Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.777066

# ANALYSIS FRACTAL MODEL FOR TONGUE DIAGNOSIS

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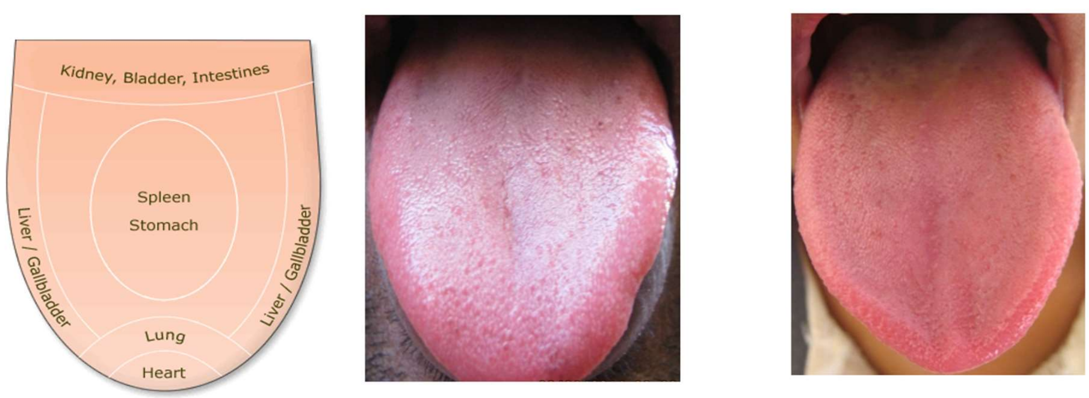
## ABSTRACT
Diagnosis of tongue diseases using fractal concept is the central theme of experimental and theoretical investigation. The variation of intensity and texture complexity of tongue including patches on the tongue are calculated by fractal dimension methods. Box Counting Method and radial distance measure are employed in identifying the shape of the tongue. Conventional Box Counting Method is compared with Sobel improved Box Counting Method. Lacunarity is used to analyze the texture of tongue. Analysis of the shape of tongue and evaluation of its dimension using Mathematical techniques saves time and increases the quality of diagnosis.
Keywords: Fractals, Tongue Diagnosis, Percolation Model, Lacunarity.

## I. INTRODUCTION
### 1.1 FRACTALS
The concept of fractals is gaining popularity due to its omnipresent nature. Almost anything and everything can be interpreted using fractals. It also gives an in depth study about any phenomena. The most erratic, unpredictable phenomenon these days is weather prediction. Minute variations in the atmosphere lead to great variations in weather. These are ignored or impossible by the existing techniques. Fractal efficiently models this feature. Applications of fractals are aplenty in the field of medicine. We have tried to explore this application in the context of tongue diagnosis. Tongue diagnosis is an interesting subject worth reading. Diagnosis and treatment of diseases through direct human observation in various forms such as pulse diagnosis, tongue diagnosis is efficient and cost effective. At times these prove to be an astrological tool, which tells the past, present and future of an individual's health. Efforts have been taken to present this paper in a step by step manner to browse through the concept of fractals, its applications in medicine, various diagnostic measures, current research in tongue diagnosis and our contribution in this fabulous field. Fractals exhibit some similarity. Most fractals are self- similar i.e., the magnification of any part resembles the original object in a specific manner. Fractals are everywhere, as in the words of Michael F. Barnsely.Fractal geometry developed in the last twenty years and is one of the most scintillating and useful scientific discoveries of the century, owing its credit to Benoit.B.Mandelbrot. Fractals are those beyond the comprehension of Euclidean geometry. They are irregular. The length of a table or class room is a one-dimensional quantity which can be measured by a ruler, as they have a regular shape. The dimension is an integer. This is called topological dimension. Border line

of any country, boundary of cloud or edge of a mountain does not have a definite shape. It is irregular and cannot be comprehended by the classical Euclidean geometry i.e., it is not possible to designate an integer as dimension. Those dimensions which lie in-between the topological dimensions say in-between 2 and 3 are called fractal dimensions. These and much more are dealt well by fractal geometry.

