Fractal Technology Based Image Processing in Botany and Biology

Istvan Sztojanov, Vasilică Voinea, Daniela Crisan and Cătălina Popescu-Mina

Abstract - **The paper discusses problems of classification in botany and biology based on the fractal theory. A quantitative evaluation of fractals and an algorithm for fractal dimension computation based on biofractal contours processing is also presented. Two applications are described: the first in botany for classification of species from the Gentianacaeae family and the second one use the same procedures in order to classify mammary tumors.**

Key words - **fractals, fractal dimension**

INTRODUCTION

The state of the art of classification based on the fractal analysis with applications in botany and biology will be presented. Fractal features describe closely the properties of natural forms. For this reason, the interest in this new mathematical field, fractal geometry, grows quickly. New techniques of fractal analysis are developed and these techniques prove their utility in real systems in various fields.

Fractals are objects with irregular, auto-similar features, with details that can be noticed at any scale of representation. Biofractals are the fractal textures/contours in biology (tissues, neurons, leaves, etc.). The similarity between fractals and the natural objects suggests that fractal properties, such as fractal dimension, may be used as a classifier in biology.

II. FRACTAL DIMENSION

With the apparition of fractals, the characterization of a form using its topological dimension proves its insufficiencies. That is why the notion – fractal dimension Df was introduced.

The German mathematician Felix Hausdorff defines a new concept for the topological spaces, this way suggesting that the fractal dimension is proportional with the minimum number of spheres, of a give radius, needed for covering the measured object. To facilitate the computer work, the coverage is made with cubes instead of spheres.

I. Sztojanov is with the Department of Applied Electronics and Information Engineering, Faculty of Electronic Engineering, Telecommunications and Information Technologies, University POLITEHNICA from Bucharest, Spl. Independentei 313, Sector 6, 060042 Bucharest, Romania, e-mail: szistvan@colel.pub.ro
V. Voinea is with the Department of Computer Sciences, University POLITEHNICA from Bucharest, Spl. Independentei 313, Sector 6, 060042 Bucharest, e-mail: v_voinea@yahoo.com
D. Crisan is with the Department of Computer Sciences, University POLITEHNICA from Bucharest, Spl. Independentei 313, Sector 6, 060042 Bucharest, e-mail: dacrisan@yahoo.com
C. Popescu is with the Department of Computer Sciences, University POLITEHNICA from Bucharest, Spl. Independentei 313, Sector 6, 060042 Bucharest, e-mail: popescu_upb@yahoo.com

In the specialized literature, there are many attempts to evaluate the fractal dimension. The algorithm based on the „box-counting” method offers two major advantages: it is easy to implement in case of using a computer and can be applied for images no matter how complex.

The ”box-counting” fractal dimension, derived from the Hausdorff coverage dimension is given by the following approximation:

$$D \approx \frac{\log(N(s))}{\log(1/s)} \quad (1)$$

Since the expression:

$$\log(N(s)) = D \cdot \log\left(\frac{1}{s}\right) \quad (2)$$

is the equation of a straight line of slope D. The ”log-log” curve described by the points of (log (N(s), log (1/s)) coordinates is plotted and through least squares method the slope of the line that approximates the points’ distribution is determined; this is the wanted fractal dimension.

For an example of how the algorithm is used, consider the image of a leaf (fig. 1.a) from which a binary version will be extracted by neglecting all the pixels under a certain luminosity (fig. 1.b). The contour of the binary image is then traced (fig. 1.c).

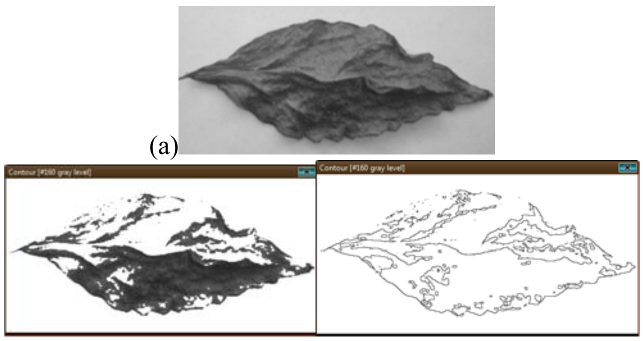

(a) (b) (c)

Fig. 1. (a) The initial image; (b) A binary (black-white) version of (a); (c) The image’s contour

Next, the “box-counting” algorithm described above will be applied, for different scale values s.

