Detection of Rice Leaf Diseases Using Chaos and Fractal Dimension in Image Processing

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***Abstract* – A novel method for detecting rice leaf disease using image processing technique called fractal dimension and chaos theory is proposed in this paper. The analysis of a diseased leaf is carried out according to its image pattern and fractal dimension, and especially box-counting ratio calculation, and chaos, are applied to be able to identify the disease pattern's self-similarity and to recreate the fractal. The image's self-similarity is the disease infected one which is same as when it is fully infected. This method is proposed as preliminary information for the development of an early detection system or for developing knowledge based expert system or decision support system.**

Keywords – Image processing,Chaos Theory, fractal dimension, rice plant diseases.

I. INTRODUCTION

Rice is a globalized staple food. It is one of the three leading food crops in the world which makes it a more significant food item worldwide. Even though, some diseases affects rice production. The current direction at present is sustainability of rice production and the prevention of its diseases. Most methods and new techniques are developed to prevent rice diseases with the initiation of communications technology (ICT) and information technology. The technology is now being employed to propose new methods in the detection and prevention of rice diseases. The latent in using technology in this period is endless with more and more branches of knowledge being discovered. In latest years, tools, applications and technologies of information have appeared as efficient measures for upgrading the whole agricultural fields and to help farmers from scientific studies. The purpose of ICT is very persuasive in the agricultural zone and its prospective is far-reaching.

The constant quest for more measures has controlled researchers to look on new technological support. One technology being discovered and used to detect rice plant diseases is digital image processing, explicitly, pattern recognition. Studies in image processing area on agriculture are few. Pugoy and Mariano [1] developed an automated system that can detect diseases present in a rice leaf using color image analysis. Sanyal and Patel [2] developed a method to detect the rice diseases in order to prevent it and enable people to treat the crop diseases at an early stage utilizing pattern recognition using color texture classification. The study presented a colour texture analysis of rice leaves for identification of leaf brown spot and blast diseases affecting rice plants. Patil and Kumar [3] studied the use of digital image processing to identify diseases in plant diseases, in general.

This article will present an algorithm developed using chaos theory and fractal dimension in image processing. It will focus on recreating fractals of rice leaf disease patterns for identification and early detection. This algorithm may be used as preliminary information or model in creating early disease detection systems or automated systems to identify or detect rice plant diseases. The information or regenerations may also be an essential information or knowledge in the development of decision support systems or expert systems in the agriculture-information. Image processing has more of practical uses aside from arts. It now has a specific role in agricultural applications for the following purposes: 1. To detect diseased leaf, stem, fruit; 2. To quantify affected area by disease; 3. To find shape of affected area; 4. To determine color of affected area; 5. To determine size & shape of fruits; etc. [3] The first application of detecting diseases on sample leaves will be dealt here.

II. PLANT DISEASES IN RICE

The rice plant, like any other living thing, is susceptible to a range of diseases. The anxieties for these inflictions on the rice plant have a major issue because this crop is a food source worldwide. The Rice Knowledge Bank classified rice plant diseases that impose the leaves, into the following: a) Bacterial leaf blight; b) Bacterial leaf streak; c) Blast disease; d) Brown spot disease; e)Leaf scald; f) Narrow brown leaf spot; g) Red stripe; h) Sheath blight; and i) Tungro.

The above said rice plant diseases have their own unique patterns but some of the infliction leaves are very similar, such as the blast disease and the brown spot, or the tungro, leaf scald and red stripe. Some diseases also mimic the pattern of natural aging of leaves. Recognizing them specifically at an early stage could expedite early prevention, thus, saving the crop.

III. FRACTAL DIMENSION IN LEAF IMAGES

Barnsley [4] has categorized fractals as physical and natural fractals. A physical fractal is an object in the real world, whether natural or artificial, whose spatial structure can be approximately modeled by a mathematical fractal. A natural fractal is a physical fractal that occurs in nature; for example, a coastline, a cloud, a feather, a leaf, a vascular system, a turbulent flow, a Brownian motion, or a pattern on marble. Jadoon and Sayab's [5] paper discussed fractal as a mathematical set that has a fractal dimension that usually exceeds its topological dimension and may fall between integers. They signify the idea of detailed self-similar repetition at same scale or they may nearly be the same at different scales. Fractals are geometrical objects with the fractal dimension (D). Their fractal geometry deals with the objects and spaces. They occupy space (x,y,z) of any dimension greater than or equal to the dimension of the objects. Jadoon and Sayab [5] used fractal dimension to analyze different alteration zones in porphyry copper deposits.

