Multi-label Classification Scheme based on Local Regression for Retinal Vessel Segmentation

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1. Introduction

- We proposed a novel multi-label classification scheme for retinal vessel segmentation.
- In our proposed scheme, a local de-regression model is designed for multi-labeling
- and a convolutional neural network is used for multi-label classification.
- At addition, a local regression method is utilized to transform multi-label into binary label for locating small vessels.
- The experimental results show that our method achieves prominent performance for automatic retinal vessel segmentation, especially for small blood vessels.

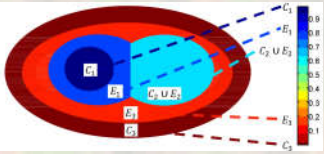

Fig. 1. Simplified mixture model of our LODESS model. C: Center, E: Edge, 1: big vessel, 2: small vessel, 3: background.

2. Proposed Method

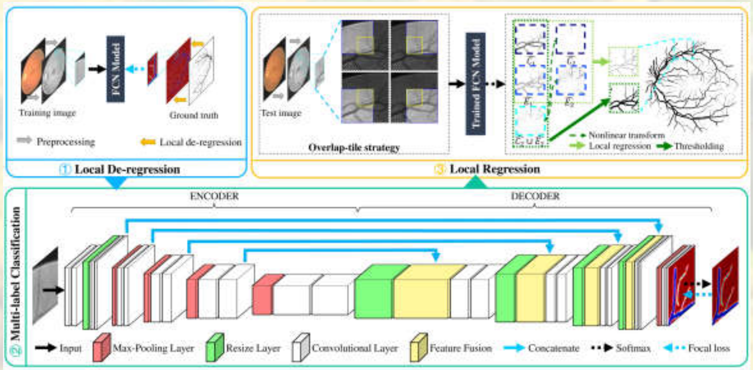

Fig. 2. Overall architecture of our method.

- The precise segmentation of retinal vessel serves as an important cue for diagnosis and evaluation of various cardiovascular and ophthalmologic disorders such as diabetes, hypertension and choroidal neovascularization. In addition, retinal vessel is found to be unique for each individual and thus its segmentation result can be used for biometric identification. However, it is tedious and time consuming to segment retinal vessel manually
- Most of previous efforts only involved finding better classifier or better network structure. They formulate this task into a binary classification problem, but they rarely consider the differences between small vessels and big vessels when doing segmentation. Therefore, previous methods are not accurate enough on small blood vessel segmentation.
- To address this issue, the problem of retinal blood vessel segmentation is reformulated to a multi-label classification task. In this manner, more discriminative representations of small vessel can be captured.

3. Materials

- The proposed method is evaluated on the DRIVE and STARE databases (40 and 20 images respectively).
- One-off and leave-one-out strategies are utilized for the division of training set and test set.

Fig. 3. From left to right: fundus image (DRIVE), ground truth (DRIVE), fundus image(STARE) and ground truth (STARE)→

4. Details

LODESS for Labeling

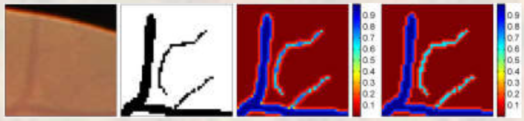

Fig. 4. Example of LODESS (from left to right: original image, ground truth, LODESS, and simplified LODESS).

- We defined the LODESS (local de-regression) as:

$$LODESS = \begin{cases} 0.5 + \dfrac{1+\Sigma_{z\in N_x} P(1\mid z)}{2(1+|N_x|)} & \text{if x is vessel} \\ 0.5 - \dfrac{1+\Sigma_{z\in N_x} P(0\mid z)}{2(1+|N_x|)} & \text{otherwise.} \end{cases}$$

where z is the adjacent pixel of x.

- To reduce the number of labels, morphological operator can be used here to simplify the LODESS as shown in Fig. 4.

LOESS for Refinement

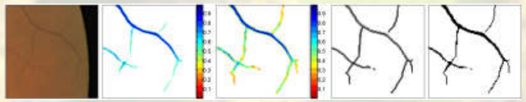

Fig. 5. Each step of refinement (from left to right: original image, LODESS, NLE, LOESS, Proposed).

- As shown in Fig. 5., the holistic flow path for refinement is considered as follows. 1) Prediction of LODESS: a multi-label result output by our CNN is used for the segmentation of big blood vessel in fundus images; 2) Nonlinear Enhancement (NLE): a nonlinear function is applied to detect small retinal vessels from the last result; 3) LOESS: a LOESS method is utilized for obtain the precise segmentation of small retinal vessels from the NLE images; 4) Proposed: LODESS and LOESS are fused into the proposed segmentation of retinal blood vessels.

Experimental Results

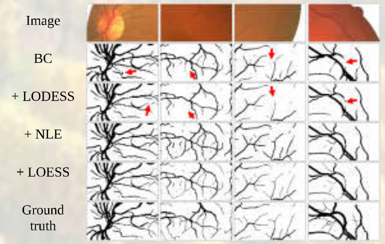

Fig. 6. Qualitative comparison of each phase on DRIVE (black: vessel, white: background).

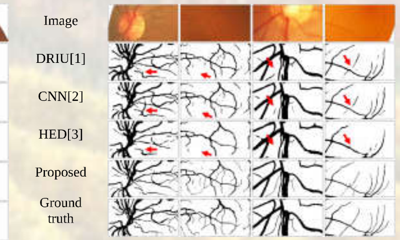

Fig. 7. Qualitative comparison of the current state-of-the-art on DRIVE (the 1st and 2nd columns) and STARE (the 3rd and 4th columns).

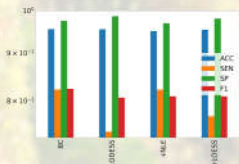

Fig. 8. Ablation experiment (BC: binary classification, NLE: nonlinear enhancement).

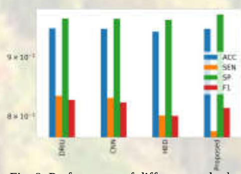

Fig. 9. Performance of different methods on DRIVE.

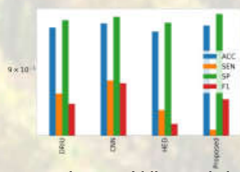

Fig. 10. Performance of different methods on STARE.

- The results show that our method is very effective for blood vessel segmentation in retinal images, and performs better than all methods of comparison on small retinal vessels because of our multi-label classification scheme.

Conclusion

- In this study, a multi-label classification scheme based on local regression is proposed for automatic retinal vessel segmentation. To effectively reformulate this segmentation problem into multi-label classification task, we proposed several dedicated methods, such as local de-regression and local-regression for the conversion between binary labels and multiple labels. We also present a FCN-based deep learning model to solve the imbalance between multi-label classes. Our experimental results have demonstrated that our method achieve prominent accuracy on the segmentation of retinal vessel in fundus images, especially for the segmentation of small blood vessels.
- Further information: mail to heqi_work@qq.com or browse https://ieeexplore.ieee.org/abstract/document/8451415/

References

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