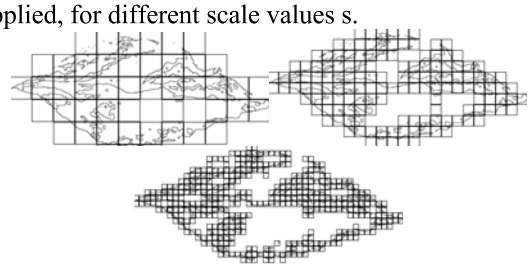


Fig. 2. Object coverage with squares of different side values “s”

The values table and "log-log" curve will be obtained:

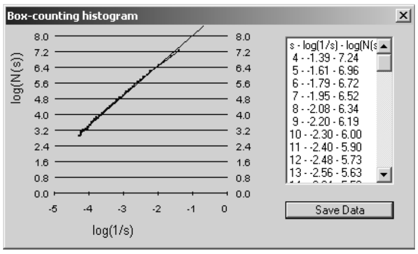


Fig. 3. The log-log curve and the s, log (1/s), log (N(s)) values.

Using the least squares method for the pairs of points (log (N(s)), log (1/s)), the regression line with the slope 1.52 is determined. The fractal dimension for the studied leaf is 1.52.

Forms of nature, as Fig. 1a, are not binary files, and choosing a single threshold over which the image is binarized may lead to irrelevant results. Therefore, a method that provides an overview of the evolution of box-counting dimension in relation to the grey-level threshold used for binarization is required.

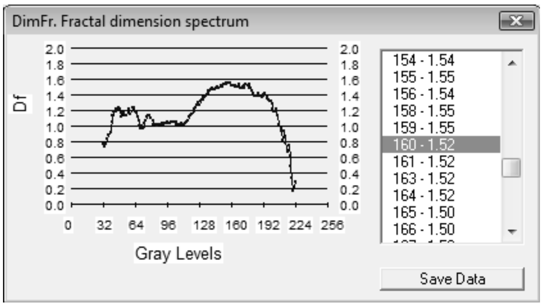


Fig. 4. The fractal spectrum of a leaf image

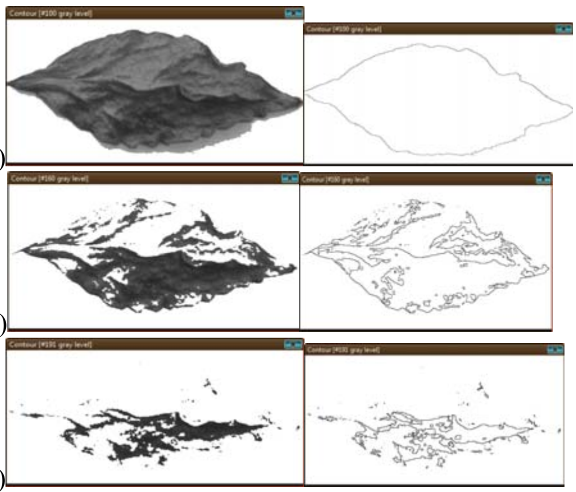
(a)
(b)
(c)


Fig. 5. The leaf image is binarized using three different thresholds, then the contour is traced; (a) 100 grey-level: Df (100) =1.05, (b) 160 grey-level: Df (160) =1.52, (c) 190 grey-level: Df (190) =1.37.

For this reason, an extension of the box-counting algorithm shown above will be proposed; the technique will provide a spectrum of fractal dimensions as follows:

- the original (true-color) image is read and converted into a 256 grey-levels image using the transformation of the RGB space:

$$I=0.299R+0.587G+0.114B$$

Where R/G/B are the red/green/blue components which defines the color of every pixel.

- the box-counting algorithm will be applied on each binary image and the obtained fractal dimensions will be graphical represented in relation to the grey-level threshold.

The fractal spectrum offers a complete image about the evolution of the form's complexity related to the different details inside the image. Choosing the threshold is a facility meant to help the analyst in selecting the most significant detail for further processing. The method was successfully used in botany and medical imaging, for mammography lesions classification.

III. Fractal Analysis in Botany

For establishing the independent position of the Gentianopsis genus, respective Gentianella ciliata for Gentiana genus, we have fractal analyzed the species Gentiana lutea and Gentianella ciliata. Taking into account that the fractal technique is used as premiere work in this field of botanic, for verifying its "sensibility", we have compared the fractal dimensions of the 2 taxons from Gentianaceae with one from Ranunculus genus from Ranunculaceae family.

The analyzed material was acquired from the transversal section made through the root, stem and leaf of the mentioned taxons.

