

Segmentation of Blood Vessels in Retinal Images

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Outline

- Problem & Motivation
- Literature review
- Methods
- Implementation
- Results



Problem & Motivation

- Automated segmentation of blood vessels
- Diagnosis of
 - Diabetic retinopathy
 - Hypertension
 - Glaucoma etc.
- Manual segmentation
 - Time consuming
 - Inter-expert variability
 - Intra-expert variability



Literature Review

- **Supervised methods**
 - Exploits prior label information
- **Unsupervised methods**
 - No prior label information required



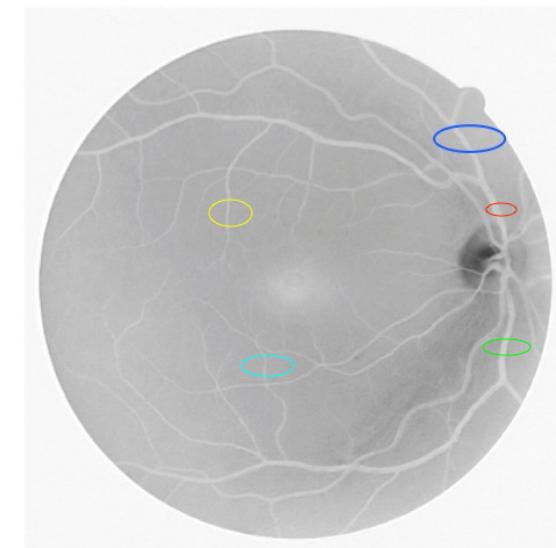
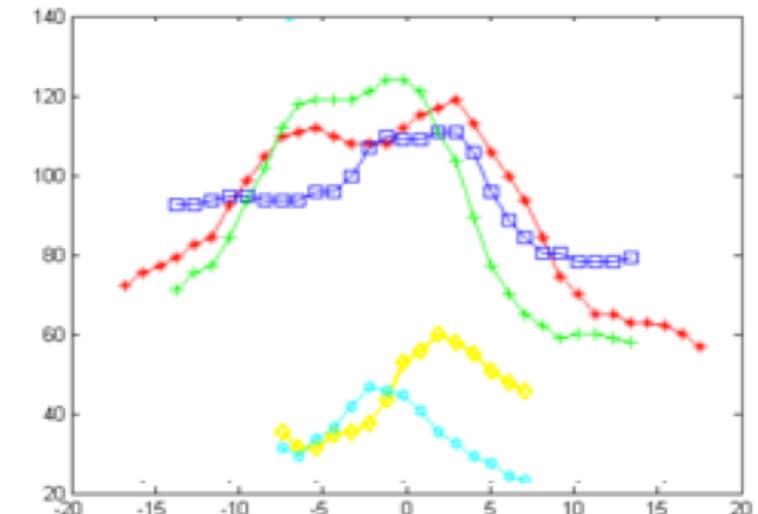
Matched Filter

■ Matched filter

- Blood vessels are piece-wise linear structures
- Intensity profile of cross section of vessel can be approximated by Gaussian
- Convolve image with 2-D Gaussian filter
- Global thresholding

$$f(x, y) = \frac{1}{\sqrt{2\pi s^2}} e^{(-\frac{x^2}{2s^2})} - m, \text{ for } |x| \leq 3s, |y| \leq \frac{L}{2}$$

