Ischemic Stroke Lesion Segmentation

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Proceedings

5th October 2015

Munich, Germany

UNIVERSITÄT ZU LÜBECK

Technische Universität München

UNIVERSITÄT BERN

MICCAI 15 MUNICH

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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August 2015

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Version: 2015-09-30

Automatic Ischemic Stroke Lesion Segmentation in Multi-Spectral MRI images using Random Forests Classifier

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Abstract. This paper presents an automated segmentation framework for ischemic stroke lesion segmentation in multi-spectral MRI images. The framework is based on a random forests (RF), which is an ensemble learning technique that generates several classifiers and combines their results in order to make decisions. In RF, we employ several meaningful features such as intensities, entropy, gradient etc. to classify the voxels in multi-spectral MRI images. The segmentation framework is validated on MICCAI 2015 ISLES challenge training data sets. The performance of the framework is evaluated relative to the manual segmentation (ground truth). The experimental results demonstrate the robustness of the segmentation framework, and that it achieves reasonable segmentation accuracy for segmenting the sub-acute ischemic stroke lesion in multi-spectral MRI images.

Keywords: Segmentation, automatic, MRI, ischemic stroke lesion, random forests

1 Introduction

Multi-spectral magnetic resonance imaging (MRI) [1] can be used for detecting the ischemic stroke lesion and can provide quantitative assessment of lesion area. It can be established as an essential paraclinical tool for diagnosing stroke as well as for monitoring the efficacy of experimental treatments.

For a quantitative analysis of stroke lesion in MRI images, expert manual segmentation is still a common approach and has been employed to compute the size, shape and volume of the stroke lesions. However, it is time-consuming, tedious, and labor-intensive task. Moreover, manual segmentation is prone to intra-and inter-observer variabilities [2].

Therefore, the development of fully automated and accurate stroke lesion segmentation method has become an active research field. In literature [2–4], several automated segmentation methods have been proposed for stroke lesion segmentation over the years. However, the automated stroke lesion segmentation is still a challenging task because of the gradual changes of stroke lesion appearance in multi-spectral MRI images.

Herein, we present a fully automated framework for sub-acute ischemic stroke lesion segmentation in multi-spectral MRI images. The framework is based on a supervised classification method called random forests. The main contribution in the framework is employing a set of meaningful features and the choice of steps for pre-processing the MRI images and post-processing of segmented data.

2 Method

The schematic procedure of the segmentation framework is shown in Fig.1. The framework takes the multi-spectral MRI brain images as input and it includes two-step pre-processing: (1) Correction of bias field using the N3 bias field correction algorithm [5] and (2) normalization of intensity values of each MRI modality to the interval [0 1], done by applying the linear histogram stretching. For each voxel of multi-spectral MRI images, the following set of meaningful features is extracted.
1. MRI scans intensities: These features comprise the intensity in the 4 MRI scans (T1, T2, DWI, and FLAIR) provided by the data sets and the difference between each two scans. The total number of these features was 16.
2. MRI scans smooth intensities: A Gaussian filter with size $7 \times 7 \times 7$ was employed to each MRI scan in order to extract the smooth intensities. The total number of these features was 4.
3. MRI scans median intensities: A median filter with size $5 \times 5 \times 5$ was applied to each MRI scan to obtain the median intensities. The total number of these features was 4.
4. The gradient and magnitude of the gradient: A gradient in the x, y and z direction and their magnitude was computed in order to get the information about the lines and edges in each MRI scan. The total number of these features was 16.
5. Local entropy: The entropy for each voxel in the MRI scans was computed using the neighborhoods size $9 \times 9 \times 9$. The total number of these features was 4.

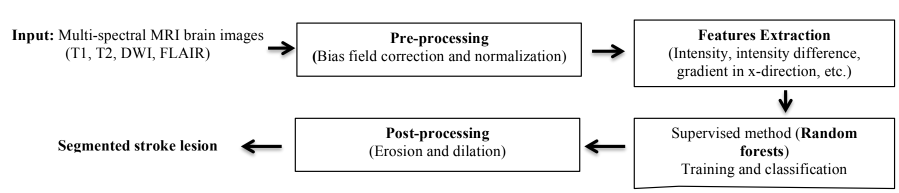


Fig. 1. Schematic procedure of the segmentation framework.