Fractal Dimension is a geometric quantity that gives an indication of how completely a fractal appears to fill space, as one zooms down to finer and finer scales.

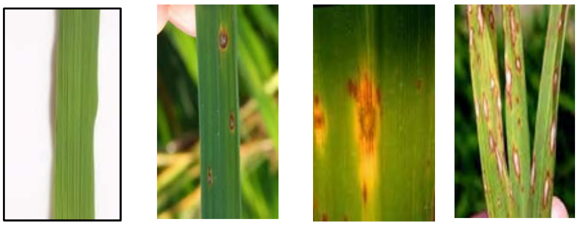
The following formula is for fractal dimension of a self-similar equation object:

$$\text{Fractal dimension (D)} = \frac{\log \text{(no. of self-similar dim.)}}{\log \text{(magnification factor)}} \quad (1)$$

Wu, Lu and Wang [6], who applied chaos and fractal dimension in water quality time series prediction, discussed that fractal distribution can be described by power exponent distribution. As for fractal function N(r)¼CrD, r is a typical variable such as time, distance and so on. Function N(r) is related with r such as price, stock index, monitoring data, etc. C is the constant that does not change with changing of r, and D is fractal dimension. Dimension of fractal can be the fraction, which greatly enriches the traditional theory whose dimension is an integer. Dimension of traditional fractal methods is invariant, which is helpful for shortening and analyzing problems. However, this fractal relationship does not strictly exist in nature so that some refined occurrences cannot be solved using traditional fractal methods.

Dong, et. al. [7] made a study on the analysis of volatile image characteristics based on fractal dimension. They discussed the calculation of fractal dimension of grey level images such that a two-dimensional image is considered as one surface (x, y, f(x,y)) of the three-dimensional space, and f(x,y) is the grey level value of point (x,y) of the image, so that changes of the images' grey level will be reflected by the degree of the surface's roughness. The dimension achieved by measuring this surface with different measurements is the image's fractal one.

Linden [8] stated that fractal dimension is a tool to measure a pattern's self-similarity. So, for this study, parameters are extracted to get the fractal dimension of the different leaves of different diseases to get the self-similarity of each and at the same time be able to recreate the pattern. The samples taken were from the normal leaf and the diseased leaf inflicted with blast disease at the final stage.



Normal Leaf Diseased Leaves

The patterns created in the final stage and the early stage will have the same fractal dimension in the idea of self-similarity. Subsequently the pattern at the start of the disease is generated the same as that of the final stage, the mathematical model of the fractal is the same. Therefore, the detection at the early stage is realistic through this method.

Fractal dimension quantities can be done in different methods, Hausdorff-Besicovitch Dimension, Mathematical calculation of self-similar fractals, Richardson's Method of varied measured lengths, and the Box-counting method. The most common is the box counting method which is what the paper will be using.

A. Box-counting Dimension

The Box counting ratio method is also called as the Brute force method or Grid Method. It is one of the most agreed fractal dimensions for the ease of mathematical calculations and experimental estimation [9]. This is an estimation procedure for calculating the fractal dimension of complex objects. It is most efficiently used when one cannot calculate an objects dimension with numerical formulas or accurately regulate a slope dimension of an irregular shape. This method is popular because it is straightforward and compliant to many situations. If one can contain an object within squares or boxes, then it can be performed as a statistical analysis to determine its physical dimension. It can be used for the calculations on very small objects to very large ones, such as the solar system.