**1.2 TONGUE DIAGNOSIS**

Diagnosis is the process of identifying a disease through some evaluation procedure. There are various procedures. The cause for a particular symptom may be analyzed from various angles, which is generally termed differential diagnosis. Other diagnostic systems include radiology diagnosis, principal diagnosis, remote diagnosis, waste basket diagnosis, pulse diagnosis, tongue diagnosis. The tongue is a soft sturdy organ on the floor of the mouth. It is composed of skeletal muscle fibers. The skeletal muscles can easily be controlled, which gives the tongue its mobility. It is one of the most important peripheral sense organs. The tongue is basically "U" shaped and is slightly pinkish in color. Ridges and colored spots are seen migrating over the surface of the tongue, a harmless condition generally referred to as geographic tongue. The interesting fact about tongue is that it is the best indicator of various diseases in the body. This is the reason for prevalence of tongue diagnosis in almost all forms of nature cure. The epithelial layer in the mouth is replaced every two to three days, promptly reflecting an individual's health. Thrush, the big tongue, white tongues are some of the common indications on the tongue. In Chinese medicine, tongue plays a vital role in identifying the disease. Tongue features aren't the same for all. The symptoms on the surface of the tongue will clearly indicate the root cause. Various parts of the tongue correspond to different organs [Fig.1], which means that if lung is affected the corresponding area in the tongue shows an abnormality. The existing procedure is visual examination. Though it reveals diseases it does have its drawback. Firstly, natural light alone provides a good environment for tongue examination, which may not always be possible. Secondly the observation and hence the inference may vary from individual to individual. To err is human. These setbacks call for qualitative and quantitative enhancements to enliven the traditional tongue diagnosis.




(a) (b) (c)

Fig.1 (a) Reflex Zones of Tongue. (b) Actual tongue 1. (c) Actual tongue 2.

Bo Pang et al have investigated Bayesian networks to model the relation between chromatic and textural metrics of tongue. These metrics are computed from true color tongue images by using appropriate techniques of image processing [11]. Jia Wu et al have proposed a unique segmentation method based on the combination of the watershed transform and active contour model (ACM). The watershed transform is used to get the initial contour, and an active contour model, or "snakes", is used to converge to the precise edge [12]. Liu Zhi et al have used hyper spectral medical tongue images with support vector machines [13]. Image processing techniques have been applied in all these papers. In addition to image processing, we analyze tongue diagnosis by Mathematical techniques. Dimension analysis highlights and focuses the dominant features. This can effectively be done using a newly emerging, yet powerful Mathematical tool; the fractal analysis. Mathematical modeling is an efficient tool in quantitative analysis. Based on the Mathematics involved in a real world scenario an appropriate model is constructed using differential equations or probability theory or game theory or more. This model is evaluated through various processes. Results are then interpreted back in the language of the real world. Fractal analysis is a newly emerging and powerful branch of mathematical modeling, which deals greatly with irregularities.This paper analyses the shape of the tongue, and the spread of patches initially using box counting dimension and radial distance method. Lacunarity, the study about gaps or holes has been employed to describe the texture of fractal (in our case, the tongue).To enhance the results we have detected the edges of the tongue and patches using Sobel Edge Detection and then applied Box Counting Method. A comparison to conventional box counting is presented. Once a particular area of the tongue is affected, there are chances that neighboring areas also get affected. In this context, percolation method has been studied. An application of Rolle's theorem has been visualized in the form of tongue.

## II METHODS

Physical features vary from individual to individual. In this line the features of tongue are also not the same. It has complex characteristics, exhibiting irregularities depending upon a person's health. These irregularities guide us to employ fractal theory in tongue diagnosis. We use Box Counting Method both by MATLAB and HarFA softwares. This we refer to as Conventional Box Counting Method (CBCM). We also detect the edges using Sobel Edge Detector in HarFA and then apply Box Counting Method. Radial distance measures, gap analysis, Percolation Model, Rolle's Theorem, a special case of Mean Value Theorem have also been studied.

### 2.1 ESTIMATION OF MINKOWSKI'S DIMENSION OR BOX COUNTING DIMENSION

Box Counting Dimension or just Box Dimension is a commonly used fractal dimension. It is also called Minkowski's Dimension, which is the slope of log- log plot. Consider a non-empty bounded subset T of the Euclidean space Rn. Cover T by boxes, usually squares of size say δ. Let Nδ(T) be the smallest number of boxes required to cover the subset T. By varying δ we get different values of Nδ(T). The logarithmic values of Nδ(T) is plotted against the logarithmic value of 1/ δ. The lower and upper box dimensions of the set T is then given as