All features, mentioned above, were normalized to zero mean and unit deviation. These features are then employed to train the RF [6, 7] classifier and classifying the sub-acute ischemic stroke lesion. In RF the training is performed using labeled data sets provided from the ground truths by building multiple decision trees, wherein every node except the leaves is a decision node that contains a feature and its corresponding threshold. Every leaf node contains a probabilistic class distribution (histogram of class labels for the voxels that have reached that node). Moreover, in RF the building of multiple decision trees is based on a random selection of a subset of features (called bootstrap aggregating), which makes RF robust to overfitting. The classification is done by traversing voxels over the trees starting from the root of each tree to a leaf node. The voxels are split at a given node based on the classification of the feature/threshold at that node. The average probabilistic decision of the class distribution from all trees is considered the final probabilistic class distribution (voxel label in this scenario). The two important parameters that affect the efficiency of RF are a number of trees and depth of each tree. In our work, we set the RF parameters: number of trees =150 and depth of each tree=50. For training, a total of 999,000 data samples (37,000 samples per training data) were used to train the RF classifier. These samples were obtained by down sampling the majority class (non ischemic stroke) data in each training data set in order to make their frequencies closer to the minority class (ischemic stroke) data. The sampling was done randomly. Finally, the post-processing is performed using the dilation followed by an erosion operation by employing the 2D 5×5 square structuring elements in order to remove the small objects classified as stroke lesion.

3 Results

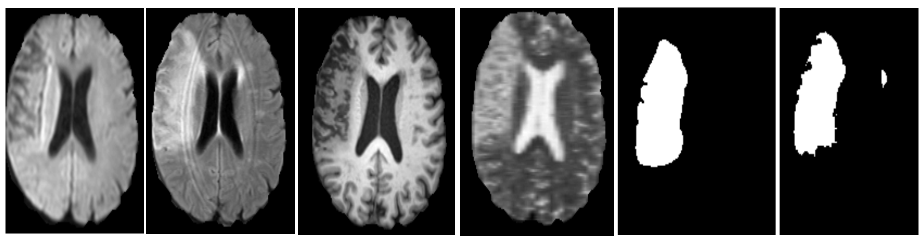
The evaluation is performed on MICCAI 2015 ISLES challenge training data sets using leave-one-out cross validation. The data sets comprise 28 sub-acute ischemic stroke lesion cases. The evaluation is done using the online evaluation system provided by the challenge organizers. Table 1 presents the average quantitative results of our segmentation framework in terms of average symmetric surface distance (ASSD), Dice, Hausdorff distance, precision and recall respectively. An example of the segmentation result for sub-acute ischemic stroke lesion for the training data set "01" is shown in Fig.2.

4 Conclusions

In this paper, we present an automated framework based on the RF classifier for segmenting the sub-acute ischemic stroke lesion using multi-spectral MRI images. We employ a set of meaningful features to train the RF and classify the ischemic stroke lesion. The experimental results show the efficacy of the segmentation framework and that it can segment the sub-acute ischemic stroke lesion with reasonable accuracy. For future work, we will explore more set of features in order to improve the accuracy of our segmentation framework. The total execution time of our segmentation framework is about 25 to 30 minutes for segmenting the stroke lesion for each training data set using the MATLAB on a MacBook Pro with an Intel processor (i5, 2.5 GHz) and 4 GB RAM.

Table 1. Average quantitative results of the segmentation framework in terms of ASSD, Dice, Hausdorff distance, precision and recall.

ASSD (mm)	Dice	Hausdorff Distance (mm)	Precision	Recall
10.30 ± 11.11	0.54 ± 0.26	82.78 ± 23.95	0.67 ± 0.33	0.50 ± 0.25



(a) (b) (c) (d) (e) (f)

Fig. 2. Example of segmentation result for axial slice number 88 for the training data "01": (a) DWI (b) Flair (c) T1 (d) T2 (e) ground truth and (f) automatic segmentation.

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