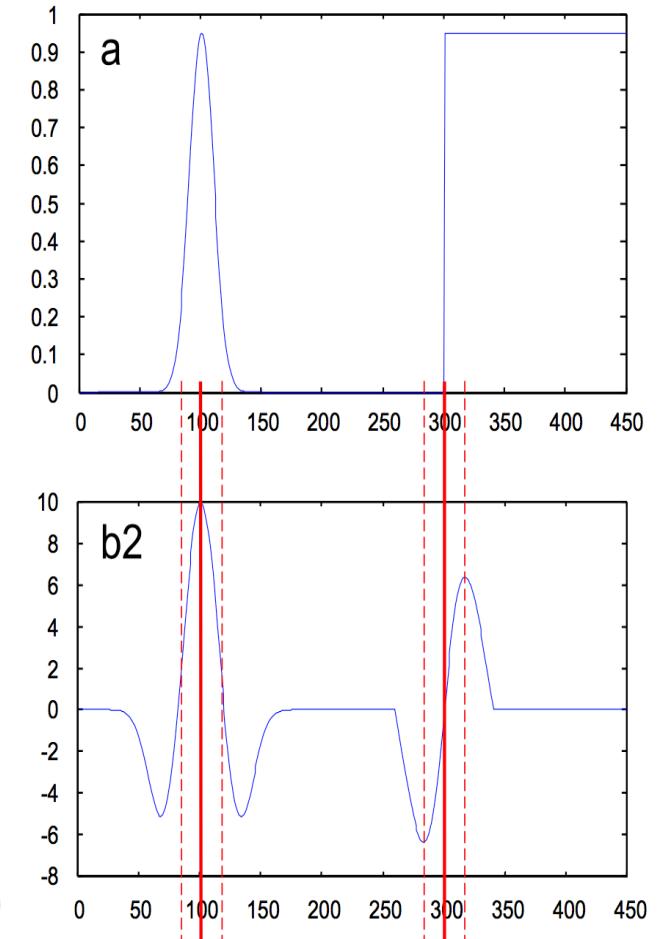
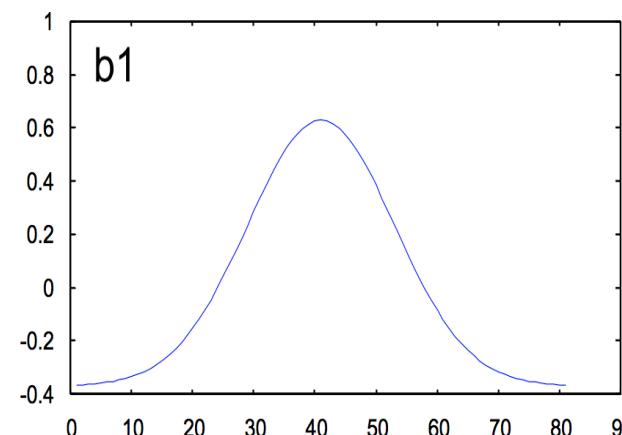
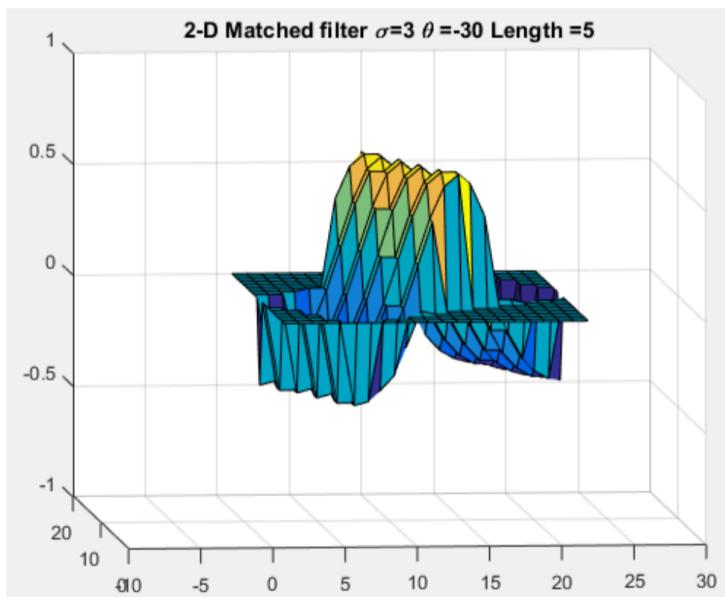
$$m = \frac{\int_{-3s}^{3s} \frac{1}{\sqrt{2\pi s^2}} e^{(-\frac{x^2}{2s^2})} dx}{2 \times 3 \times s}$$