Ade and Lam [10] discussed that the basic idea of box dimension is to cover a subject with a series of boxes of the same measurement (size=δ). These boxes may be of a round or square shape, planar grids or cubic grids, and intersecting or communally exclusive. If these boxes completely cover the subject and when the size approximates to zero, the ratio of the logarithm of the number of boxes to the reciprocal logarithm of size is referred to as box dimension. The fractal analysis here was accomplished by digitizing the measured images with a lateral resolution of 256x256 pixels. If a finite set in n-dimensional Euclidean Space R^n is covered by boxes of size δ, the number of non-empty boxes is $N(\delta)$, and then the box dimension D may be defined as equation object:

$$D = \lim_{\delta \to 0} \frac{\ln N(\delta)}{\ln (1/\delta)} \qquad (2)$$

The negative slope of the straight line is the fractal dimension (D); a D value of 2 indicates the surface is smooth and a value near 3 means an extremely rough surface [11]. Fractality is typically limited to some length scales which strongly depend on the nature of the material and on the preparation method. Normally, the experimental samples are fractal at certain length scales where they exhibit fractal behavior. Outside these upper and lower bounds, the samples behave as almost flat surfaces.

For the statistically self-similar fractals, particularly the unequal distribution on a planar graph, box dimension is the most suitable calculation method. The practical calculation of box-counting method for box dimension of a planar graph is demonstrated below:

1. Let the image being dignified be covered by small squares with sides equal to e in length, and count the total number of the small squares that contain the measured image N(e).
2. Shrink the small squares to e=e/2, and count the total number of small squares that contain the measured image N(e), and so forth.
3. Count the N(e) of different values of e, and calculate their logarithms separately. Draw the statistical curve on a double logarithm synchronize system.
4. Calculate the gradient of the almost straight curve; the gradient shall be the box dimension.

The paper first took sample images of the normal leaf and the full blown affected leaf. A gray scale graph is resulting from these and space decomposition is treated according to the gray scale. The maximum gray scale value is z_{max}, the minimum gray scale value is z_{min} and z is the analyzed gray scale value of the leaves, and also the inception of the pattern analysis. Taking the threshold gray scale value z_h :

$$z_h = \frac{z - z_{min}}{z_{max} - z_{min}} \qquad (3)$$

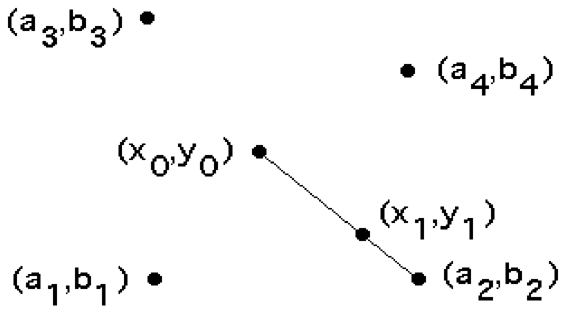
From the analysis above, the fractal analysis algorithm is developed, giving a threshold of 0.5 and a box count dimension of 1.43 calculated using MATLAB program.

IV. CHAOS THEORY

Kellert's [11] definition states that, "Chaos theory is the qualitative study of unstable aperiodic behavior in deterministic nonlinear dynamical systems." It specifically underlines the analysis of systems that are unpredictable and random as considered in linear mathematics. Valle [12], discussed the characteristics from this definition. First, that the system is dynamical, it means that it changes over time. Second, that the behavior of the system is aperiodic and insecure means that it does not repeat itself. Third, although chaotic behavior is complex, it can have simple causes [13]. Fourth, because the system is nonlinear, it is, as we have already seen, sensitive to initial conditions.

Barnsley's [14] chaos theory is a mapping mechanism whereby new fractals can be reproduced. Jampour et al. [5] used the chaos theory in the recreation of the fractal for fingerprints and also for identification purposes. As discussed in their paper, Jampour stated that the theory on the strength of Shannon Theorem is presented in a way that by using Random Walk mechanism and by the aid of a polygonal, a fractal can be created. There were two important points discussed in the study, one is by performing chaos game appliance on a fractal, a new fractal can be recreated. Two, besides properties of fractal some parameters can be attained which would be useful in identification process.

