Deformable Models (Snakes) for Fractal Analysis of Brain Tumors on T2-Weighted Images

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INTRODUCTION

Premature detection and classification for a disease process, is one of the most important objectives for a physician. In reference to the brain, MRI can detect abnormal structures from the early stages of development, showing the morphological characteristics of neoplasic tissue, specifically the presence of rugosity or irregularities on its boundaries. The main goal in this work is to employ the rugosity on the boundary of the lesion to classify a mass as belonging to any of the two kinds of lesions (benign or malign) present in T2-weighted MRI images of the brain. To reach this goal, tumor image is segmented and a deformable model (snake) is adapted to the boundary of the lesion. The energy density functional obtained from the deformable model is analyzed as an artificial time series to determine fractal correlation dimension. Also the fractal capacity dimension was calculated on the same model. To validate the proposed methodology, it was applied to a significant number of images with different types of lesions to establish a reliable classification method.

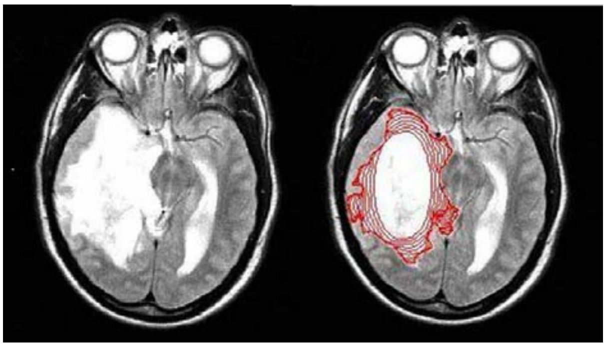

Figure 1. On the left, T2-weighted image of a glioblastoma multiforme. Right, different stages of the snake evolution toward the boundary of the lesion, starting from a central ellipse.

MATERIALS AND METHODS

T2-weighted images were digitally processed to equalize the histogram by a gamma correction procedure. Image segmentation was carried out by thresholding and binary images were obtained. The contour was determined by a Canny edge detector operator [1] and closed by the "bug following" algorithm [2]. Binary images were used to apply deformable models or snakes minimizing the energy functional given by [3,4]:

$$E = \int_0^1 \frac{1}{2}\left(\alpha\left|x'(s)\right|^2 + \beta\left|x''(s)\right|^2\right) + E_{ext}\left(x(s)\right)ds$$

with

$$E_{ext}^{(1)} = I(x, y)$$

$$E_{ext}^{(2)} = G_\sigma * I(x, y)$$

for binary images. In the first case the external energy is directly dependent on image intensity while for the second case it is convoluted with a Gaussian distribution to increase the range of convergence of the snake [3]. In Figure 1 it is shown the evolution of the snake towards the outer boundary. For the contour obtained by the snake, the fractal capacity dimension is obtained by a box counting procedure [5,6] and the fractal correlation dimension was calculated on the energy density functional with the Grassberger-Procaccia algorithm [7].

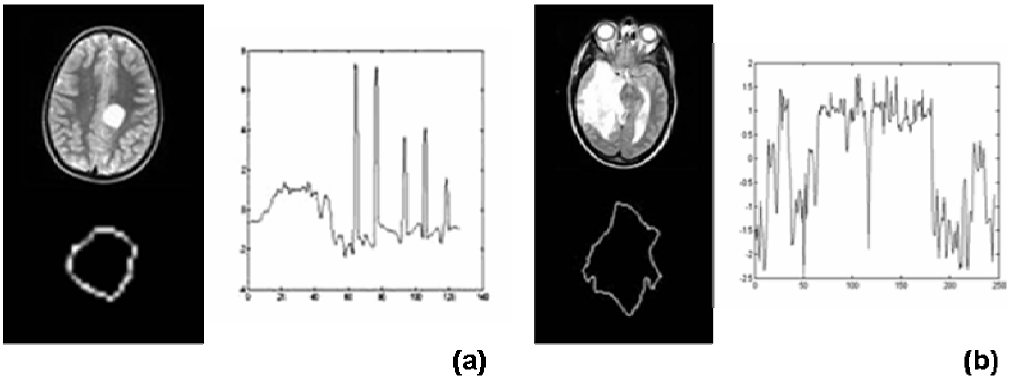

Figure 2. T2-weighted images, deformable model or snake and energy density functionals for (a) benign lesion and (b) malignant lesion.

RESULTS AND DISCUSSION

Some of the tumoral lesions studied in this work are shown as an example in Figure 2. In the Figure are represented T2-weighted images, the contour corresponding to the adapted snake and its energy density functional for (a) a benign lesion and (b) a malignant one. It is readily seen that there is a remarkable difference both in the contour shape or rugosity and in the energy density functional patterns. The calculated fractal dimensions are the following: Capacity dimension, benign lesions 1.0750 ± 0.0973, malignant lesions 1.0972 ± 0.0265; Correlation dimension, benign lesions 1.0962 ± 0.0657, malignant lesions 1.2248 ± 0.0935. According to these results, it seems that correlation dimension is a better discriminant for the nature of the lesion than capacity dimension.

CONCLUSIONS

Geometrical properties of contours obtained for segmented brain tumor images can be characterized by means of fractal analysis and deformable models. The analysis demonstrate that correlation dimension is better than capacity dimension to discriminate between malign or benign lesions, and maybe it can be used for tumor grading.

REFERENCES

[1] J. Canny, "A computational approach for edge detection", *IEEE Trans. Pattern Anal. Machine Intell.*, 8:679-698, 1986
[2] A. Jain, *Fundamentals of Digital Image Processing*, Prentice Hall, Inc., 1989
[3] C. Xu, J.L. Prince, "Gradient vector flow: a new external force for snake", *IEEE Proc. CVPR* 97:66-71, 1997
[4] C. Xu, "Deformable models with application to human cerebral cortex reconstruction from magnetic resonance images", PhD dissertation, January 1999
[5] J. Feder, *Fractals*, New York: Plenum Press, 1989
[6] T. Parker, L. Chua, *Practical Numerical Algorithms For Chaotic Systems*, New York: Springer –Verlag, 1989
[7] P. Grassberger, I. Procaccia, "Measuring the strangeness of strange attractors", *Physica*, 9:189 – 208, 1983