Matched Filter - Drawback

- Responds to vessels as well as non-vessel edges





First Order Derivative of Gaussian

- Convolve with FDoG filter to get D

$$f'(x, y) = \frac{-x}{\sqrt{2\pi}s^3} e^{(-\frac{x^2}{2s^2})} - m$$

- Decide threshold based on FDoG output

$$D_m = D * W$$

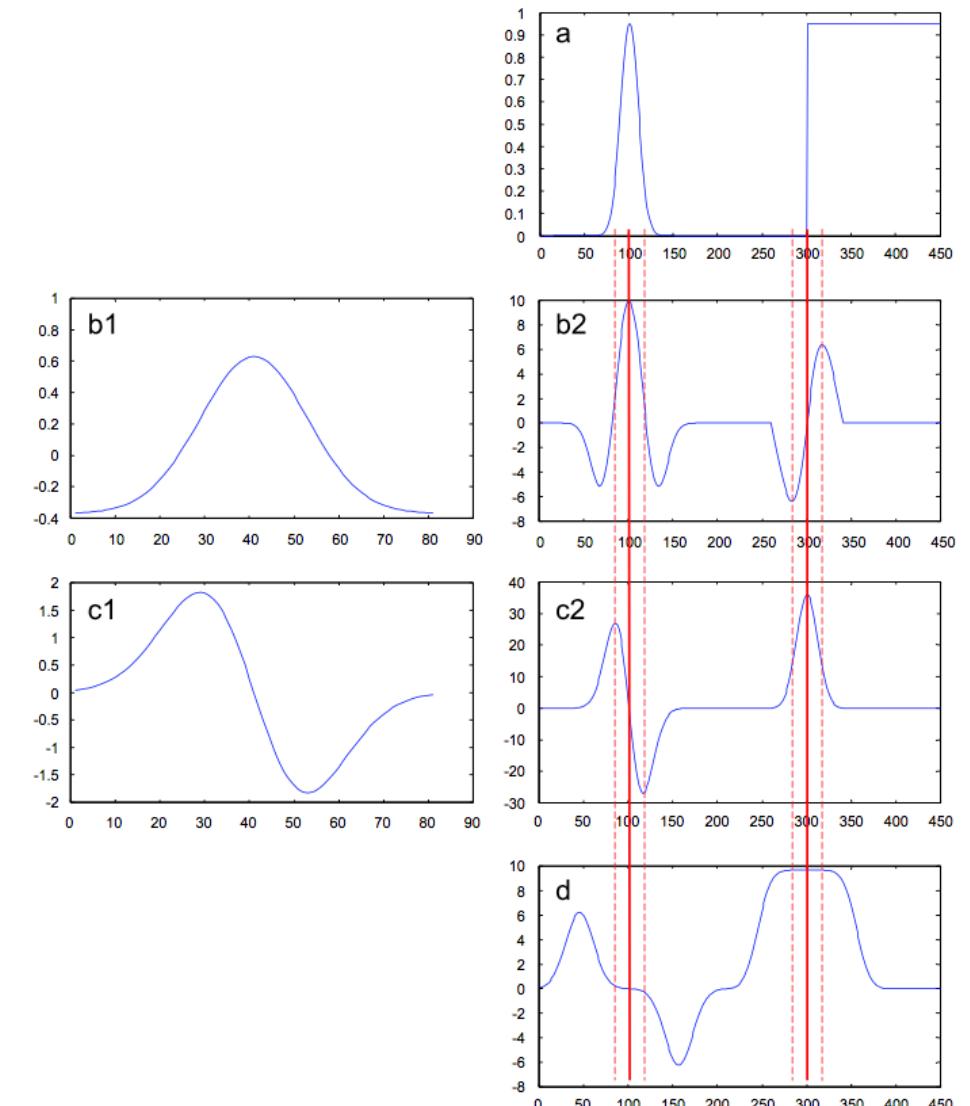
$$T = (1 + D_m)\mu_H$$

W – Mean filter of size w×w

T – threshold

D_m – Mean filtered D

μ_H = mean of Matched filter output



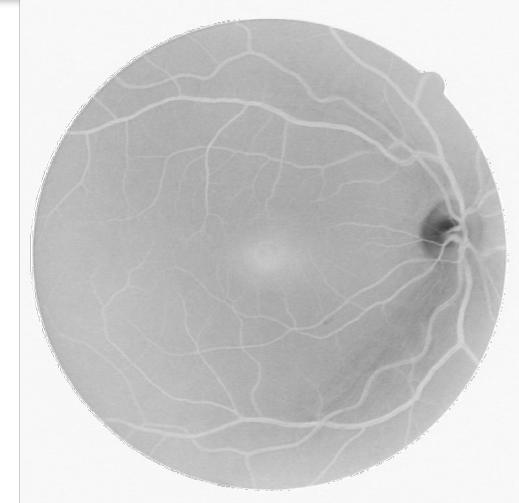


