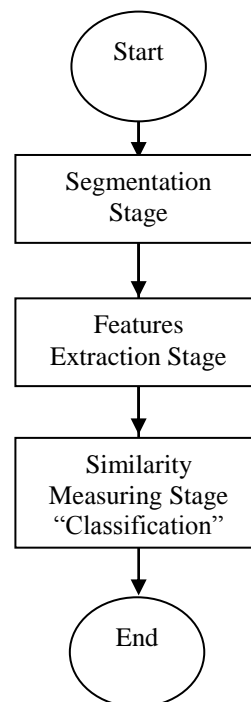
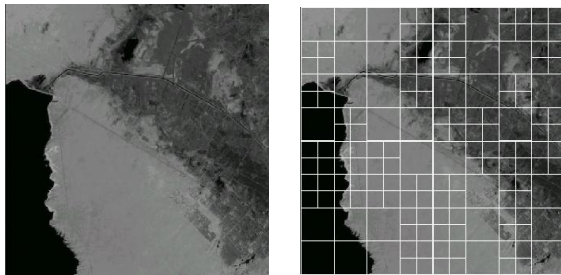


Figure (1): Block diagram shows the sequence of classification process.

Segmentation stage: The quad tree traditional method is used to segment the image with new suggested conditions. The segmentation stage was segmenting the parent image into many of the sub images depending on the variety of the local gray levels of the sub images. The results of the segmentation gave good impress about the splitting conditions. The suggested conditions depend on the local mean and standard deviation of both the parent root and its four son nodes. Because band 5 has the largest variance (1873.6) and the widest range of brightness (197) [6], this band is adopted for segmentation. Figure (2) show the result of applying split and merge method for Ramadi Scene (band 5).



(a): Ramadi image (b): Segmented image
Figure (2): The result of applying split and merge method (band 5).

Feature extraction stage: For each segmented block, the fractal dimension and lacunarity are computed to be two classifier parameters. It is noticeable the neighbors blocks were different, which lead to make their extracted features have recognizably among other blocks.

In addition to the roughness, it is found that the fractal dimension depends on the brightness of the segmented block, which affects the recognition task. In order to pass this problem, the second fractal parameter "lacunarity" is used to give the recognizing decision of the block under consideration. The increasing of brightness causes to increase the fractal dimension and shift the lacunarity curve upward, while its decreasing causes to decrease the fractal dimension value and shift the lacunarity curve downward, In both cases the lacunarity shape was conserved all lacunarities are normalized. Therefore, the fractal dimension

ignored since it showed weak distinguishing, whereas the lacunarity remained used alone as a fractal recognizable parameter.

Similarity measuring stage: This stage can be branched into two steps,

Step1: Estimating the weight for each shared band in the classification decision. Because of the image bands cannot have different details comparing with each other's, each band contributed by a weight is proportional to its carried information. The contribution weight is estimated depending on its gray variance. Therefore, each band has a contribution percentage given as follows;

$$W_i = \frac{Var_i}{Var_{Total}} \times 100\%$$

where,

W_i is the contribution percentage of the i^{th} band,

Var_i is the gray variance of the i^{th} band,

Var_{Total} is the summation of variance of all bands.

Step2: Identifying the set of lacunarities belong to a specific band with known others stored previously in lookup table, the identification is carried out by computing the similarity measure with regarding the contribution percentage of each band as follows;

$$S_{ij} = \left(1 - \left| \sum_{i=1}^6 W_i \times \sum_{j=1}^N \sum_{k=1}^6 (Lac_{ij} - LacL_k) \right| \right) \times 100\%$$

where, N is the number of resulting blocks in the current band, i is pointer refers to the current band, j is pointer refers to the current block, k is pointer refers to the current class, Lac_{ij} is the lacunarity of the j^{th} block existing in i^{th} band, and $LacL_k$ is the lacunarity of the k^{th} class existing in the lookup table.

Now, for each band, each block was classified according to its similarity measure. It is noticeable that this type of similarity measure is need to normalize the lacunarity curve before use it, this credits to achieve actual difference between the two compared lacunarities curves, this makes the resulting similarity measure is also normalized. Where, $S_{ij} = 100\%$ means that the two compared lacunarities are similar to each

other, and the $S_{ij} = 0\%$ means they are different, whereas the fractional number indicates the similarity in between.

4. Results and Analysis

The condition of estimating the fractal feature by box counting method is to make the sliding window is large enough (minimum blocks size 10×10 pixels). However, this confuses the segmentation results. Where, the segmented blocks appeared not very spectral uniform. Thus the resulted lacunarity shapes belong to the same class have small differences in between, while the lacunaritys of different classes show different shapes when they compared with each other.

The lacunarity gave wonderful classification results comparing with the previously known training areas (classes) of the tested image, where each class of image had a relatively different shape of lacunarity. A presentation of resulting lacunarity curve for different classes is pictured in figure (3), whereas figure (4) displays the classified image corresponding to figure (2).

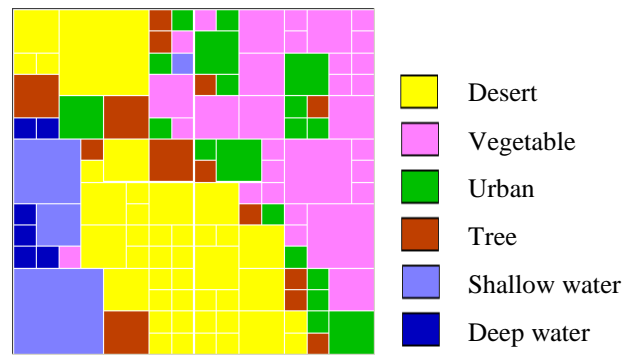


Figure (4): The classified image.

