

Computer-aided GBM tumor ROI contouring and mapping framework for structural and physiological MR images in a multi-center clinical trial

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Introduction

The main goal of this study is to develop a computer-aided 3D multi-modal tool to facilitate radiologists outline GBM brain tumors on T1-weighted contrast-enhanced volumetric, diffusion-weighted (DW) and perfusion-weighted MR images, including apparent diffusion coefficient (ADC) maps, dynamic contrast enhance (DCE) images, and dynamic susceptibility contrast-enhanced (DSC) images, in the setting of multi-center clinical trials.

Methods

First of all, we developed a 3D semi-automated tool to automatically segment the contrast enhanced region on T1w post contrast images, and then we applied a ROI mapping tool to map the lesions onto other modalities.

The 3D segmentation tool uses adaptive thresholding based on Otsu's thresholding method [1]. The original method assumes an image intensity histogram including two classes, exhaustively searches for the threshold that minimizes the within-class variance, defined as a weighted sum of variances of the two classes, and find the optimal thresholding value to separate these two classes.

The 3D ROI mapping tool uses a rigid body transformation with the parameters extracted from the DICOM header based on physical locations.

Equation 1 shows the way to calculate the 3D physical location voxelwise. $\Delta_{i,j,k}$ is the voxel size read from the tag "pixel spacing" and "slice thickness"; $X_{x,y,z}, Y_{x,y,z}$ is image orientation read from the tag "image orientation" which specifies the orientation of the image frame rows and columns, $Z_{x,y,z}$ is the z-direction orientation calculated from $X_{x,y,z}, Y_{x,y,z}$;

$S_{x,y,z}$ is read from the tag "patient position" which specifies the anterior-left-upper corner; i, j, k are voxel index; and $P_{x,y,z}$ are the calculated physical location of the voxel in millimeters. The transformation matrices are calculated for both source and target ROI respectively. For each voxel in the source ROI, the physical location is first calculated, and then the inverse operation is performed to calculate the new voxel index of the target ROI. Finally, radiologists visually evaluate the contours on ADC images and manually correct the tumor contours on ADC.

$$\begin{bmatrix} P_x \\ P_y \\ P_z \end{bmatrix} = \begin{bmatrix} X_x \Delta_i & Y_x \Delta_j & Z_x \Delta_k & S_x \\ X_y \Delta_i & Y_y \Delta_j & Z_y \Delta_k & S_y \\ X_z \Delta_i & Y_z \Delta_j & Z_z \Delta_k & S_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i \\ j \\ k \\ 1 \end{bmatrix}$$

Equation 1 The physical location calculation of a voxel (i, j, k)

Results

We used this tool for all 106 patients with scans at multiple timepoints, totaling about 650 scans in our research database. We randomly selected 31 GBM tumors for quantitative evaluation. The 31 tumors are from ADC mapping database, 20 of which have different image resolutions between the T1 and ADC images in all three dimensions while 11 of which have exactly the same 3D image resolution in both modalities. We calculated the overlap ratio of the mapped ROI generated automatically by the tool and the one corrected by the radiologist. The overlap ratio is defined as the $2 * \text{size}(A \cap B) / (\text{size}(A) + \text{size}(B))$, where A and B are two tumor ROIs. The results are shown in table 1, where 20 out of 31 (64.5%) have an overlap ratio over 90%. Figure 1 shows two illustrative examples of the proposed tool. Each row shows T1w, DSC, DCE and ADC images for a particular tumor.

Overlap ratio	100%	95~100%	90~95%	80~90%	60~80%	0~60%
Number of patients	10	7	3	2	5	4

Table 1 Distribution of overlap ratios

Conclusion

The proposed 3D semi-automated tumor contouring and mapping tool promotes reproducibility in the tumor contouring task and saves time for radiologists, even when it is difficult to visually identify the tumor boundary on some of the MR sequences. This contouring framework has significant applications in oncologic clinical trials.

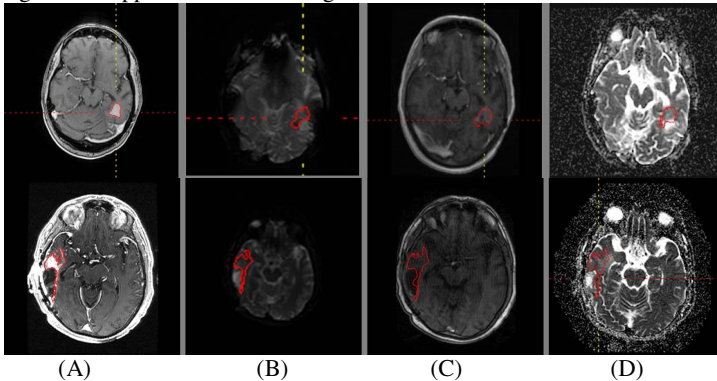


Figure 1 Two illustrative examples of the proposed tool: (A)T1w, (B)DSC, (C)DCE, (D)ADC.

Reference

[1] Otsu N. "A threshold selection method from gray level histograms", IEEE transactions on Systems, Man and Cybernetics 9(1): 62-66, 1979.