Implementation

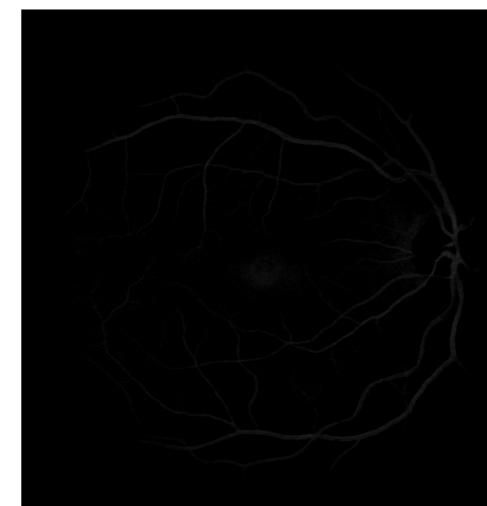
- Invert green channel image
- Pre-processing
 - Intensity inhomogeneity correction
 - Subtract mean filtered image



Original image



Inverted green channel image



After mean subtraction

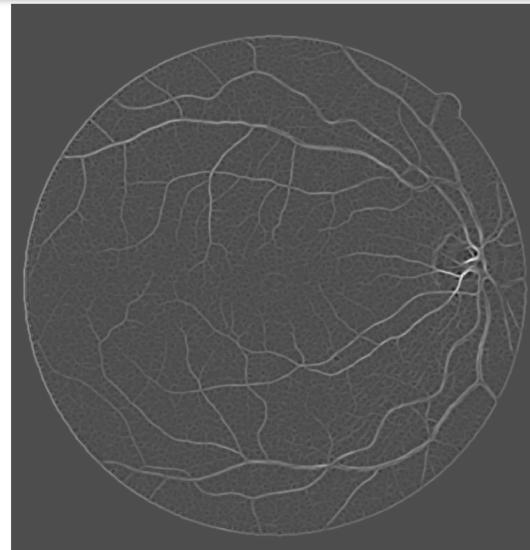


Normalized image



Implementation

- Convolution with oriented matched filter
 - 2 scales – $s \in \{1.5, 3\}$
 - 6 angles –
 $\{0, 30, 60, 90, 120, 150\}$
 - Fuse all responses – max response for each pixel



