

Cerebral tissue segmentation using q-entropy in multiple sclerosis magnetic resonance images

Paula R. B. Diniz

Departamento de Neurologia,
Faculdade de Medicina de Ribeirão
Preto, USP, Ribeirão Preto- SP-Brazil
paula.rejane@gmail.com

Antônio Carlos dos Santos

Departamento de Radiologia,
Faculdade de Medicina de Ribeirão
Preto, USP, Ribeirão Preto- SP-Brazil
acsantos@fmrp.usp.br

Luiz Otávio Murta Júnior

Departamento de Física e Matemática,
Faculdade de Filosofia Ciências e
letras de Ribeirão Preto, USP,
Ribeirão Preto- SP-Brazil
murta@ffclrp.usp.br

Abstract

The brain volume measurements have important clinical applications in the treatment of neurodegenerative illnesses. The segmentation and the volume calculation are important in the medical context to provide information to assist the physician in disease diagnostic and prognostic. Furthermore, it can improve the speed of the diagnostic. The objective of this article is to describe the development and evaluation of a tool for calculation of the brain volume using Tsallis Entropy.

1. Introduction

The quantification of the cerebral volume is a relatively simple procedure; even so, when made manually, it is a time consuming exhaustive task. Moreover, there is a large variability between the results of different individuals. To solve these problems the use of an automatized segmentation process is required. However, the computational algorithm to be used must be precise to detect small differences and robust to allow reproducible measurements to be used in evolutionary accompaniments.

This paper proposes a method with the objective of skull extraction, segmentation and volume calculation of cerebrospinal fluid (CSF), white (WM) and gray (GM) matters.

2. Methodology

This method was developed using ImageJ as development base. ImageJ, created by the National Institute of Health (NIH), is a software for image processing and analysis developed under an open architecture, in which allows creation of Java plugins making it possible to extend its functionalities.

In this section we detail the developed algorithm and the study made to evaluate the method.

2.1. Skull Extraction: The head magnetic resonance images (MRI) are used for skull extraction in two stages: pre-processing, consisting on the application of a series of filters with the objective to obtain adequate images to application of the Snake active contour procedure.

Initially, an anisotropic filter is used for smoothing the image. This procedure tends to minimize the noise. After this, a binary image is

created using the **autoThreshold** method in **ImageProcessor** class.

The Snake is a particular type of active contour in which an initial curve is deformed towards the edge by the action of internal and external forces. Active contours make use of local information on a contour. Its use is indicated when we do not have necessary information of the geometry of the edges of objects. [1] The result is a binary mask. Finally, an AND operation is applied to the mask and the original image.

2.2 Classification of the Brain tissues: To segment the brain in different cerebral tissues (White Matter, gray Matter and cerebrospinal fluid) we applied an algorithm based on maximum generalized entropy principle. The entropy is frequently used to indicate the amount of information contained in a certain source. Entropy is also used to graduate the disorder or complexity of a dataset. [2]

For a certain class of physical systems, which entail long-range interactions, long time memory and multifractal feature macro states, some kind of extension becomes necessary. Inspired by multifractals concepts, Tsallis has proposed a generalization of the Boltzmann–Gibbs–Shannon (BGS) statistics. [4] The Tsallis statistics has been considered useful in describing the thermodynamics properties of nonadditive systems, and it is based on a generalized entropic form:

$$S_q = \frac{1 - \sum_{i=1}^k (p_i)^q}{1 - q} \quad (1),$$

Where k is the total number of possibilities of the system and the real number q is an entropic index that characterizes the degree of nonadditivity. This expression meets the BGS entropy in the limit $q \rightarrow 1$. The Tsallis entropy is nonadditive in such a way that for a statistically dependent system, the entropy of the system is defined by the following nonadditivity entropic rule

$$S_q(A+B) = S_q(A) + S_q(B) + (1-q) \cdot S_q(A) \cdot S_q(B) \quad (2),$$

Considering $S_q \geq 0$ in the pseudo-additive formalism of Eq. 1, three entropic classifications are defined as follows

•Subadditive entropy: $(q < 1)S_q(A+B) < S_q(A) + S_q(B)$
(3)

•Additive entropy: $(q = 1) S_q(A+B) = S_q(A) + S_q(B)$
(4)

•Superadditive entropy: $(q > 1)S_q(A+B) > S_q(A) + S_q(B)$
(5)

The entropy of an image is a positive measure and the maximum entropy occurs when an image contains the same amount of pixels for all intensities, that is, all intensities have the same occurrence probability. [2]

The developed algorithm is based on the entropy algorithm proposed by KAPUR and PUN. [5,6] According to the Pun algorithm, the entropy associated to the black pixels (dark pixels), S_b , and the entropy associated to the white pixels (bright pixels), S_w , is delimited by the threshold value t . The algorithm assumes that t is such that maximizes the total accumulated entropy function. In this case, S_b and S_w are: S_b is the accumulated entropy ranging from dark black gray level till threshold and S_w is the accumulated entropy from threshold till bright white gray level.

The first structure segmented is the cerebrospinal fluid that is then subtracted from the original image. The image without the cerebrospinal fluid is submitted again to the algorithm of maximum entropy that extracts the gray matter. Once subtracted the gray matter has the white matter.

2.3 Volume Calculation: From the information contained in the header of DICOM images, it is possible to get several information tags regarding the patient and the exam. Among these information tags, some were of special interest for this software development such as thickness, width and length of pixels. Using the tag of the related information, together with the development of methods that read and capture the header of images DICOM, it is possible and viable the calculation of the volume of the brain tissues.

In the end, the pixels with the same color are counted (different colors for different tissue). Finally, the width and the thickness of the pixels are multiplied by the total number of pixels of the volume. The result is the volume.

3. Results

Initially, we search the optimum q value for the tissues of interest, segmentation through exhaustive tests. The table 1 presents the q values found.

Table 1. q values found for tissues in patients and controls images.

	patients	controls
Gray Matter	1,5	2,0
White Matter	0,1	0,2
cerebrospinal fluid	0,3	0,5

The algorithm in subject is independent on the pulse sequence and insensitive to the non uniformity of the image signal that could influence the results.

The sensibility was evaluated through variations of the volume of these structures in patients of Multiple Sclerosis along the time.

The statistical analyses demonstrated that this tool is reliable for volume calculation. It is possible to observe a small variation on the volume along the time; however this variation is statistically insignificant as shown in analyses enclosed.

Thus we can conclude that this tool has shown to be sensitive enough to detect the variation of the total volume along the time besides the decrease of the white matter, as it is told thoroughly in the literature. [3] However it was not capable of detecting differences as the gray matter and the cerebrospinal fluid in the time slices of 1 and 2 years.

4. Discussion

This tool was shown efficient for atrophy detection, because it was shown invariant for the total volume ($p < 0,05$) and it got to detect variations in the patient's white matter with Multiple Sclerosis ($p < 0,05$), as it is told thoroughly in the literature.

The method has been shown able to define tissue volumes with the necessary sensitivity to detect cerebral atrophy. This study suggests that the proposed algorithm is a good alternative when we just want to know whether atrophy is present or not in examined patients.

5. References

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