Rapid Quantification of Stroke Infarct from Diffusion Weighted Images

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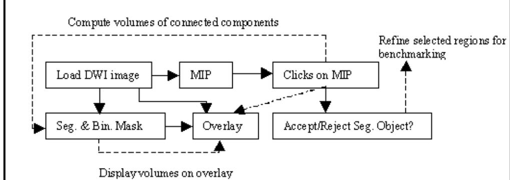

Fig. 1: Flow-Chart of Workflow

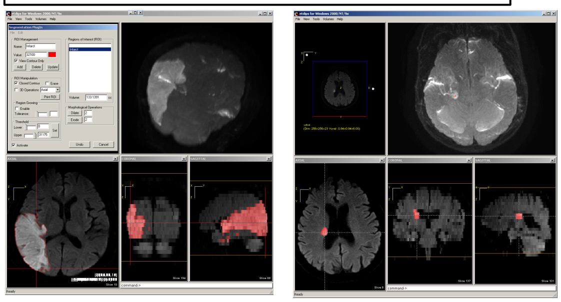

Fig.3:Visualization and quantification of potential infarcts

Introduction: A vital step in the evaluation of acute and chronic stroke involves volume quantification of the infarct as determined from diffusion-weighted images (DWI) [1]. The routine assessment of infarct size is by visual review of the approximate size reported along with the location of the defect with reference to the brain anatomy. Assessment of the infarct volume is critical to management decisions in acute stroke, especially for thrombolytic therapy, and calls for quantitative methods. There are multiple efforts to develop post-processing methods to segment and automatically measure the infarct from DWI images[1]. Given T2 shine-through artifacts from pre-existing old infarcts in the DWI images make this task very challenging. In order to offer a robust workflow for this evaluation we present a hybrid (visualization and segmentation) method to address this. The core concept is to integrate the presentation of maximum intensity projections (MIP) of the DWI data to the user to select suggestive infarct regions and use an underlying level-set based (top-down) image segmentation approach for rapid quantification of suspect regions.

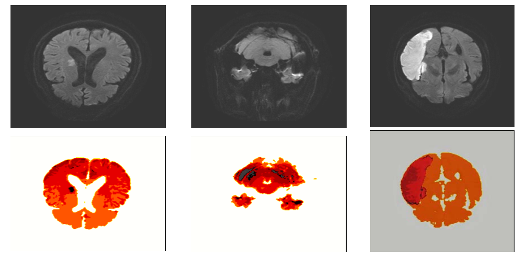

Fig. 2: Segmentation Results from HCVLS Algorithm

Methods: *Image Acquisition*: We applied our approach to 8 stroke patients with varied lesion sizes in DWI images. All the patients were imaged on a 1.5T (Signa HDX, GE Healthcare, Waukesha, WI) with an 8-channel head coil (8 HRBRAIN, GE Healthcare). Axial DWI images were acquired using a SE-EPI sequence (TE/TR = 78/10000, FA = 90°, NEX = 2, Acquisition matrix = 128 x 128, FOV = 240x 240 mm^2, slice thickness varying from 3.5mm to 7 mm, b = 0 s/mm^2 and 1000 s/mm^2, diffusion encoding along axial, sagittal and coronal directions). To remove the effect of anisotropy, the final DWI image was the trace of DWI images along the three principal axes [2]. *MIP Creation*: Orthogonal MIP's were generated using eTDIPS [3]. *MIP-based Infarct Segmentation*: To further the goal of rapid workflow in infarct quantification, we run a robust, PDE-based segmentation algorithm to cluster potential suspect regions. We have developed an efficient implementation of Pizzi et al. hierarchical Chan-Vese level set segmentation (HCVLS) algorithm [4] in ITK. However susceptibility artifacts due to image acquisition, as well as other regions (e.g., cerebellum) having similar intensities leads to ambiguities in identifying correct infarct locations. MIP is a fast, semi-supervised method for potentially removing these ambiguities. Ideally, two operations are done: a.) MIP images in three orthogonal directions are generated, b.) HCVLS segmentation results are generated that may potentially include false positives. In doing this hybrid approach, we have reduced the search area that a clinician would have to traverse to identify potential infarct regions. Using a few mouse clicks, large ambiguous regions (e.g., regions of the brain having similar intensities as that of infarct regions) can very effectively be removed from the scene, thus increasing the workflow. A flow chart of the proposed workflow is shown in Fig. 1.

Results: As seen in Fig. 2a and 2b (Case #0032 – slices14 and 16, 5-levels of segmentation), actual infarct regions, as well as artifacts (shine-through, as well as regions of non-interest) are generated during the segmentation process. As indicated also from Fig. 2a and 2c (Case #0031 – slice 11, 5 levels of segmentation), infarct regions can have varied shapes (from very small that are hard to detect- Fig. 2a, to large contiguous regions that are relatively easier to detect – Fig. 2c). Overlay images have been shown for ease of display that generated during the segmentation process can be quickly ruled out from further consideration by a simple mouse click made on the MIP (top-right) image. Using a few mouse clicks, a trained clinician can quickly identify the actual infarct location from a subset of regions that are generated by the HCVLS algorithm. This is shown in Fig. 3. As the segmentation results in a binary mask (having disjoint connected components), it becomes very easy to compute the volume of the region (i.e., volume of the true infarct region) that the clinician has indicated with the mouse. As indicated in the flowchart, if benchmarking of the infarct is required, the clinician can isolate the selected regions very efficiently for further editing. It was found that using this approach resulted in a 30x times speedup in generating benchmarked results when compared with a traditional method of benchmarking (i.e., having to delineate potential infarct boundaries in all slices, individually). To demonstrate the performance of the segmentation, we have included comparative results for infarct volumes that were generated using non-MIP based benchmarking, as well as MIP-based selection without any further editing in Table 1.

Conclusions: A semi-supervised, MIP-based process for improving workflow in infarct detection and quantification has been presented. The designed workflow has the potential to significantly reduce the overhead time required to quantify an infarct by leveraging automated segmentation methods under user guidance. This is beneficial when fast workflow (for treating patients suffering from trauma) and benchmarking (i.e., ground truth generation for comparative analysis) is required.

References: [1] V.Gupta et al, Acad. Rad. v(15),no.1,p.24-39,2008 [2] M.Wintermark et al., Stroke, vol 39(5), May 2008 [2] R.Mullick et al.SCAR, 1998 [3] M.Jeon et al. Patt. Recon. Lett. v(26), p.1461-1469,2005

Table 1: Infarct volumes (in cc.) generated from MIP's and ground truth

Case No.	0002	0003	0021	0031	0032	0034	0035	0037
MIP-LS Method Based	0.6744	0.8253	319.89	116.87	1.47	0.572	6.07	13.28
Ground Truth	0.5605	0.8499	411.79	124.55	1.31	0.671	5.86	14.65