Medical Image Segmentation Based on Deep Feature Learning and Multistage Classification

WANG XIAOHONG

Abstract

Automatic segmentation of objects in medical image plays a crucial role in the computer-aided diagnosis of human diseases, like retinal vessel from fundus image, and melanoma from dermoscopic image. Manual segmentation of those tissues is a time consuming and labour intensive task that is not feasible for clinicians to detect a large amount of medical images by hand. Thus, a reliable medical image segmentation system with lower cost and less human interaction than the observed-based techniques is attractive in the field of medical image analysis area. This thesis investigates medical image segmentation architectures through deep feature learning and multistage classification. Specifically, we proposed two novel multistage classification schemes for retinal vessel segmentation. For more complex and large dermoscopic image data analysis issue, we proposed a novel deep feature learning scheme for skin lesion segmentation. Details of the completed works are summarized follows:

In the first scheme, a novel and robust retinal vessel segmentation framework is proposed, which envelops a set of computationally efficient Mahalanobis distance classifiers to form a highly nonlinear decision. Different from other nonlinear classifiers that need a predefined nonlinear kernel or need iterative training, the proposed cascade classification framework is trained by a one-pass feed forward process. Thus, the degree of nonlinearity of the proposed classifier is not predefined, but determined by the complexity of the data structure. Experimental evaluations on three publicly available databases show that the proposed cascade classification framework achieves high vessel segmentation accuracy consistently on all three diverse databases.

In the second scheme, a hierarchical architecture for retinal vessel segmentation based on a divide-and-conquer strategy is designed. Current works for retinal vessel segmentation typically train a global discriminative model for retinal vessel classification that is still not sufficiently to fit the complex pattern of vessel structure. In fact, the large geometrical structure difference among retinal vessels with different

scale and position greatly limits the precision of the decision boundary of the global discriminative model. To overcome this problem, an efficient dividing algorithm, named multiplex vessel partition (MVP), is proposed to divide the retinal vessel into well constrained subsets where vessel samples with the same geometrical property are assigned together. Then, a set of homogeneous classifiers are trained in parallel to form discriminative decision for each subset. Moreover, a funnel-structured vessel segmentation (FsVS) framework is proposed to link the classification results from each disjoint subset, which reduces the probability of poor partition at the dividing phase and further enhances the complexity and discriminative capability of the decision model. Both quantitative and qualitative experimental comparisons on three publicly databases demonstrate the flexibility and efficiency of the proposed work on retinal vessel segmentation.

In the last scheme, a bi-directional feature dermoscopic learning framework with multiscale consistent decision fusion is proposed for skin lesion segmentation. Previously published skin lesion segmentation works enhance lesion detection performance by using deep learning based methods like fully convolutional network (FCN). Nevertheless, relationship between skin lesions and their informative context, as well as the consistency of the decision from multiple classification layers, have not yet been well explored by these previous studies. Different from the naive way of FCN learning an abstract feature representation of image, this thesis proposes a bi-directional dermoscopic feature learning (biDFL) framework that produces more meaningful dermoscopic feature maps by controlling information propagation from two complementary directions at high level parsing layer. With the integration of both directional feature information passing, the proposed biDFL module gives better insight to the network about the complex structure of the skin lesion. Furthermore, this thesis proposes a multiscale consistent decision fusion (mCDF) that is capable of selectively focusing on the informative decisions generated from multiple classification layers. By analysis of the consistency of the decision at each position, mCDF automatically adjusts the reliability of decisions and thus allows a more insightful skin lesion delineation. With the embedding of consistency analysis to the decisions from each classification layer, the proposed mCDF assists the network to learn better about which scales of features are more desirable for each individual pixel. The comprehensive experimental results show the effectiveness of the proposed method on skin lesion segmentation, achieving the state-of-the-art performance consistently on two publicly available dermoscopic image databases.

Publications

Journal papers:

[J1] **X. Wang**, X. Jiang, and J. Ren. Blood vessel segmentation from fundus image by a cascade classification framework, *Pattern Recognition*, 88: 331–341, 2019.

[J2] **X. Wang**, X. Jiang. Retinal vessel segmentation by a divide-and-conquer funnel-structured classification framework, *Signal Processing*, 165: 104-114, 2019.

[J3] **X. Wang**, X. Jiang, H. Ding, J. Liu. Bi-directional dermoscopic feature learning network with multi-scale consistent decision fusion for skin lesion segmentation, (submitted to *IEEE transaction on image processing*)

Conference papers:

[C1] **X. Wang**, H. Ding and X. Jiang. Dermoscopic image segmentation through the enhanced high-level parsing and class weighted loss, in *Proc. 26th IEEE International Conference on Image Processing (ICIP)*, 2019.

[C2] **X. Wang** and X. Jiang. Post-processing for retinal vessel detection, in *Proc. 10th International Conference on Digital Image Processing (ICDIP)*, p.1080656, 2018.

[C3] **X. Wang** and X. Jiang. Enhancing retinal vessel segmentation by color fusion, in *Proc. 42nd IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 891–895, 2017.

[C4] **X. Wang** and X. Jiang. Nonlinear retinal image enhancement for vessel detection, in *Proc. 9th International Conference on Digital Image Processing (ICDIP)*, p. 104202M, 2017.