TABLE 1. Comparative Table of the Obtained Data

D_f	Root		Stem		Leaf	
	rind	central cylinder	rind	central cylinder	meso-phyll	vascular bundle
Ranunculus repens	1,55	1,60	1,52	1,57	1,53	1,58
Gentiana lutea	1,62	1,80	1,63	1,75	1,55	1,69
Gentianella cilliata (Gentianopsis)	1,65	1,86	1.62	1,78	1,58	1,77

The microscopical images of the extracted samples were analyzed using fractal techniques based on the "box-counting" algorithm in order to use other criteria then the morphological ones for establishing the position of the Gentiana, Gentianella and Gentianopsis genera in the Gentianaceae family. Concretely, there were extracted window-images from the rind and the central cylinder of the root and stem and also from the mesophyll and nervure/rib of the leaf. The contours of the window-images were processed with the "box-counting" algorithm in order to establish the fractal dimensions for the analyzed sections.

The obtained results are presented in the Table 1.

From the above table the different position of Gentianela ciliata (Gentianopsis) can be observed.

All the experimental results are presented in [3] therefore we shall give only as an example the determined fractal dimensions for leaf mesophyll of Gentianella cilliata (Gentianopsis) in Fig. 6.

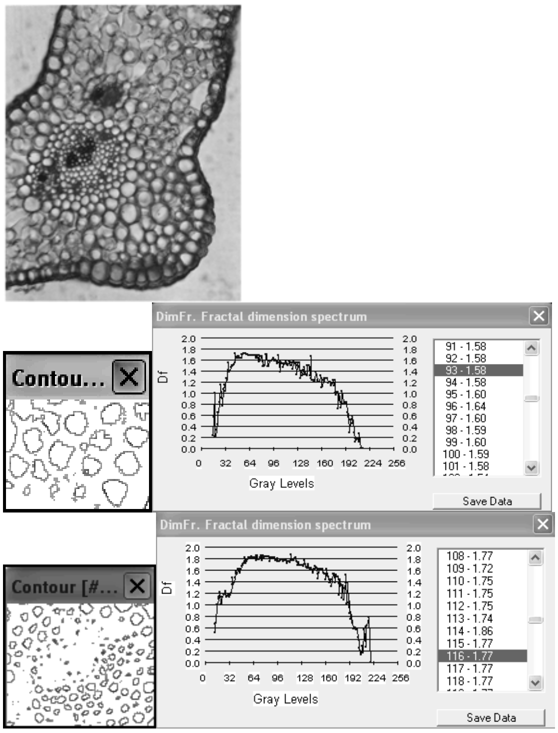


Fig. 6. Fractal dimensions for leaf, in the mesophyll and vascular bundle for Gentianella cilliata (Gentianopsis).

IV. Fractal Analyses in Medicine

Breast cancer is the most common women disease in modern world; statistics shows that a woman's lifetime risk of developing breast cancer is 1/8. Mammography is the most efficient tool for detection and diagnosis of breast lesions. In the last decades, medical exams became a regular act; thus, the amount of mammograms interpreted by a radiologist increase dramatically. As a result, a focused effort initiated two decades ago, is under way to develop a Computer-Aided Diagnosis of Mammograms (CADM).

One of the most important components in a CADM is to classify the lesion. The similarity between the breast tissue and synthetically generated fractals suggests that fractal properties, such as fractal dimension, may be used as a classifier

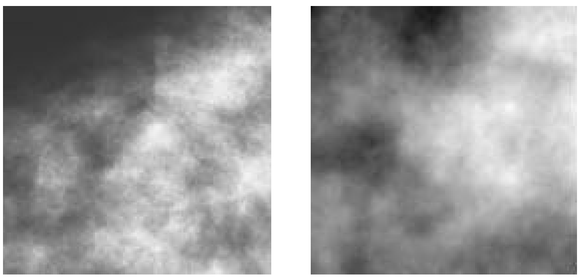


Fig.7 The similarity between the breast tissue (a) and synthetically generated fractals (b)

Fractal dimension measures the complexity of an object; it grows as the shape is more irregular. This observation will be very useful in order to characterize mammography lesions. When categories a mammography anomaly, the radiologist has to observe several properties of the lesion and one of the most important features is the contour's shape: a regular contour is associated to a benign case, while an irregular shape characterizes a malign lesion. The fractal dimension grows with the irregularity of the shape; this could be an essential observation in order to classify the lesions, with no need of further investigations or biopsy. The lesions with a regular contour are more probably benign, while the lesions with an irregular contour are more probably malign.

