

Improved Melanoma Diagnosis Support System Based on Fractal Analysis of Images

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Abstract Computational intelligence is finding more and more applications in computer aided diagnostics, helping doctors to give the right decisions. In dermatology it is extremely difficult to perform automatic diagnostic differentiation of malignant melanoma basing only on dermatoscopic images. In the introduction we describe the probabilistic approach to decision making. One has to bear in mind that wrong decision in the case of a melanoma patient [9] carries very high probability of death of the patient. Fractal analysis can greatly enhance the diagnostic process for doctors and even bring tools for automatic diagnostic. This paper presents fractal analysis comparison of different skin lesions. We begin with an explanation of the concepts used. Next we present a practical approach of using fractal methods in skin lesion analysis. At the end results and comparison of skin lesions analysis are given.

Keywords Melanoma; Skin Lesion; Fractal Analysis

1 Introduction

Skin cancer is reaching 20% increase of diagnosed cases every year. Dermatoscopy is commonly used method for skin lesion diagnosis. This method is non-invasive and requires a great deal of experience to make correct diagnosis. To describe the performance of the diagnostic process specificity and sensitivity indexes can be calculated:

$$Sensitivity = \frac{TruePositive}{FalseNegative + TruePositive} \quad (1)$$

$$Specificity = \frac{TrueNegative}{TrueNegative + FalsePositive} \quad (2)$$

True Positive and *False Negative* parameters means a good diagnosis. The problem is when a doctor diagnose a lesion as not malignant when the lesion is actually malignant. It is described above as False To understand this better, parameters used in both above equations are described as follows:

Table 2 helps to imagine how important the problem is. In an optimistic scenario 10% of diagnosed melanoma lesions are diagnosed as healthy. In the worst case it is

about 38% of diagnosed melanoma lesions. Accuracy at this level is caused of diagnosis problems in the early stages of melanoma. It is very difficult to diagnose a malignant lesion in early stage, because it does not exhibit melanoma's characteristics. In general it is better to diagnose an actually healthy lesion as malignant rather than a malignant lesion as healthy. This should also be done very rarely. Both solutions does not satisfy anyone. That is why doctors improve their methods, so each additional parameter that makes the diagnosis accuracy greater is very helpful. Only experts have a 90% sensitivity and 59% specificity in skin lesion diagnosis (Table 1). Otherwise, for less experiences personnel specificity and sensitivity are much lower.

Doctors so far have a few diagnosis methods. In all these methods some mathematical factors characterising the lesion are calculated manually. Most known and used method Is called ABCD [12]. It is calculated by recognizing four features of the dermoscopic image: asymmetry, border, color and differential structures. The result is called Total Dermoscopy Score and is calculated in following way:

$$TDS = A * 1.3 + B * 0.1 + C * 0.5 + D * 0.5 \quad (3)$$

If TDS is greater than 4.75 then lesion should be handled as suspicious. Lesion with TDS greater than 5.45 give strong indication that this lesion is cancerous. An alternative method was proposed by Menzies. Scoring is based on finding positive and negative features in lesion image. Positive features means here features that indicates that lesion is cancerous. Menzies method describes only two negative features. First is patterns symmetry which means if the whole structure of lesion or color is symmetrical. Second feature is the color count. If lesion contains only one color then lesion in this approach should be recognized as benign lesion. Menzies scoring method describes eight positive features. Most of these features base on melanoma's specific patterns like dots, veil or broadened network. Evaluating the approaches Argenziano [2] and Johr [6] made a comparisons of different methods. Several aspects of geometric analysis of skin lesions and their coloring can be done automatically and were the subject of our earlier studies [10, 11, 13, 14].

Table 1: Sensitivity and Specificity

	Actually Abnormal	Actually Normal
Diagnosed as Abnormal	True Positive (TP)	False Negative (FN)
Diagnosed as Normal	False Positive (FP)	True Negative (TN)

Table 2: Sensitivity and Specificity in Diagnosis

	Sensitivity	Specificity
Experts	90%	59%
Dermatologists	81%	60%
Trainees	85%	36%
General practitioners	62%	63%



2 Concept Of the Fractal Method

Fractal methods are commonly used in various areas of signal and image analysis. Applications of fractal analysis includes: classification of histopathology slides in medicine, fractal landscape or coastline, complexity, generation of new music, generation of various art forms, signal and image compression and many more. In general fractal methods can be divided into two groups. Fractal methods can be used for creation, like music or art. Methods can be used also for comparison purpose by using measurements methods. The most known method is fractal dimension. The simplest formula to calculate the fractal dimension is so-called box-counting dimension:

$$D = \frac{\log N(l)}{\log l} \quad (4)$$

which basically tells how the number of boxes needed to cover the considered geometric structure scales with the size of the boxes (magnification factor).

