Brain Lesion Segmentation in MRI Images

Group Number 17

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***Abstract*— This paper looks at brain lesion segmentation from MRI images implementing a new workflow to automatically find the lesion region, highlighting its surface and calculating its area. The implemented method was tested with different noise levels and showed robustness regarding "salt & pepper" noise.**

Keywords—magnetic resonance imaging, brain lesion, segmentation, image processing, image noise reduction

I. Introduction

Magnetic Resonance Imaging (MRI) is a modern tomographic technique that allows healthcare professionals to investigate thoroughly, through virtual planar slices, the patient's tissues morphology. It's a very effective tool for diagnostics and surgery planning, especially when investigating soft tissues. This paper presents a comprehensive analysis on the segmentation of MR images for detection and surface estimation of a lesion in the brain area, moreover we investigate the effect of image noise on our approach.

II. Material & Methods

The MATLAB programming language was used to perform all data analysis and visualization in this work.

The first step of the process consisted in the visualization of the volume to approximately determine, for each orthogonal plane, the Region Of Interest (ROI). Then, single slice segmentation was carried out by means of an algorithm employing filtering, thresholding and the analysis of properties of continuous regions [1][2].

To evaluate the robustness of the segmentation approach, the analysis of the sensitivity to two types of noise was performed. To assess the accuracy of the segmentation the Dice index was adopted to compare similarities with the ground truth, obtained through manual segmentation.

Moreover, a comparative analysis between Otsu's method and the proposed approach was conducted.

A. Volume Visualization

The MATLAB function `orthosliceViewer()` was used in multiple occasions to visualize the volume along its three orthogonal planes, firstly for approximately assessing the ranges of the slices of interest for the segmentation for each plane, secondly for identifying the slice with the biggest lesion extention. The latter was used to empirically define the coordinates of the region of interest using the MATLAB function `imcrop()`.

B. Lesion Segmentation

The segmentation was performed implying the following pipeline: first, the determined ROI was extracted from the slice. An empirical thresholding was applied to the standardized image, with range between 0.5 and 0.85. The MATLAB function `bwlabel()` was used to label continuous regions with a unique identification number. Subsequently, statistical properties of those regions, namely "solidity" and area, were computed adopting the function `bwregionprops()`.

The identification of the region corresponding to the lesion was based upon the assumption that it coincided with the relatively densest area with greater extention within the ROI, based on an empirical density threshold. As it was also assumed that the lesion forms a contiguous area, the MATLAB function *`imfill`*() was utilized to correct the image.

C. Noise Sensitivity Analysis

To investigate how noise affects the implemented algorithm and to tackle its weaknesses we performed tests comparing the detected area without noise and subsequently with increasing levels of noise, either 'additive gaussian' noise or 'salt & pepper' noise.

Subsequently, the impact on the accuracy of lesion identification was measured by computing the cross-sectional area of detected regions. Two metrics were computed for each noise level: the lesion area with and without the preemptive application of a filter.

D. Manual Segmentation

To investigate how noise affects the implemented algorithm and to tackle its weaknesses we performed tests comparing the detected area with a manual segmentation obtained with the built-in application called "Volume Segmenter": first applying volumetric Otsu's method, filling holes, smoothing edges and finally removing mistakes by checking individual slice segmentation. The final result was saved and used as ground truth for the following steps.

E. Dice Coefficient

The Dice coefficient is a measure used in image segmentation evaluation, comparing the overlap between a segmented area and the ground truth. It ranges from 0 to 1, where 1 signifies perfect agreement. It's calculated by assessing the intersection of the segmented area and the ground truth, providing a numerical indication of segmentation accuracy. In medical imaging, a higher Dice coefficient indicates better performance, ensuring accurate identification of regions of interest, like tumors or organs, aiding in reliable clinical diagnoses and treatments.

