EXTRACTIONS OF INTRINSIC FEATURES USING THE LACUNARITY HIGHLIGHTED FROM FMRI SOURCES

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An algorithm for the fractal analysis of MRI images has been developed. This algorithm begins with box counting to determine lacunarity factor and often stops with highlighting the structure associated with Alzheimer's disease. The fractal dimension and a lacunarity visual analysis on the cerebral map generated by the EEG signal, against the background of the overlapping RMI representation has been presented.

Keywords: Electroencephalography, Magnetic Resonance Imaging, Fractal Analysis, Lacunarity, Fractal Algorithm

1. Introduction

The human brain is one of the most complex systems observed in nature, and the phenomenological simultaneity of physical, chemical and electrical interactions presents a series of problems in continuous research, starting, without question, from mapping how our brain interacts with reality. To solve this problem, multiple software / programs have been developed on the computer and thousands of visualizations of brain processes have been implemented, among which we list EEG (Electroencephalography), MRI (Magnetic Resonance Imaging) and FMRI (Functional Magnetic Resonance Imaging) brain scan [1-2].

Among other nicknames used in place of MRI (Magnetic Resonance Imaging), we can mention that the most common other names are some of the following accepted synonyms, such as nuclear magnetic resonance imaging (NMRI) and magnetic resonance tomography (MRT).

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body. MRI does not involve X-rays

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or the use of ionizing radiation, which distinguishes it from CT and PET scans [3]. MRI is a medical application of nuclear magnetic resonance (NMR) which can also be used for imaging in other NMR applications, such as NMR spectroscopy.

Historically speaking, the prime researcher who has developed a way to generate the first Magnetic Resonance Images (MRI), in 2D and 3D, using gradients, was American chemist Paul Lauterbur, in 1973. More precisely, Lauterbur described an imaging technique that removed the usual resolution limits due to the wavelength of the imaging field, laying the foundations of MRI technique [4].

The purpose of this paper is thus easy to state and refers to exploring the hypothesis of using the analysis of lacunarity in order to determine the degree of correlation with the topological structures (fractals) existing in the brain.

In order not to compare apples to pears (as funny it is expressed with concern), it is assumed that the lacunarity is a measure of the discernibility of a structure or signal, i.e., more precisely, the larger the lacunarity (more empty space) the easier to distinguish an object from its background, and the opposite case, when the lacunarity is low (dense space), it is even more difficult to distinguish an object or signal from its established background [5-6]. The results of fractal and lacunarity analyzes, in the case of FMRI images, are predictable fixed values, as we expect, by the way.

We will explore the relevance of MRI in the characterization and diagnosis of pathology and diseases of the brain, especially in relation to strokes and dementia. We will also review the imaging sequences and post processing applications available for exhaustive examinations of the brain [7].

2. Some of the FRMI procedures

As stated above, we mention it once again, but with immediate application on the subject of this article. Thus, as it has become commonplace in the medical world, nuclear magnetic resonance imaging it is first and foremost a method of investigating the internal structure of organs that has applications especially in the medical field.

Through this method, sections are obtained through the human body in the form of images, where the various anatomical structures are rendered in various shades of gray, depending on the chemical composition of the tissues and the method of obtaining data. Magnetic resonance images can be obtained by several methods, below are the methods T_1 and T_2, of interest for the present study.

A MRI device consists of a series of coils, located in a cylindrical chamber, thermally and magnetically insulated, in the center of which the patient will sit. From outside to inside the main components are the following [8]:

- a superconducting electromagnet, cooled with liquid helium, which emits a constant and high intensity magnetic field,

- a series of coils that can emit gradient magnetic fields, in the 3 spatial directions, important for locating the NMR signal,

- a coil for transmitting or receiving radio signals.

The high-intensity magnetic field produced by the superconducting coil orients the hydrogen nuclei in the patient's body in two directions of spin, which correspond to different energy levels [8]. Under these conditions, there is a surplus of nuclei oriented in the direction of the magnetic field, characterized by its own magnetic field, much weaker. Under the influence of radio waves, the nuclei aligned with the magnetic field lines can be excited at the higher energy level, antiparallel, if the radio frequency corresponds to the Larmor precession frequency of these nuclei, thus they resonate [9].