$$\underline{\dim}_B T = \lim_{\delta \to 0} \frac{\log N_\delta(T)}{-\log \delta} \tag{1}$$

$$\overline{\dim}_B T = \overline{\lim_{\delta \to 0}} \frac{\log N_\delta(T)}{-\log \delta} \tag{2}$$

respectively. When the upper and the lower values coincide i.e., $\overline{\dim}_B T = \underline{\dim}_B T$ it is called the box dimension denoted by $\dim_B T$ and is given as

$$\dim_B T = \lim_{\delta \to 0} \frac{\log N_\delta(T)}{-\log \delta} \tag{3}$$

The method of least squares linear regression is employed here [14]. This procedure is presented in the form of an algorithm.

**Algorithm 1**

**Step 1:** Divide the image into regular meshes of size δ.

**Step 2:** The number of square boxes that intersect the image is calculated and is denoted by $N_\delta(T)$.

**Step 3:** $N_\delta(T)$ is purely dependent on the choice of δ.

**Step 4:** For varying δ , find $N_\delta(T)$.

**Step 5:** Plot $(\log(1/\delta), \log N_\delta(T))$ and find the slope. This slope is the dimension D.

Straight line is fitted to the plotted points by

$$\log N_\delta(T) = \log C + D \log(1/\delta), \tag{4}$$

where C is a constant and D is the slope which indicates the fractal dimension, the degree of complexity. This algorithm has been applied to the tongue images [Fig.2] of few patients and the corresponding dimension has been evaluated using MATLAB.

**2.2 SAUSAGE METHOD**

Infections on the tongue have an impact on its shape. The boundary would not be a perfect U shape. It might have bumps of various sizes or even cracks. So evaluation of perimeter is needed. For this purpose Sausage method is used, which estimates the boundary using the parametric equation

$$P = \int \sqrt{x^2(t) + y^2(t)}\, dt \tag{5}$$

This method is also known as boundary dilation method. The images were dilated with circles of increasing diameter. The circles are best approximated with pixels of sizes 1 x 1, 3 x 3, ….. 17 x 17. Correspondingly, the approximate radius in pixels was calculated by

$$r = (A/\pi)^{1/2}, \tag{6}$$

where A denotes the area in pixel. The slope of the regression line $k_S$ of the double logarithmic plot of the counted pixels with respect to the radii give

$$D_S = 2 - k_S, \tag{7}$$

which is called the fractal capacity dimension. The diameter of the tongue can thus be calculated. Sausage method also helps to evaluate quantitative parameter such as Area, Perimeter, Form Factor, and Invaslog.

$$\text{Form Factor} = 4\,\pi\,\text{Area} / \text{Perimeter}^2 \tag{8}$$

$$\text{Invaslog} = -\log(\text{Form Factor}) \tag{9}$$

Computation of Invaslog helps in analyzing the invasions of disease on the surface of the tongue. Radial distance, the distance from the centre of mass to the perimeter point $(x_i,y_i)$ is defined as

$$d(i) = \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2} \tag{10}$$

d(i) is a vector obtained by the distance measure of the boundary pixels.

## 2.3 BOUNDARY DESCRIPTORS

For irregularly shaped object, the boundary direction is the best representation. Consecutive points on the boundary of a shape give relative position or direction. A four or eight-connected chain code is used to represent the boundary of an object by a connected sequence of line segments. Eight-connected number schemes are used to represent the direction in this case. Each direction provides a compact representation of all the information in a boundary. The direction also shows the slope of the boundary. Compactness is a dimensionless quantity which defined as $\frac{Perimeter^2}{Area}$. We can find Roundness from this by Roundness = Compactness/4π , which is minimal for an irregularly shaped region. It is a simple measure and used to find the invasiveness of the patches. It is used as region descriptors including the mean and median of binary levels, the minimum and maximum binary level values and the number of pixels with values above and below the mean. It is a simple region descriptor such as normalized area can be quite useful in extracting information from images. The pathological cells in the tissue can refined by normalizing it with respect to population numbers, land mass per region and so on. From the compactness we can find the region of interest is invariant and also find the shape of the irregular border.