The Chaos Game [15] is played by specifying a number of vertices (a_1, b_1), (a_2, b_2),and (a_N, b_N), and a scaling factor $r < 1$. To play the game, start with the point (x_0, y_0) and pick one of the vertices, say (a_i, b_i), randomly. The point (x_1, y_1) is the fraction r of the distance between (a_i, b_i) and (x_0, y_0). That is, $(x_1, x_1) = r\cdot(x_0, y_0) + (1 - r)\cdot(a_i, b_i)$. For example, with four vertices, $r = 1/3$, and (a_2, b_2) is the first randomly selected vertex, we obtain:



(If $r = 1$, the point (x_1, y_1) is the same as the initial point (x_0, y_0); if $r = 0$, the point (x_1, y_1) is the same as selected vertex (a_i, b_i).) Now pick another vertex, (a_j, b_j), randomly. The point (x_2, y_2) is given by:

$$(x_2, x_2) = r\cdot(x_1, y_1) + (1 - r)\cdot(a_j, b_j) \qquad (4)$$

and so on.

The Chaos Game Plot is the sequence of points (x_0, y_0), (x_1, y_1) ... generated this way.

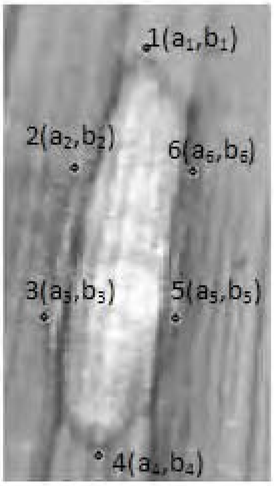
Same idea is used in the paper such that using game theory, the fractal image for the disease patterns are reproduced for evaluation with other patterns which would identify the specific disease. Since the patterns for the diseased leaves are fractals, fractal dimension alone cannot isolate it specifically. A new fractal is replicated and new parameters can be acquired.

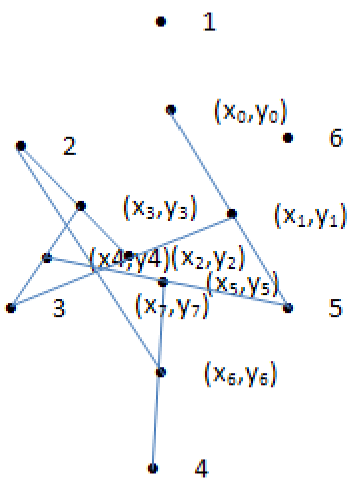
Six vertices were identified in the diseased leaf pattern, (a_1, b_1), (a_2, b_2) …. (a_6, b_6), showing a hexagonal shape. The scaling factor r is set to ½. An

accidental point (x_0,y_0) is picked from the area. Vertices are arbitrarily selected, using a random generator from 1 to 6 and the following is the generated parameters:

Random vertices generated

Vertices	Generated points
5	(x_1,y_1)
3	(x_2,y_2)
2	(x_3,y_3)
3	(x_4,y_4)
5	(x_5,y_5)
4	(x_6,y_6)
2	(x_7,y_7)





Sample seven points generated to produce the fractal using Chaos Game

V. CONCLUSION

The study surveyed the most effective techniques to extract new knowledge and information from existing image processed and extracted data confined with numerous other parameters to return a dynamic solution.

More than a few data and image mining coupled with chaos and fractal dimension technique discussed here can be used to detect the rice leaf disease. It has sound theoretical foundations, involves only a dozen examples for training, and is unaffected to the number of dimensions. It can be said that efficient training methods can be developed using the above said technique.

In this paper, the authors have surveyed a few important research challenges in chaos and fractal dimension in image processing for the detection of rice leaf diseases. The fractal for the leaf pattern of the diseased leaf at the final stage will have the same pattern during the initial stage for every kind of rice leaf disease because of self-similarity. Therefore, the recreation of the fractal would enable the early identification of the disease. The processes done through fractal dimension and chaos theory to recreate the fractal from the blast disease affected leaf patterns to be done the same way to other types of leaf diseases. In this way, there is identification for every type of disease that has been studied. The recommended methods and findings can also be of much interest and gives scope for a future research in the field of chaos and fractal dimension in image processing for other applications and fields.

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