To show the typical properties of a fractal geometric structure let us look at the example shown in figure 1. This fractal is generated iteratively. For more iterations the fractal is more complex and many substructures resembling the whole are visible. This property is called self-similarity. One can also find a characterization in terms of dimension, using a concept different to the typical euclidean one.

Fractal analysis provides methods for measurement. Fractal methods are commonly used in medical illnesses recognition [5]. So far it was successfully used in liver [15] or brain image [1] diagnosis. It can be also used in psychiatry [7] or even skin histopathology images [8].

For comparison Figure 2 shows some of typical images obtained via video dermatoscopy which clearly display fractal properties (high irregularity and existence of self similar regions and structures).

3 Skin Lesion Box-Counting Dimension Analysis

In case of skin lesion box-counting dimension is calculated on grayscale images. So the first step of pre-processing is to convert images to grayscale. Next step is binarization of the image. This action gives as output only the lesion without the normal skin color. The skin is presented by white color. At the end a noise removing algorithm is used. These pre-processing steps performed on images makes calculation of box dimension more accurate.

In the figure 3 a clean skin lesion image is divided into boxes. Scaling between the number of boxes and their sizes are calculated to get box dimension.

Figure 2: Some of the skin-lesion images showing fractal properties

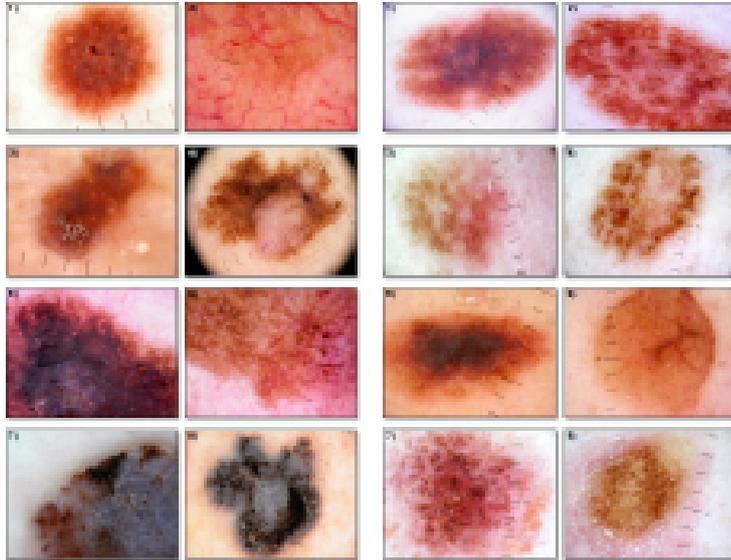
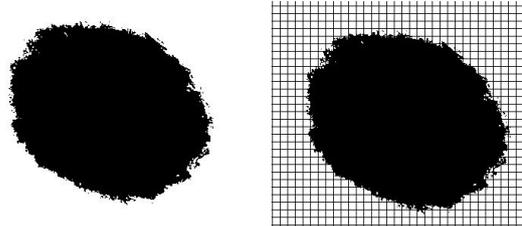


Figure 3: Fractal Analysis of Skin Lesion



4 Results

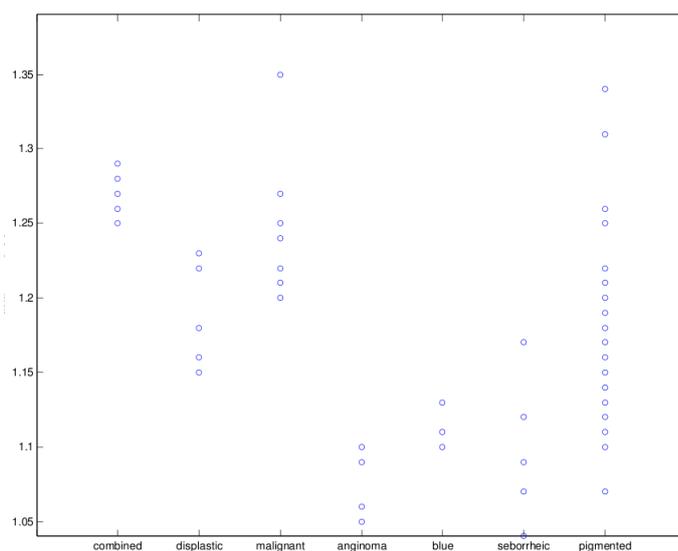
In this section we present the results for malignant melanoma lesions. Only 8 lesions in the total count of 82 images was recognized as malignant. The rest of images was recognized as healthy or as a different illness than skin cancer. All suspicious lesions were assigned to a group following the Clark and Breslow staging (Breslow thickness of the lesion is measured in mm whereas the Clarke's level describes depth relative to other skin structures). Calculated box dimension values are presented in table 3. Clark and Breslow stage values were confirmed by lesion observation or biopsy test.

Analyzing the results one can see that the Breslow and box-counting dimension values are correlated.

