Super-pixel based Convolutional Neural Networks for Tumor Identification and Segmentation in Brain MRI

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Abstract

Tumor segmentation is a crucial task for a quantitative analysis of diverse radiological applications and yet remains a challenging problem, especially in magnetic resonance (MR) imaging due to its highly heterogeneous tissue-contrast. However, some brain tumors such as glioblastoma multiforme (GBM) are much more difficult to localize than other brain tumors. This study aims to investigate if deep learning is able to perform GBM segmentation assistants in multi-parametric brain MR imaging. MR images of 66 GBM patients (30 females, 36 males) were downloaded from The Cancer Imaging Archive (TCIA). Among them, 36 GBM sets were randomly selected as a training set and the rest 30 sets were used for a testing set. In this study, we implemented two-step tumor segmentation schemes: step one was multiscale super-pixel algorithms; step two was convolutional neural network type deep learning which further classifies super-pixels into the tumor or parenchymal tissue. Among the 750 tumor containing images, tumors were correctly identified in 710 images, with 40 false markings, yielding 96.4% sensitivity and 94.8% specificity. The overall segmentation agreements assessed with dice similarity coefficient was 0.87. The performances of deep learning as a tumor segmentation assistant was reasonably acceptable in most of the cases.

1 Introduction

Segmentation of heterogeneous tumors are clinically demanding task for improving reliabilities in diagnosis and treatment procedures, and yet remains a challenging problem. In particular, glioblastomas multiforme (GBM) are much more difficult to localize than other brain tumors since these tumors tend to be diffuse and poorly contrasted. Recently, deep learning methods have been widely used for several applications including image segmentation and classification [1-3]. In brain tumor segmentation also, deep learning method is reported [1] to bear a good potential for providing superior results over conventional methods. In this study, we propose a fully-automated brain tumor identification and segmentation based on convolutional neural network (CNN). We designed super-pixel based CNN architecture to learn the tumor characteristics and we ordered the patch from multiscale of super-pixel images. The super-pixel patches were extracted from each of the tumor and tissue areas. Those patches were fed into the CNN for training. At the same time, we also extract a statistic feature from the whole data sets and feed it on the CNN for every patch which is derived from the same brain images in order to teach the context information.
2 Materials and Methods

2.1 Dataset

MR images of 66 GBM patients were downloaded from The Cancer Imaging Archive (TCIA) database [4], in which T1 pre-image, post contrast T1-weighted image, and fluid-attenuated inversion recovery (FLAIR) MR sequences were tested. Of those 66 GBM sets, 36 GBM sets were randomly selected as a training set and the rest 30 sets were used for a test set to validate the trained CNN. In addition, two radiologists provided the tumor region segmentation masks on the training set.

2.2 Schematic overview

The overall procedure consisted of three main steps as shown in Figure 1. The first step was preprocessing step, in which the image was over-segmented using super-pixel and grouped into similar pixels from the three different image modalities. The second step involved the CNN training in a supervised mode. In the last step, the probability map of tumor region or parenchymal tissue was extracted from the trained CNN and the final tumor region was calculated.

![Figure 1: An overall schematic diagram.](image)

2.3 Super-pixel based convolutional neural network

The CNN architecture is shown in Figure 2. The local and global statistics features were extracted from the over-segmented super-pixel regions and fed into the CNN along with patch-wise probability derived from the binary masks for each patch image. The final segmentation of the tumor region was obtained at the final node of CNN and those pixels with probability values higher than 0.8.

![Figure 2: Schematic diagram of the CNN used in this study.](image)
3 Results

3.1 Visual assessment

Examples of the visual assessment are shown in Figure 3. In Fig. 3(a) shows the three different original images and Fig. 3(b) shows the tumor identification result in the green box. Here, the red one is the reference image. The probability map of the final tumor region obtained the follow Fig.3(c) from the trained CNN was marked with the red contour in Fig.3(d).

![Figure 3: Results of super-pixel based CNN tumor identification and segmentation.](image)

(a) The original image, (b) Identification result, (c) Probability map of extraction, (d) Segmentation result with the red contour (reference image: yellow contour).

3.2 Quantitative assessment

Tumor identification performance was evaluated with sensitivity and specificity. Agreements of computer-assisted tumor segmentation evaluated by calculating the dice similarity coefficient between the reference and our segmentation results. Shown in Table 1 are the average value of sensitivity, specificity, and dice similarity coefficient. Among the 750 tumor containing images, tumors were correctly identified in 710 images, with 40 false markings, yielding 96.4%±3.6 sensitivity and 94.8%±5.1 specificity. The overall segmentation agreements as assessed with dice similarity coefficient was 0.87.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Tumor Components</th>
<th>Contrast enhancing</th>
<th>Edema</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td></td>
<td>95.7% ± 3.7</td>
<td>97.1% ± 2.8</td>
<td>96.4% ± 3.6</td>
</tr>
<tr>
<td>Specificity</td>
<td></td>
<td>94.1% ± 5.8</td>
<td>95.5% ± 4.1</td>
<td>94.8% ± 5.1</td>
</tr>
<tr>
<td>Dice Similarity Coefficient</td>
<td></td>
<td>86.5% ± 6.3</td>
<td>87.7% ± 4.7</td>
<td>87.1% ± 5.9</td>
</tr>
</tbody>
</table>

4 Conclusion

Our study explored the potential of deep learning-based identification and segmentation technique for multiparametric MR images. The result of deep learning as a fully automated tumor segmentation was reasonably acceptable in most of the cases. In particular, the identification of the tumor images was correctly detected. The proposed method has a potential to work as an assistant for tumor segmentation and quantitative analysis of tumor characteristics, especially in brain MRI.

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Reference