The working protocol in MRI imaging involves a series of repeated radio pulses with a certain frequency, which differ depending on the study methods (T_1 or T_2), followed by measuring the echo resulting from the relaxation of the nuclei. The differences between the tissues in the NMR (Nuclear Magnetic Resonance) signal are due to the density and mobility of hydrogen atoms, mainly found in water molecules. Thus, in the T_1 method it is observed that dark areas correspond to tissues with a higher degree of hydration, bone tissue or cerebrospinal fluid, while light areas overlap with areas where there is mainly fat. By T_2 imaging, hydrated areas and bones will be brighter while areas with fat will appear brighter [10].

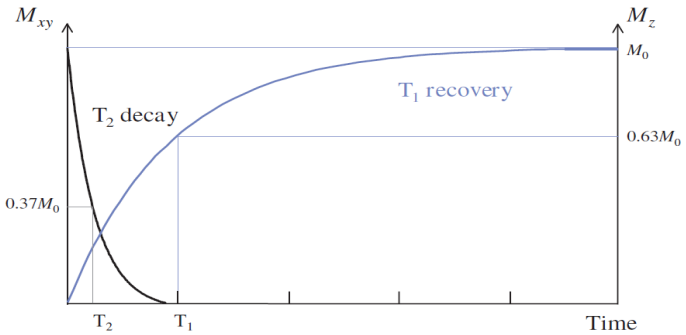

Fig. 1. Calculation graphical method of T_1 and T_2

In Figure 1 a calculation graphical method of T_1 and T_2, (T_1 recovery in blue color and T_2 decay in black color) is represented.

2.1 Tissue types observed by medical MR imaging

The main types of tissues that can be observed in brain MRI are nerve tissue, bone tissue, meninges, some blood vessels but also areas filled with cerebrospinal fluid. Nerve tissue is made up of neurons and auxiliary cells, called glial cells. Neurons are made up of neural bodies and extensions, dendrites and axons, the latter being very long and often surrounded by helper cells called Schwann cells, which

secrete a substance called myelin. In the nervous system there is most often a segregation of neural bodies and extensions in different areas. The place where neuronal bodies are found in particular is called gray matter and the place where extensions are found is called white matter, because areas with white matter appear lighter in color when observing a section through tissue with the naked eye. Areas with white matter appear lighter in color because the axonal extensions present here are surrounded by the myelin sheath, which plays a role in electrical insulation and which is lipidic in nature and whitish in appearance. Also for this reason, in T1 MRI imaging the white substance appears lighter in color than the gray matter, due to the presence of lipids, while in T2 imaging the gray matter is lighter in color than the white one. In addition, bone tissue appears light in color in T1 imaging and dark in T2 and cerebrospinal fluid, due to its water content, appears darker in T1 and brighter in T2 [11].

The areas of interest for the present study are the white matter areas, which as stated above represent the axonal extensions of the neurons. If through these extensions connections are made at the cellular level between neurons (connections called synapses), at the macroscopic level, the areas of white matter form connections between different areas of gray matter through a series of axonal cords. MRI imaging does not provide a good enough spatial resolution to easily delimit these cords in the mass of white matter and therefore this paper aims to approximate the major pathways of connectivity, starting from the morphological characteristics of the white matter, using the method of skeletonization. These trajectories thus extracted will be subjected to fractal analysis in order to identify distortions associated with certain pathologies. In order to validate the structure of these major connectivity pathways, the study aims to correlate in the future with the data obtained by diffusion imaging (DTI or DSI).

Another type of tissue successfully investigated by MRI was lung tissue, after the systematic application of the skeletonization procedure, in what can be called, without modesty, a new way in fractal analysis of pulmonary medical images [12]. The work gathered, in two years from the publication, a record number of citations.

3. Fractal analysis of MR images

Diverse methods have been used successfully to evaluate the lacunarity [13] and fractal dimensions [14-15]. The ones utilized in this paper engage the box counting mechanism implemented in digital image analysis software. We have written about the fractal dimension and how it is calculated in countless works. We will make a brief report only about measuring the lacunarity of an MR image, especially about its mathematical part [16-18].

Lacunarity at a certain value ε indicated as $\lambda\varepsilon$, is considered as the squared quotient of variation, CV, for a real pixel distribution obtained

$$\lambda_{\varepsilon} = (CV)^2 = \left(\frac{\sigma}{\mu}\right)^2 \quad (1)$$

where σ is the standard deviation and μ the mean of the pixels per box at ε. To arrive at a single number, the values for λ_{ε} can be summarized as the mean $\overline{\lambda}$ for the total number of calibres (E) used:

$$\overline{\lambda} = \frac{\sum \lambda_{\varepsilon}}{E} \ . \quad (2)$$

Fig. 2 shows the general logical scheme for the Fractal Analysis Algorithm of FMRI images, designed for this occasion.

