# Initial clinical experience using fractal methods in complex systems analysis of diagnostic images

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*Abstract* - **The report describes the application of fractal analysis in complex systems of visual diagnostics in order to expand its diagnostic capabilities by increasing the information content for intelligent decision modeling to reduce subjectivity in the perception and interpretation.**

*Keywords* - **ultrasonography, mathematical modeling, imaging fractal analysis, fractal dimension.**

## I. Background

The purpose of the study was to investigate whether mathematical algorithms can improve the information content in medical imaging, providing an objective measurement. Most objects found in nature is non-Euclidean nature. Biological systems are predominantly irregular, complex and non-linear. Irregularities of biological system cannot be quantified by means of classical Euclidean geometry approach. From data and information-guided practice we must strive to model-guided medicine for intelligent decision making in medical diagnosis and therapy to form the model-guided medicine and general model of knowledge about the patient. The term fractal was introduced in 1975 by Benoît B. Mandelbrot [1]. Fractal image analysis reported in various areas of medicine: pathology, radiology, physiology and others [2-4]. However, fractal analysis must be applied with certain caution in natural objects such as bio-medical ones.

## II. Objectives

At the size limits of the measuring element, the linear relationship is no longer maintained and a unique fractal dimension cannot be defined. The various methods of FD measurement were described: 1) modified pixel dilatation; 2) perimeter-area method; 3) ruler counting method and 4) Box counting method. Box counting method is most commonly used for detection of FD. It is a simple and reproducible way of measuring fractal dimension [6]. We proposed a method [7] of medical images analysis obtained from a wide range of sources – radiology imaging, diagnostic ultrasound, photographic information of endoscopy, surgery, dentistry, anatomy and microscopy. The values fractal parameters of these images (fractal dimension, fractal index, etc.) are calculated by "covering" the parts of these expertly segmented images by two-dimensional geometric shapes (squares, rectangles, triangles, circles, ellipses) and three-dimensional (cubes, simplices, balls, ellipsoids, pyramids) for vector and voxel three-dimensional models of different directions (for processing ultrasound, CT, MRI, photographic, endoscopic images, etc.).

FD is calculated from the basic generalized formula:

$$FD=\ln N(\delta)/\ln f(1/\delta),$$

where, FD - fractal dimension and δ – shape diameter; N - the number of identical shapes with δ -diameter necessary for covering image. f(1/δ) – formula for calculation the dimension of the elements of the set.

Fuzzy visual information may be difficult to interpret, the limits for fractal dimension calculation are close to the digital resolution of the image, or at sizes greater than one-third the maximal diameter of the object.

A B

Fig. 1. Fractal dimension calculation of C3-branches tree (A) and three-dimensional reconstruction of portal venous tree (B). Calculation FD by measurement the similar parts of portal veins.

$$Fd=\frac{\log(3)}{\log(2)}=1.5849.$$

A B

Fig. 2. Fractal dimension calculation of bladder cancer (A) and lymphosarcoma (B) using HarFA software.

## III. Conclusion

Fractal analysis of medical images is a promising direction of development the existing diagnostic methods. It becomes a highly informative indicator of pathological formations using nonlinear mathematical parameters of structure. The proposed method to determine the fractal parameters requires expert medical approach, wich is more objective than existing automated. It can be used for educational and research purposes is noninvasive, accessible and informative method and can be recommended for implementation in all areas of medicine, where the visual information is used, mostly in oncology. Fractal analysis can be a major factor in determining the prognosis of doubtful clinical conditions. According to preliminary results, the malignant formations have higher fractal dimension.

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