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**COMP 478 Image Processing**

Retinal vessel extraction by matched filter with first-order derivative of Gaussian

# Review

**Motivation and Contributions**

The extraction of retinal vessel is one of the most important tasks in retinal image analysis for various medical applications. There are several different approaches to vessel segmentation, including filtering-based methods, mathematical morphology, trace-based methods and machine-learning models.

Of all the methods, matched filter (MF) is introduced as a representative approach, emphasizing its simplicity and effectiveness. However, MF has limitation, as it may produce false detections due to its strong response to non-vessel edges. To address these limitations, a novel method is introduced called Matched Filter with First-Order Derivative of Gaussian (MF-FDOG). This is an extension and generalization of MF which aims to improve vessel extraction accuracy.

**Main approach**

The proposed method MF-FDOG involves using a pair of filters, the zero-mean gaussian filter (MF) and the first-order derivative of the Gaussian (FDOG) to detect vessels. The Matched filter assumes that the cross-section of vessels can be approximated by a Gaussian function. It utilizes a Gaussian-shaped function to “match” vessels for detection. MF will be rotated and applied in 8 directions to detect different orientations of the blood vessels.

The response to the MF is strong around the peak position of vessels, while the response to the FDOG is anti-symmetric. In contrast, non-vessel edges have positive and symmetric responses to both MF and FDOG. By adjusting the threshold based on the local mean response of the FDOG, the MF-FDOG aims to improve vessel detection accuracy.

The proposed thresholding scheme involves setting the threshold for vessel detection based on both the MF response and the local mean response of the FDOG. This adaptive thresholding allows for the differentiation between vessels and non-vessel structures more effectively.

Moreover, a multi-scale MF-FDOG approach is used to extract both thick and thin vessels. Different scales are used to detect thick and thin vessels, and the results are combined using the logical OR operation.

**Critiques**

The paper compares the proposed MF-FDOG method with several existing methods, but the comparison is somewhat limited. It would be beneficial to include a more comprehensive analysis, comparing a wider range of state-of-the-art methods and discussing their strengths and weaknesses.

Common performance metrics are used such as detection accuracy, true positive rate (TPR), and false positive rate (FPR). While these metrics are standard, the paper could benefit from discussing additional metrics or providing a more detailed analysis of the chosen metrics. For instance, precision, recall, and the F1 score could offer a more comprehensive evaluation.

# Implementation

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Description automatically generated

The goal of the paper was to implement a simple and effective method to extract blood vessels from retinal images, along with not having strong responses to the edges of bright blobs and red lesions of retinal images. The primary goal of this re-implementation was to faithfully recreate the method described in the paper and evaluate its performance on retinal images.

After implementing the give methods from the paper, the results were able to extract vessels from the retinal images. The vessels weren’t close to the ground truth. It detected all of the thick vessels, but not all of the thinner vessels. Also because of the MF-FDOG, the results didn’t detect any edges of bright blobs and red lesions, which was the main point of using FDOG.

Also just applying the methods from paper, didn’t remove much noise.

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Description automatically generated

So to remove it, I applied morphological operations to remove noise and enhance the binary images. Which removes a lot of the noise, however still left with smaller noise particles.

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Description automatically generated

To remove that as well, I applied contour removal by first finding contours and filter them based on area, then filter out contours based on aspect ratio to remove square noise.

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Description automatically generated

After testing out with different parameters, including the once given in the paper, it resulted in some images, having almost no noise, but some of them, especially that have connected vessels, that form a shape had noise in between them. I was not able to remove that noise.

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To test the methods, I used the DRIVE dataset that was provided. I tested the algorithm on all the 20 images and compared them to the 1st manual folder as the ground truth to check to accuracy. With the given parameters, it works well on multiple images, but not on all of them.

s and L were set to 1.5 and 9 respectively for wide vessels. Other parameters resulted in wither no detection in vessels or too much noise.

S=5 and L = 10A close-up of a white object

Description automatically generated s = 1.5 and L = 10A close-up of a white object

Description automatically generated

For morphological operations, the size of the array could not exceed 2x2 as it would remove too many edges including a lot of the vessels. However, it did remove the edge surrounding the retinal

A close-up of a white object

Description automatically generated3x3 array

The re-implementation of the MF-FDOG method for retinal blood vessel extraction proved to be successful. The implementation reproduced the algorithm described in the paper, and the results demonstrated its effectiveness in accurately detecting retinal vessels. The multi-scale approach, adaptive thresholding, and the use of both MF and FDOG contributed to the method's robust performance, showcasing its potential utility in computer-aided diagnosis applications.

While the re-implementation was successful to some extent, further refinements could be explored, including additional post-processing steps to address specific limitations in challenging cases. Future work may also involve an exploration of the method's applicability to other medical imaging tasks.

# References

[1] B. Zhang, L. Zhang, L. Zhang, and F. Karray, “Retinal vessel extraction by matched filter with first-order derivative of Gaussian,” *Comput Biol Med*, vol. 40, no. 4, pp. 438–445, Apr. 2010, doi: 10.1016/J.COMPBIOMED.2010.02.008.