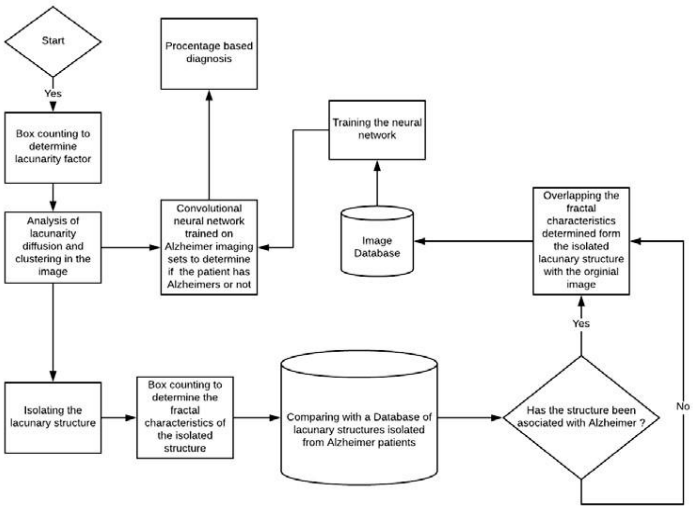

Fig. 2. Logical scheme for the Fractal Analysis Algorithm of FMRI images

This algorithm begins with box counting to determine lacunarity factor and often stops with highlighting the structure associated with Alzheimer's disease.

The algorithm used for the fractal analysis of MRI images is described below (only the beginning and its end). The main part of the agenda/mathematical content is missing, this program being subject to patent action as original software.

```
Load image
 //input the image
M = image.height ,N = image.width;
s = 2;
//the origin size of box
.....
……
Fit(log Nr, log(1/r))
//the least square method
Obtain FD ;
End; .
```

4. Results and discussion

The BOLD (blood-oxygen-level dependent) contrast mechanism has a complex relationship with functional brain activity, oxygen metabolism, and neurovascular factors. Accurate interpretation of the BOLD signal for neuroscience and clinical applications necessitates a clear understanding of the sources of BOLD contrast and its relationship to underlying physiology.

In general, the physiological components that contribute to the BOLD signal are known, and the steady-state BOLD models that enable quantification are calibrated of functional changes, what is constituted in a separate challenge paradigm. The principles derived from these biophysical models are then used to interpret BOLD measurements in different neurological disorders in the presence of confounding vascular factors related to disease.

In Figure 3, theoretical BOLD signal response is represented. Thus we have T2 * on the ordinate (oy axis) and on the abscissa (ox axis) we have the time, measured in seconds.

Note. This graphic representation describes the principal/basic of the BOLD signal in functional Magnetic Resonance Imaging (FMRI). Today, researchers in the medical field use modern FMRI to determine which regions are most active from a neuronal point of view or for detecting changes in the brain's blood flow, at least.

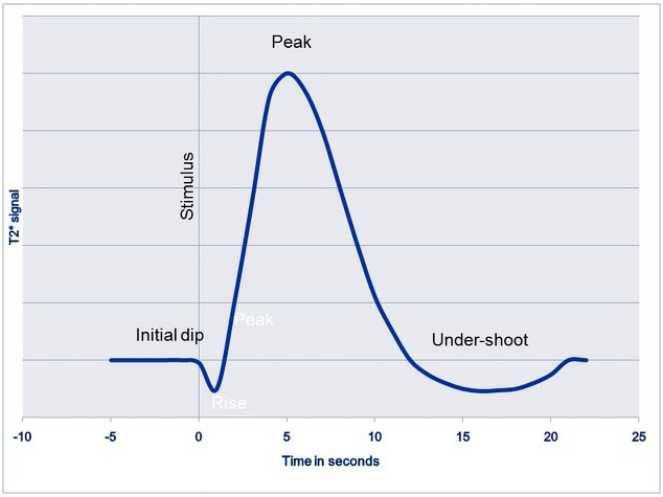

Figure 3. Theoretical BOLD signal response

The *BOLD signal* is a valuable tool for detecting changes in neuronal activity in the human brain.

