Ischemic Stroke Lesion Segmentation

www.isles-challenge.org

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Preface

Stroke is the second most frequent cause of death and a major cause of disability in industrial countries. In patients who survive, stroke is generally associated with high socioeconomic costs due to persistent disability. Its most frequent manifestation is the ischemic stroke, whose diagnosis often involves the acquisition of brain magnetic resonance (MR) scans to assess the stroke lesion's presence, location, extent, evolution and other factors. An automated method to locate, segment and quantify the lesion area would support clinicians and researchers alike, rendering their findings more robust and reproducible.

New methods for stroke segmentation are regularly proposed. But, more often than desirable, it is difficult to compare their fitness, as the reported results are obtained on private datasets. Challenges aim to overcome these shortcomings by providing (1) a public dataset that reflects the diversity of the problem and (2) a platform for a fair and direct comparison of methods with suitable evaluation measures. Thus, the scientific progress is promoted.

With ISLES, we provide such a challenge covering ischemic stroke lesion segmentation in multi-spectral MRI data. The task is backed by a well established clinical and research motivation and a large number of already existing methods. Each team may participate in either one or both of two sub-tasks:

SISS Automatic segmentation of ischemic stroke lesion volumes from multi-spectral MRI sequences acquired in the sub-acute stroke development stage.

SPES Automatic segmentation of acute ischemic stroke lesion volumes from multi-spectral MRI sequences for stroke outcome prediction.

The participants downloaded a set of training cases with associated expert segmentations of the stroke lesions to train and evaluate their approach, then submitted a short paper describing their method. After reviewing by the organizers, a total of 17 articles were accepted and compiled into this volume. At the day of the challenge, each teams' results as obtained on an independent test set of cases will be revealed and a ranking of methods established.

For the final ranking and more information, visit WWW.ISLES-CHALLENGE.ORG.

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Lesion Segmentation of the Penumbra in Acute Stroke in the MICCAI 2015 ISLES Challenge

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Abstract. The proposed method is based on a left-to-right comparison of the brain hemispheres to (i) restrict the segmentation only to the affected one and (ii) to pre-select the potential lesion by a threshold-free comparison with the contralateral, healthy side as a reference.

1 Method

In almost all cases of acute embolic anterior circulation stroke only one hemisphere is affected (corresponding to the ground truth segmentations of the training dataset). We exploit this feature to (i) restrict the segmentation to only the affected hemisphere and (ii) to pre-select the potential lesion by comparing local histograms of the affected side with the contralateral, healthy counterpart used as reference values. The algorithm is illustrated in Fig. 1 below.

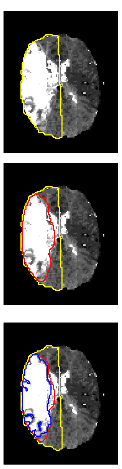

Fig. 1. Illustration and description of the propsed algorithm.

Due to the perfusion-diffusion-mismatch conceptm, our approach is based on the evaluation of just the Tmax and ADC-values. The important steps of the proposed method are described below in more detail.

1.1 Separation of the Hemispheres

For the separation of the hemispheres, we use a simple, but fast and robust algorithm. Since the brain extraction was already performed in the training datasets, the brain mask can easily be generated by thresholding the Tmax maps with Tmax $>$ 6s. A additional, mirrored mask is generated as by flipping the original mask on the L-R direction. The separation plane of the brain hemispheres can be found by the optimal overlap of the mirrored and the original masks. To achieve this, a global search on the grid of all possible rotations and translations between the to masks is performed, and the correlation value is computed. The highest correlation indicates the best transformation, from which the separation plane can be derived.

1.2 Potential Lesion Segmentation

The affected hemisphere is identified as the one with the highest median value of Tmax. For each voxel at position $\boldsymbol{x}$, a normalized, regional histogram $H(\boldsymbol{x}, t_i)$ is calculated in a $20 \times 20 \times 12\,\mathrm{mm}^3$ neighborhood with a bin-width of $t_{i+1} - t_i = 1.5\,\mathrm{s}$. The difference to the corresponding contralateral histogram $\tilde{H}(\boldsymbol{x}, t_i)$ taken from the mirrored part of the brain is calculated via

$$D(\boldsymbol{x}) = \frac{1}{2} \sum_i \left| H(\boldsymbol{x}, t_i) - \tilde{H}(\boldsymbol{x}, t_i) \right| \tag{1}$$

This resulting map of histogram differences is thresholded by 0.5 to find the regions with unusual Tmax values. The distance map does not show whether the unusual value is higher or lower than the one of the corresponding healthy side. Therefore, only voxels with a Tmax median value greater than the one of the healthy side are selected. Further, to remove potentially noise voxels, only those with a sufficient number of non-zero values in their neighborhood – corresponding to 1/2 of the neighborhood volume – are considered. To clean the mask, we apply morphological erosion with a kernel of $6 \times 6 \times 4\,\mathrm{mm}^3$, then we omit connected components with a volume smaller than $20\,\mathrm{mL}$, and finally apply morphological dilation with the same kernel used for erosion.