Each mammogram was analyzed following the steps:

Step 1 - the radiologist traces a FAR (Focused Attention Region), using a mobile cursor. The size area can be 64X64, 128X128, 256X256 or 512X512. The selection must contain the anomaly and it is based on radiologist's experience.

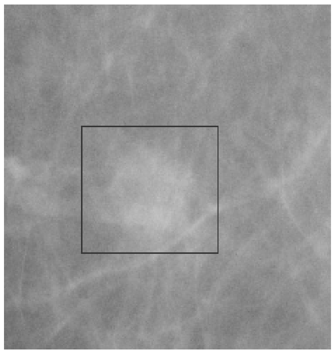


Fig. 8. A FAR traced by the radiologist.

Step 2 - the image is binarized using a threshold between 1-255 gray levels: all pixels whose gray level is greater or equal to the threshold will be transformed in white, the rest will become black. At this point, the forms inside the image are white on a black background.

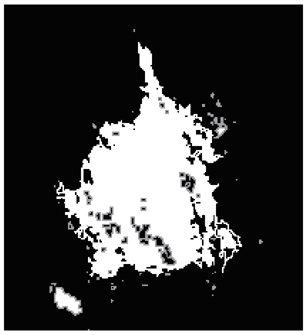


Fig. 9. The FAR is binarized; the white pixels are part of the form on a black background

Step 3 - the contour is automatically traced: once the image is binarized, the next step is to trace an outline of the white areas: all the white pixels which have at least one neighbor black will become part of the contour (every pixel has 8 neighbors: N, NE, E, SE, S, SV, V, NV). The rest of pixels will be transformed in black.

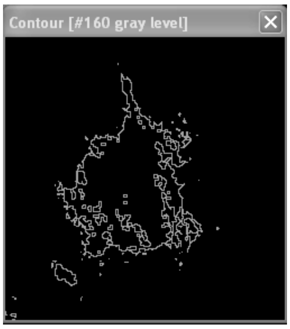


Fig. 10. The contour is traced - an outline of the white areas.

Step 4 - the fractal dimension of the outline will be computed using the box-counting algorithm. The result will be 1.36.

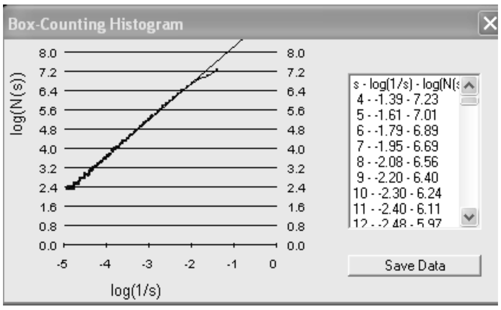


Fig. 11. The box-counting algorithm will provide 1.36-fractal dimension

The results of 30 cases of classified lesions are as follows: the benign lesions have lower fractal dimension, between 1-1.50, while malign lesion have higher dimension, from 1.35 to 2.

V. CONCLUSIONS

In conclusion, the presented application, from botany is dedicated to analyzing the particularities of some species from Gentianaceae family, with the purpose of establishing their affiliation to the Gentina genus. To achieve this goal we have fractally analyzed microscopical images from species Gentiana lutea, Gentianella ciliata and Ranunculus repens.

The different positions of Gentianela ciliata (Gentianopsis) and Ranunculus repens can be observed. From our provisional observations it results that, from fractal dimensions point of view, the separation of the Gentiana and Gentianopsis genera is justified.

The presented application, from biomedicine, involves non-invasive techniques based on processing mammography images. The method allows diagnosing mammography tumors and it is based on two observations: The hypothesis that cancers have higher fractal dimensions than benign lesions was tested on 30 cases and the results are encouraging.

REFERENCES

[1] Anchisi A., A. Berlini, N. Cartasegna, F. Polani , "Genziane d'Europa", Oltrepo'Pavese, 2000

[2] Andrei M. "Morfologia Generală a Plantelor", Editura Enciclopedică , Bucureşti, 1997

[3] Sztojanov I., Voinea V., Popescu C., "Image Processing for Classification in Biology Systems", IEEE-SOFA 2007, 2nd International Workshop on Soft Computing Applications, 21-23 August, Gyula-Hungary, Oradea-Romania, Proceedings, pp.33 – 38.

[4] Rusu M., "Image processing. Fractal Analysis", workshop IAFA, Bucharest, 2003-2005

[5] *** Breast Imaging Reporting Data System - http://www.birads.at