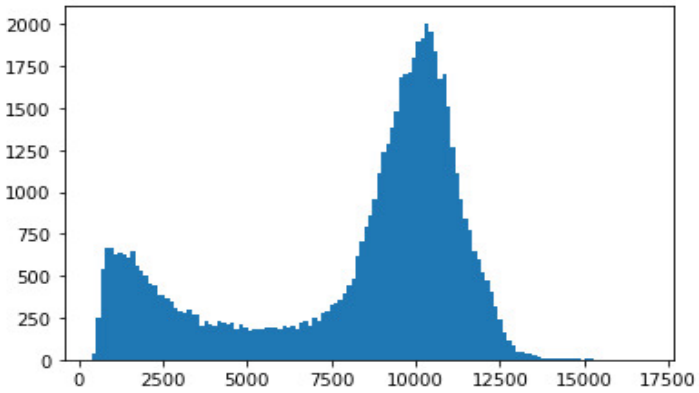

Figure 4. The replicate sample of Raw Signal Value Histograms

The graph, represented in the Figure 4, is the histogram of the Bold signals, so on the ox axis it is Raw signal value, and on the oy axis is found the Signal frequency. It is mainly used for choosing the real value of lacunarity threshold.

Observation. Difference between raw value and physical value. The raw value of a signal is the value as it is transmitted in the network. The physical value of a signal is the value of the physical quantity (such as speed, temperature, etc.).

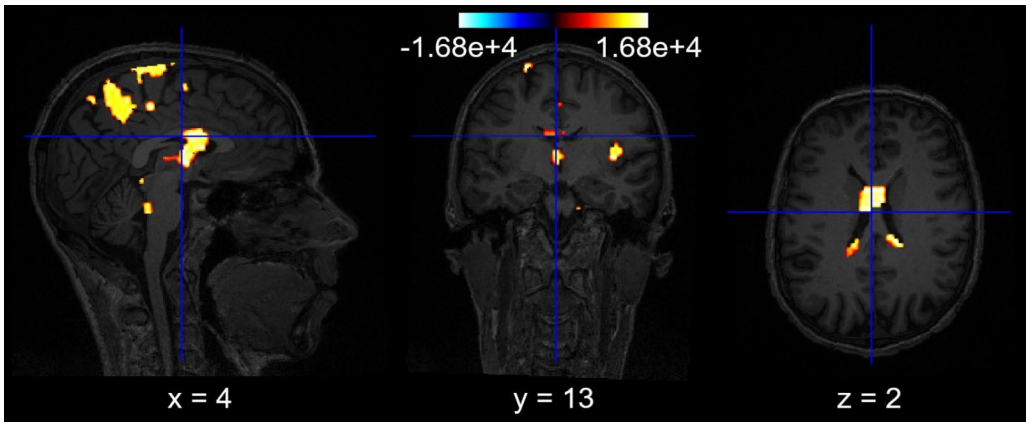

Figure 5 Fractal and lacunarity analysis on the map generated by the EEG signal

In Figure 5, a fractal and a lacunarity analysis on the map generated by the EEG signal, against the background of the overlapping RMI representation is presented. It can be noted the appearance varies over time due to the Bold signal and the subject going through a series of exercises, which target specific areas of the brain.

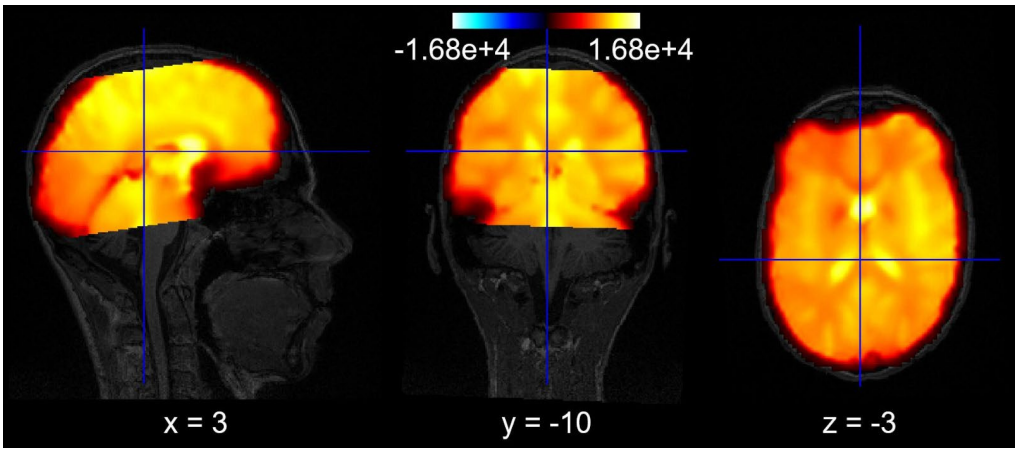

Figure 6. Fractal lacunarity visual analysis on the cerebral map by RMI generated