III. Results & Discussion

A. *Sagittal Slice 135 Segmentation*

Figure III.1 portrays the requested lesion segmentation of sagittal slice 135. Its cross-sectional area resulted being of 332 pixels.

Figure III.1 Sagittal slice 135 lesion segmentation

B. *Whole Volume Segmentation Command-Line Interface*

The command-line interface allows for the display of the segmentation of the whole volume along a chosen orthogonal plane with the optional addition of noise and chosen noise level. **Figure III.2** portrays a sample of segmentations that is possible to generate with the CLI.

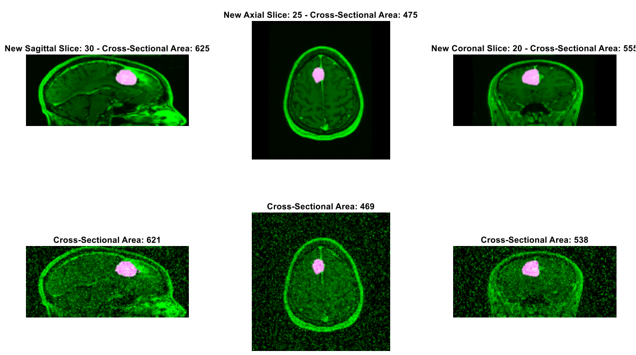

Figure III.2 Samples of lesion segmentation across different planes with and without added "salt & pepper" noise

C. *Local Operator Performance Analysis*

To assess whether to include the application of preemptive filters to our segmentation pipeline an analysis on performance with cross-sectional area

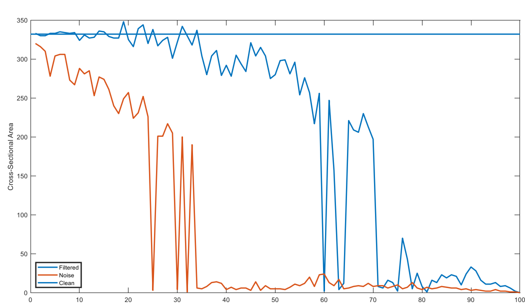

Figure III.3 Cross-sectional area over noise percentage with and without the use of a preemptive median filter

Figure III.3 illustrates the detected cross-sectional area under increasing noise condition, highlighting the difference between the areas with and without noise reduction techniques. Due to deteriorating accuracy of the area of the non-filtered ROI, the study proposes the application of a preemptive median filter, to avert potential degradation caused by "salt & pepper" noise.

The same analysis conducted with increasing levels of Gaussian noise showed no significant improvement by applying a preemptive averaging filter to the volume.

D. *Comparison With Other Methods*

The implemented pipeline was compared against Otsu thresholding also testing the sensitivity to point operators such as gamma correction.

The two methods were compared computing the Dice coefficient with respect to the ground truth obtained from manual segmentation: the workflow resulted more sensible to extreme levels of gamma correction, both brightening and darkening, but at the same time it matched or outperformed Otsu's method when close to the original image, meaning no gamma adjustments were necessary.

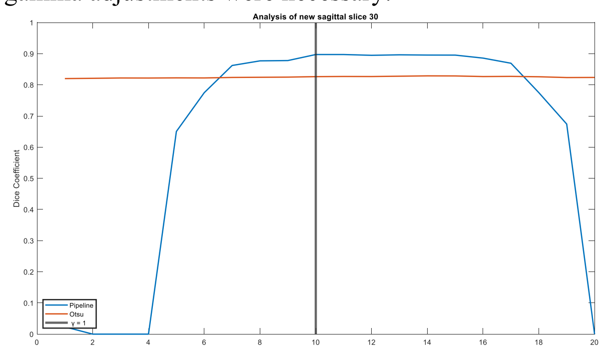

Figure III.4 Comparison with Otsu's method over different levels of gamma

Such performance can be assessed for all the slices of interest of each one of the orthogonal planes using a command-line interface with same functionality as the one for volume segmentation.

References

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