Figure (5) show the lacunarity behavior as a function of box size for different selected regions (Desert, Shallow water, and Tree) belongs to the same class. This figure gives an impress about the general shape stability of the lacunarity for some classes of the image. One can notes that the resulted lacunarity shapes have not exact identification with each other, or with that of the lookup table, but their general behavior is seen to be similar.

Practically it is found that the similarity measure that less than 68% leads to different classes, other wise leads to similar classes. Table (1) presents the error matrix may occur in the classification process. The resulting classification percentages may be telling us that the fractal geometry was effective to process the satellite images. In addition, the adopted lacunarity was a succeed classification parameter.

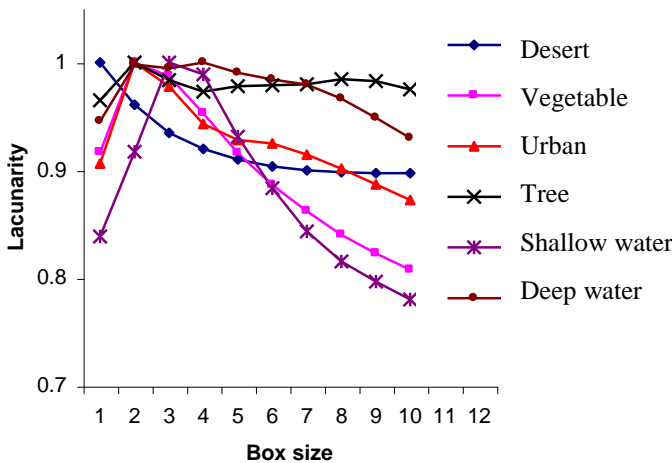


Figure (3): Different lacunarity shapes showed the six classes of Ramadi image that used in the lookup table.

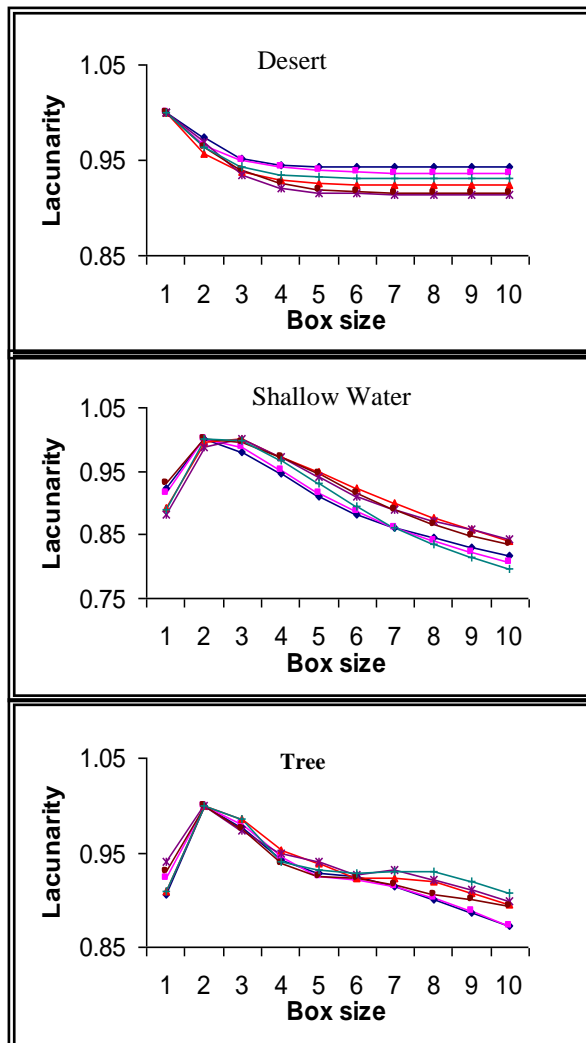


Figure (5): Lacunarity behavior as a function of box size for different selected regions belongs to the same class.

Table (1): Error matrix of the classification process.

Classifier lable \ Ref. data lable	1	2	3	4	5	6
1	87%	8%	1%	3%	0%	1%
2	7%	84%	3%	1%	1%	2%
3	0%	0%	85%	0%	7%	4%
4	2%	3%	2%	87%	2%	10%
5	1%	2%	5%	1%	89%	2%
6	1%	3%	4%	8%	1%	81%
Sum	100%	100%	100%	100%	100%	100%

5- Conclusions

The analysis of fractals applied on satellite images showed good classification results. One can note that the fractal technique is sensitive to the image contrast through specific resolution. The reason of using the quad tree as a segmentation method is the need to uniform square blocks. These

blocks must be large enough (i.e. 10×10 pixels) in order to use the box counting method to compute the fractal features. The practical results show that the fractal dimension cannot classify the segmented blocks of an image because that its values take a fraction restricted between 2 and 3. This does not allow employing it as good classification parameter. The lacunarity gave acceptable results in the classification task when it is employed as a classifying parameter. It had different shapes for different classes of image

6- References

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الخلاصة

استخدم في هذا البحث ست صور حزمية لمنطقة الرمادي بواسطة الأقمار الصناعية لغرض التصنيف الموجه. استخدمت الطريقة التقليدية المسماة (Quad tree) كمعالجة أولية لتقطيع الصور. لكل قطعة من الصورة، تم احتساب الصفات الكسورية؛ البعد الكسوري والفجوة لتصنيف مقاطع الصورة. بينت النتائج العملية أن البعد الكسوري ليس له القدرة على تصنيف مقاطع الصورة بشكل دقيق، بينما أعطت الفجوة نتائج تصنيف جيدة. بصورة عامة، فإن الهندسة الكسورية كانت كفوءة في وصف الصورة وأن هناك علاقة وثيقة بينهما حيث أظهرت النتائج أن دقة التصنيف تصل إلى 85.5%.