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Pneumothorax Detection and Localization in X-Ray Images Given Richer Annotation Information

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Introduction

A pneumothorax is a collapsed lung that occurs when air leaks into the space between the lung and chest wall. It is one of the most common thoracic injuries and poses a risk of serious morbidity. The diagnosis of pneumothorax using chest X-ray is considered a difficult task due to its subtle characteristics, which consist of a subtle curved contour due to the visceral pleura and a dark region due to the increased transparency and a lack of lung structure. In this paper, we propose a novel end-to-end deep learning framework to automatically detect and localize the pneumothorax regions in X-ray images given mask annotations pertaining to regions of interest (ROI). The classification and localization network (ClaSegNet) is a fully convolutional neural network (CNN) and outputs the image-level label and localization map during inference. The experiment results showed that our method can improve both classification and localization accuracy while using mask information, compared to classification using image-level labels only.

Methods

As shown in Fig. 1, the input image is processed by a CNN (any CNN can be used, e.g. ResNet and Inception) to extract convolutional feature maps, which would be used by the classification and localization network that creates a score map. During training, we use the mask of ROI that is matched with the size of feature map by rational mask pooling for comparing it with the predicted mask of the same size. Please note that the class label is rather implicit and comes from mask (any positive mask elements above a size threshold would signal the presence of the class). For testing, the score map provides predicted classification label with a localization map.

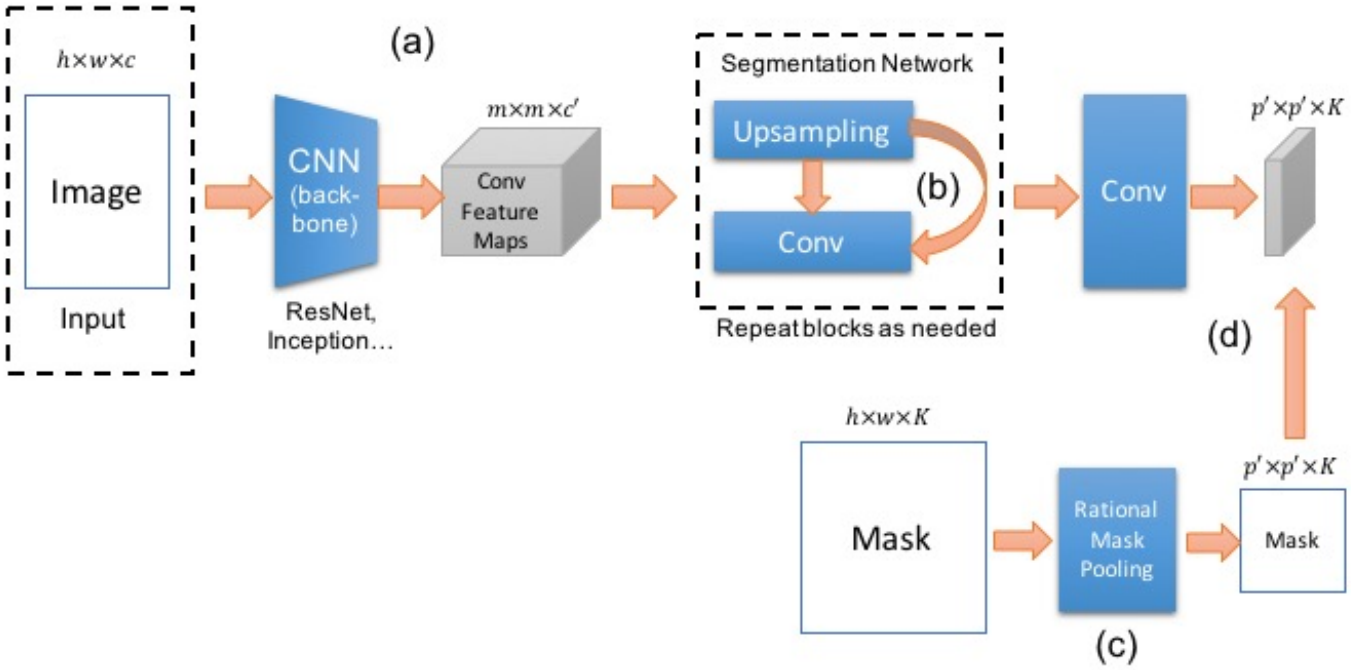

Fig. 1 The diagram of ClaSegNet: (a) feature extraction by CNN; (b) repeatable segmentation network; (c) novel rational mask pooling to generate masks for training and (d) end-to-end training with node-wise loss function.

Results

We conducted experiments on a dataset consists of pneumothorax and non-pneumothorax chest X-ray images that are extracted from a public NIH database. All the pneumothorax masks are annotated by our radiologists. The total 1806 images are split to 1444 training (80%), 180 validation (10%) and 182 testing (10%) images. The results are shown in Table I. The testing accuracy of the proposed method is 0.923 and AUC is 0.979 with dice coefficient 0.5, which is outperformed the classification network trained only with image-level labels. Some qualitative examples are shown in Fig. 2.