5 Comparison

Beyond malignant lesions in the total group are also lesions with different illnesses. In figure 4 a comparison between melanoma and 6 other detected skin lesion illnesses.

Figure 4: Fractal Dimension Comparison for different Skin Illnesses



Some skin illnesses exhibit characteristic values of box-counting dimension. For anginoma, blue and seborrheic lesions dimension values are below 1.18. The problems with melanoma diagnosis mentioned before are very well presented in figure 4. Pigmented lesions are covering almost all values, also values assigned for melanoma.

TDS values were calculated for each lesion image. It is not a surprise that almost all values are concentrated somewhere in the middle. Only 9 lesions were detected as suspicious.

Table 3: Malignant Melanoma Fractal Dimension

Breslow	Clark	Fractal Dimmension
0,25	II	1,28
0,25	IV	1,25
0,7	IV	1,24
0,8	IV	1,20
0,9	III	1,24
1,0	III	1,22
1,5	IV	1,21

Figure 5: Comparison of Box-counting Dimension and TDS

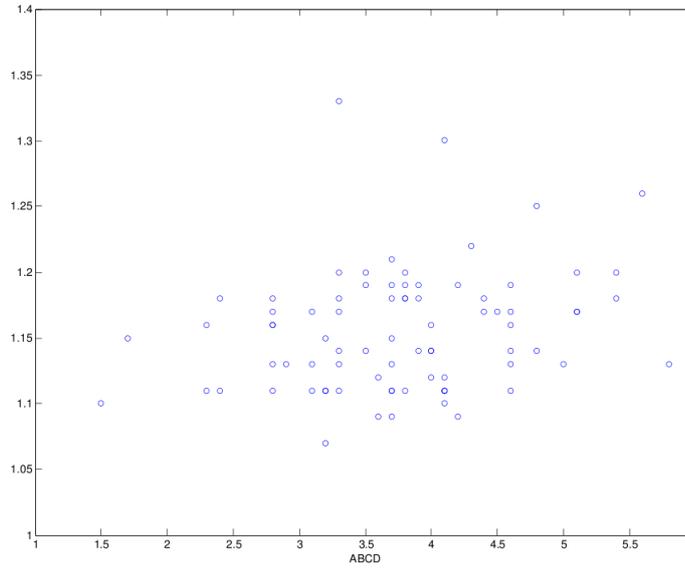
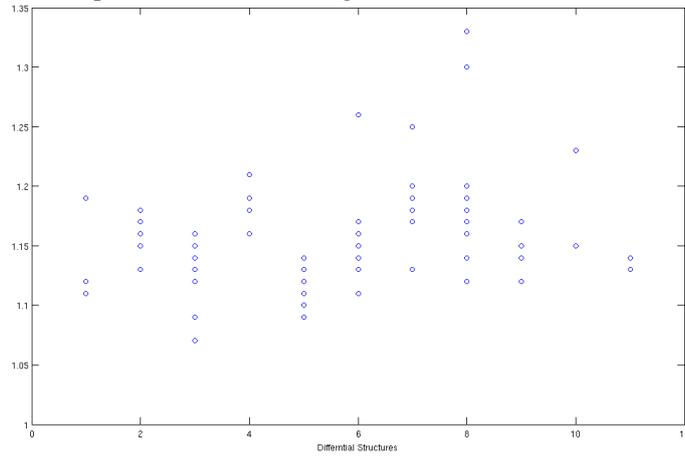


Figure 6: Comparison of Box-counting Dimension and Differential Structures



The most interesting results can be observed in figure 6. Differential structures are numbered from 1 to 11. All observed structures are listed in table 4.

Table 4: Differential Structures

	Differential Structure
1	Regular pigment network
2	Irregular pigment network
3	Homogeneous areas
4	Homogeneous areas and irregular pigment network
5	Homogeneous areas and regular pigment network
6	Regular pigment network and twig streaks
7	Irregular pigment network and twig streaks
8	Homogeneous areas and pigment dots
9	Homogeneous areas and twig streaks
10	Irregular pigment network, twig streaks and homogeneous areas
11	Pigment cells

6 Conclusions

Box-counting dimension of images of skin lesion can be one of the characteristic features in melanoma diagnosis. For some of the skin lesions show distinctively different fractal dimension values. However this characterization should not be used as a separate parameter for skin lesion diagnosis. More research needs to be done to check the efficiency of fractal methods together with other melanoma characteristics like color or assymetry.

7 Future work

Further exploration of the data could be interesting and give more precise results. We want also compare our results with results that will be given by other methods. We want also increase of lesion images count. Additionally we want to use this tool in early malignant melanoma detection algorithm in the future. This will be the goal of our future works. We want also compare current results based on dermatoscopic images and images based on SIAscope images [MC1].

Acknowledgment

This research has been supported by the Research Grants No. N518 419038 and N518 506439.

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