In Figure 6, a fractal lacunarity visual analysis on the cerebral map generated, having the areas of interest of yellow color, respectively with an intensity of level 1.68e + 4, as interpreted from the attached color band, located in the range (-1.68e + 4, + 1.68e + 4).

The software program is done through a medical imagining suite taken in 3 mm slices with a voxel of standard 512x512x12 size. The prime step for diagnostic determination is the image processing by the instrumentality of the differentiable package/box counting procedure (for deduction of lacunarity degree, ultimately).

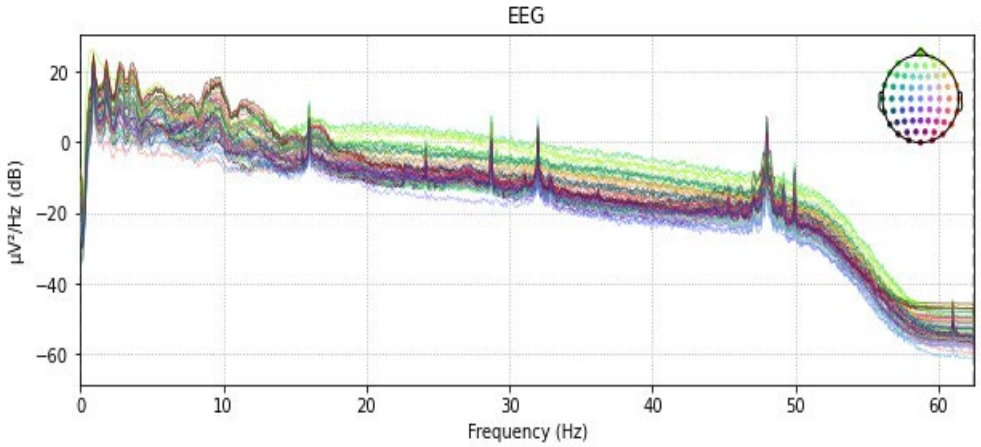

Figure 7 A recorded electroencephalogram in graphical representation (Hz, dB)

In Figure 7 a recorded electroencephalogram is presented. It is about a graphical representation having on the abscissa (x-axis) the frequency (Hz) and on the ordinate (y-axis), the logarithm of the energy or power ratio (dB) of signal received, respectively.

The electroencephalogram (EEG) is a non-invasive evaluation that detects, potentiates and records the bioelectrical activity of the brain. The neuronal cells that make up the cerebral cortex emit post-synaptic potentials with electrical value that can be taken, recorded and evaluated using an electroencephalogram. The goal of this investigation is to provide the doctor with information about the electrical activity of the brain in the context of clinical manifestations of a possible brain damage.

The detailed presentation of the designed software was made within the articles found in the bibliography, in a complex but more general way than the one in the present study [19].

5. Conclusions

In the paper, the brain RMI has been analyzed to find out the fractal dimension and lacunarity of benign tumor samples. By easy to understand reasons, the RMN images were processed in the manner presented in an above section of current study to remove the noise and just keep the formatted cell lines. After that, the neuro-image was transformed into binary format and the differential box-counting (DBC) method was applied to arrive of expected results.

The software algorithm developed here, to identify special formations associated to grave Alzheimer's disease, leads at the estimation of the fractal dimension and the lacunarity, with great accuracy. In principle, however, the article develops an algorithm for identifying abnormal structures in the brain, which has happened. These structures were chosen, through MRI pictures / recordings used, from those of patients susceptible to Alzheimer's syndrome. For these reasons, we said that we estimated the fractal dimension and the lacunarity to identify serious Alzheimer's disease. We made a quantitative determination of this disease and expressed a superior diagnosis, as a level of confidentiality!

About it, we can say that it is original and has been detailed in absolute premiere by the authors.

In the end, it can be said that extractions of intrinsic medical features using fractal lacunarity took place, highlighted from FMRI sources.

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