## III MATHEMATICAL MODELING OF TONGUE

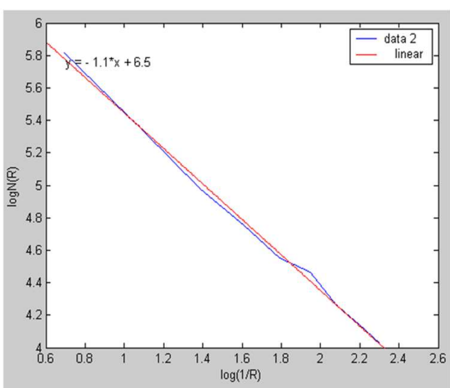
The human tongue is approximately 4 inches in length(10 cm), from the oropharynx to the tip. The surface of the tongue is not uniform, be it the color or texture. Also there may be at least one point which is not affected. It is also possible that two or more points may have same texture or pigmentation. These conditions remind us of Rolle'sthorem, a special case of Mean Value Theorem. " Let f be a real valued function that satisfies the three conditions : f is defined and continuous on the closed interval [a, b]; f is differentiable on the open interval (a, b); f(a) = f (b). Then there exists atleast one point c ∈ (a,b) such that f ′(c) = 0. Tongue is real. Length of tongue is 10 cm; i.e., it lies between [0,10]. Tongue surface is not uniform in (0,10). There may be two points on the surface of the tongue that are similar. The point which s not infected is a constant, whose differentiation is 0. The final statement of the theorem links Percolation Model, where the non-infected sites are marked '0'.

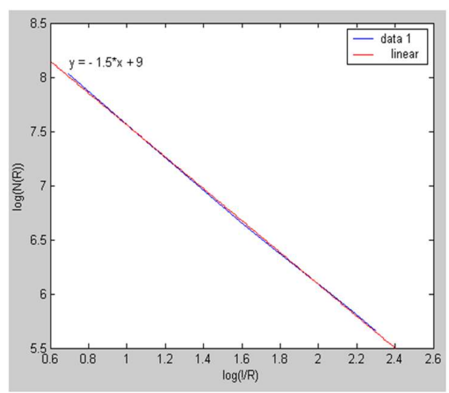
## IV RESULTS AND DISCUSSION

Fractal Dimension analysis has been applied to demarcate the infected tongue from normal one and also the intensity. We have used the Box Counting Method to analyze tongue disease. We found that a significantly higher architecture complexity was noted for normal and infected tongue. The dimension increases as the patches increase on the tongue. For CBCM, (Table 1), we see that the normal tongue shows a lower dimension of 1.1, whereas the infected tongues show higher dimension.

**Table 1 Data Analysis of Tongue Images Using Conventional Box Counting Method(CBCM)**

| Image | Scaling | | | | | | | | | DB |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| I | 336 | 207 | 145 | 116 | 95 | 87 | 71 | 63 | 56 | 1.1 |
| II | 3081 | 1645 | 1073 | 765 | 589 | 476 | 394 | 334 | 285 | 1.5 |
| III | 2673 | 1372 | 827 | 568 | 422 | 320 | 255 | 215 | 183 | 1.7 |
| IV | 3357 | 1724 | 1092 | 765 | 573 | 443 | 349 | 289 | 262 | 1.6 |
| V | 3106 | 1584 | 1000 | 702 | 530 | 418 | 356 | 293 | 257 | 1.5 |
| VI | 2331 | 1187 | 749 | 526 | 393 | 310 | 251 | 211 | 176 | 1.6 |
| VII | 308 | 179 | 122 | 102 | 83 | 70 | 54 | 44 | 46 | 1.2 |
| VIII | 1541 | 784 | 493 | 345 | 259 | 203 | 171 | 147 | 122 | 1.6 |
| IX | 1996 | 1000 | 642 | 435 | 325 | 262 | 217 | 182 | 148 | 1.6 |
| X | 2321 | 1179 | 727 | 509 | 371 | 284 | 232 | 194 | 166 | 1.6 |