Table 1

Table I The experimental results

Model	val Accuracy	val Precision	val Recall	val AUC	val Dice	test Accuracy	test Precision	test Recall	test AUC	test Dice
Classification	0.894	0.899	0.889	0.941		0.896	0.875	0.923	0.945	
ClaSegNet	0.95	0.966	0.933	0.98	0.518	0.923	0.953	0.89	0.979	0.5

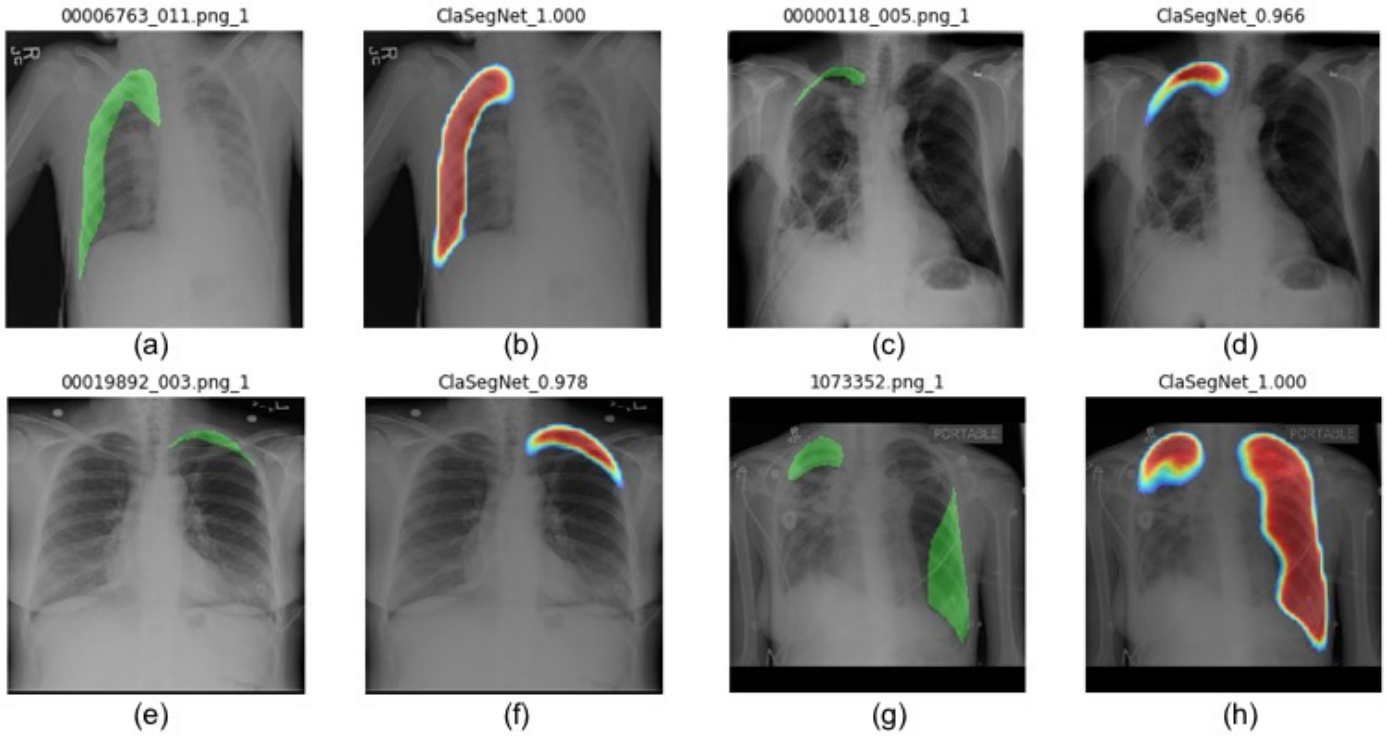

Fig. 2 Qualitative examples of localization maps: (a), (c), (e), (g) are ground truth and (b), (d), (f) (h) are the corresponding predicted localization maps.

Discussion

From the experimental results, we can see that by providing richer annotation information, e.g. masks, the classification accuracy is improved, and the network also outputs promising localization maps. This is achieved by the same underlying prediction model for both tasks. The framework is flexible and can be generalized to other applications due to three aspects: 1) The selectable CNN backbone; 2) the repeatable segmentation network and 3) the tunable mask size.

Conclusion

We propose a novel network that jointly models classification and localization and apply it to pneumothorax detection in chest X-ray images. The experimental results demonstrate that our method outperforms the classification network using image labels only and can also provide accurate localization maps.

Keywords

convolutional neural networks; pneumothorax; X-ray; classification; localization