1.3 Thresholded Lesion Segmentation

The previous step already provides us with a good segmentation of the potentially abnormal region. To select only the penumbra region with critical perfusion deficit, an additional threshold has to be applied. We applied a thresholding with the generally accepted value of Tmax $>$ 6s, as performed for the ground truth segmentation of the MICCAI ISLES challenge. To clean the mask, we again apply the same morphological operation as described above.

1.4 CSF removal

The ADC maps are thresholded with $\mathrm{ADC} > 1700\,\mathrm{mm}^2/\mathrm{s}$ to define a simple, but effective CSF mask. This mask is multiplied with the Tmax segmentation.

2 Results and Discussion

The following discussion refers to the 30 examples of the training dataset of the MICCAI ISLES challenge.

In all examples, the plane separating the left and right hemisphere of the brain could always be determined. With this, the affected hemisphere was always identified correctly.

The generally applied hard threshold of Tmax $>$ 6s, but not free from limitations, as the critical perfusion delay might depend on individual factors such as patient age and previous diseases, and measurement noise.

The proposed method can help overcome this problems, as it includes a pre-selection of the potential lesion based on a comparison with the contralateral, healthy regions of the brain. This can be observed in e.g. example 10, Fig. 2, where the brain extraction did not remove some regions outside of the brain where the Tmax map show an enhancement. This is falsely included in the ground truth, but excluded in our approach, as it appears equally on both sides of the brain.

With this pre-selection, the final segmentation could be restricted to a reasonable region: on average, the ground truth was included by a rate of 85% with a false positive rate of 67%. With a final thresholding by the standard value of Tmax ¿ 6s, followed by morphological operations, the false positives could be reduced to 21% by a false negative rate on an equal order of 20%. This is satisfiable, as for the diffusion-perfusion mismatch ratio, not the precise shape of the segmentation is crucial, but the volume.

We limited the evaluation to the Tmax and ADC maps only in order to keep the method as practical as possible. Further, in many cases stroke patients are unsettled and move heavily, such that the image quality does not allow for a proper coregistration of different modalities on the level of the voxel-size. Finally, the computational costs of the proposed method are very low, which is crucial in acute stroke. The evaluation is performed in a couple of seconds on a standard desktop PC.

3 Conclusions

We presented a simple and fast algorithm for penumbra segmentation in acute stroke. The key features of the method are the low computational costs, the restriction to the affected hemisphere only, and the threshold-free pre-selection of abnormal Tmax values.

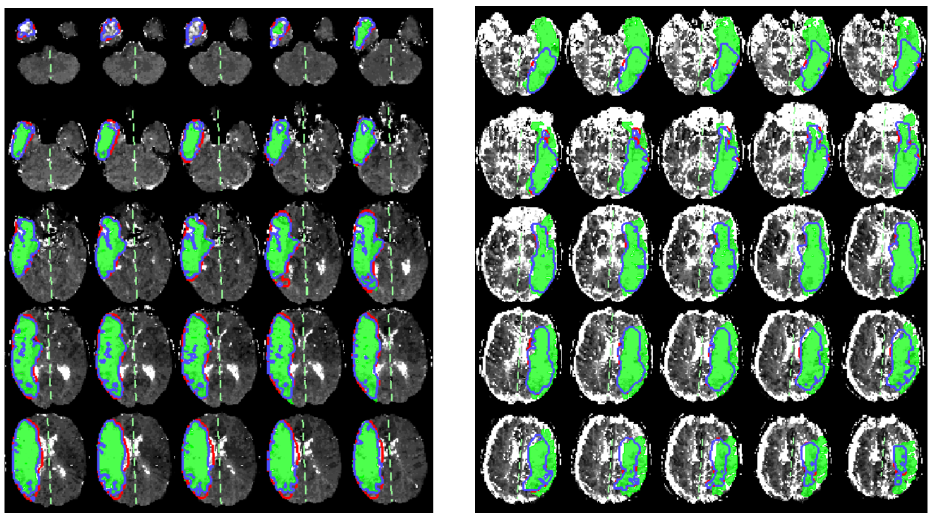

Fig. 2. Left: Training set 16. This example shows a good agreement with ground truth (green). The pre-selection of the potential lesion (red) defines an accurate restriction to the final segmentation (blue). **Right: Training set 10.** The significant discrepancy to the ground truth can partly be explained by the apparently insufficient brain extraction, which retains vessels outside of the skull with a strong Tmax enhancement. This might be falsely included in the ground truth, but excluded in the proposed method, as the enhancement is also present in the contralateral, healthy reference regions. The frontal part in the lower slices was likewise excluded in our segmentation, since the contralateral region also shows a significant enhancement.