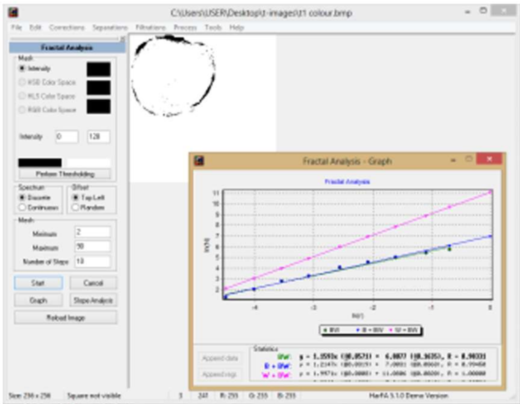

**Graphical Representation of Tongue Images- CBCM**

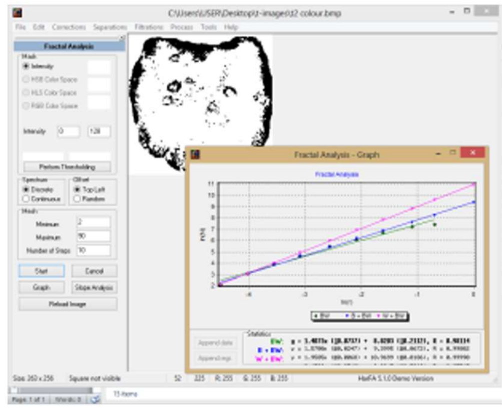
**Graphical Representation of CBCM Using HarFA**

**Table 2- HarFA Fractal Analysis of Tongue (CBCM)**

| Image | Discrete | | | Continuous | | |
|---|---|---|---|---|---|---|
| | BW | B+BW | W+BW | BW | B+BW | W+BW |
| I | 0.8847 | 1.1278 | 1.9933 | 0.8424 | 1.1619 | 1.994 |
| II | 1.0171 | 1.5049 | 1.9222 | 1.1029 | 1.5159 | 1.9268 |
| III | 1.0378 | 1.7443 | 1.9633 | 0.9807 | 1.7121 | 1.9674 |

| | | | | | | |
|---|---|---|---|---|---|---|
| IV | 1.1529 | 1.6991 | 1.9163 | 1.1081 | 1.6889 | 1.9167 |
| V | 0.8661 | 1.5976 | 1.9466 | 0.8217 | 1.5821 | 1.9474 |
| VI | 0.916 | 1.7222 | 1.9213 | 0.9295 | 1.7241 | 1.9245 |
| VII | 0.9311 | 1.3868 | 1.9916 | 0.8951 | 1.3659 | 1.9947 |
| VIII | 0.9729 | 1.6147 | 1.9675 | 1.0294 | 1.6352 | 1.9704 |
| IX | 0.9101 | 1.713 | 1.9412 | 0.8857 | 1.7224 | 1.9437 |
| X | 1.1025 | 1.6072 | 1.9507 | 1.0487 | 1.622 | 1.9528 |





**Graphical Representation of CBCM Using HarFA**

The Sausage method helps in finding the area and hence the radius. The slope of the regression line of the double linear logarithmic plot of the counted pixels versus radius gives ks. From this the Dimension is found as 1.6 and 1.4 (Table 3), which is very much in agreement with the Box Counting Dimension.

**Table 3 Sausage Method**

| Scaling | Area | Radius | ks | Ds = 2-ks | Area | Radius | ks | Ds = 2-ks |
|---|---|---|---|---|---|---|---|---|
| 3 | 792 | 15.874508 | 0.4 | 1.6 | 850 | 16.445502 | 0.6 | 1.4 |
| 5 | 238 | 8.7021418 | | | 226 | 8.4799228 | | |
| 7 | 96 | 5.5267942 | | | 101 | 5.6688944 | | |
| 9 | 49 | 3.9485325 | | | 48 | 3.9080337 | | |
| 11 | 31 | 3.1406427 | | | 17 | 2.3257452 | | |
| 13 | 17 | 2.3257452 | | | 16 | 2.2563043 | | |
| 15 | 8 | 1.5954481 | | | 5 | 1.2613124 | | |
| 17 | 5 | 1.2613124 | | | 3 | 0.9770084 | | |

## V CONCLUSION

Box Counting Method has been used to analyze the diseases on the tongue and hence the diseases in the body. This has been done using MATLAB. This we have termed as Conventional Box Counting Method (CBCM). The patches on the tongue varies for normal and abnormal tongue, which has been analysed with HarFA, Fractal Analysis software. The dimension shows the intensity of the disease. Lacunarity asseses the texture pattern of the tongue i.e., the size and distribution of the empty domain. From these methods the intensity of the disease can be found. The higher the dimension the higher the intensity of the disease. Tongue with more dark patches show higher dimension. The fractal dimension DB is likely to be the most promising tool for the effectiveness of therapies in various clinical contexts. It will be very helpful for the doctors in diagnosing the disease and hence the appropriate treatment.

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