Max response when $s = 1.5$

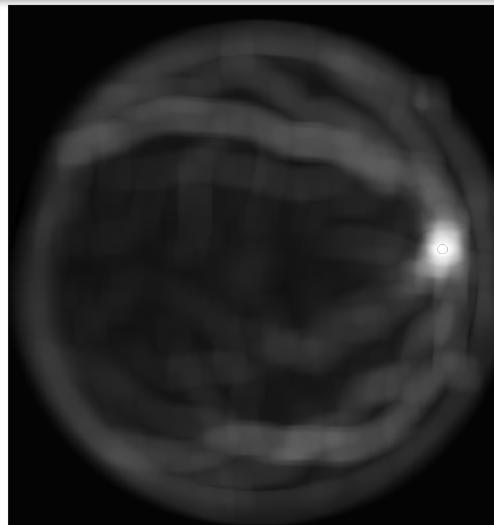


Max response when $s = 3$

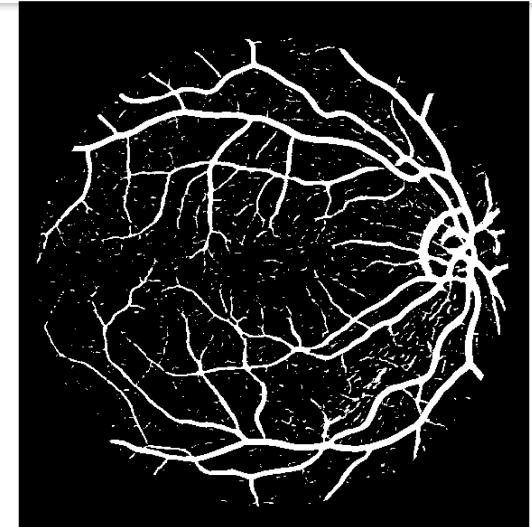


Implementation

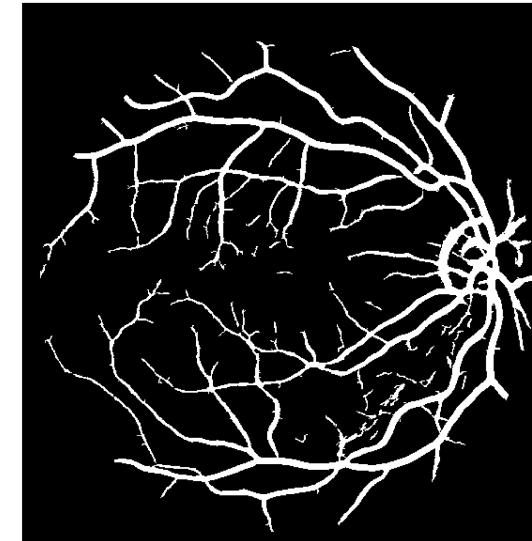
- Convolution with oriented FDoG filter
 - 2 scales – $s \in \{1.5, 3\}$
 - 6 angles – $\{0, 30, 60, 90, 120, 150\}$
 - Fuse all responses – max response for each pixel
- Thresholding based on FDoG response
- Post-processing
 - Connected component analysis to remove speckle noise



Fused response of FDoG



Response of Thresholding



After post processing



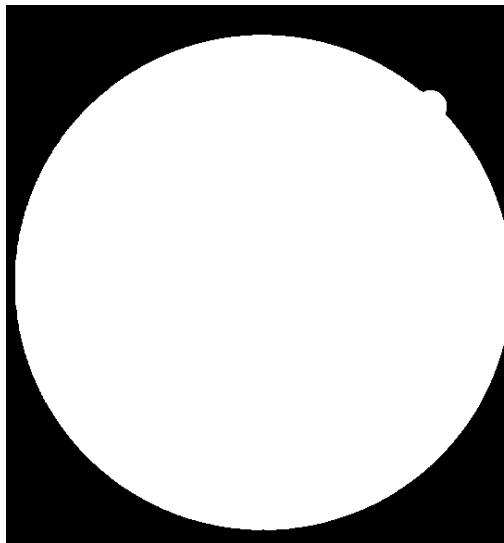
Data set

■ DRIVE dataset

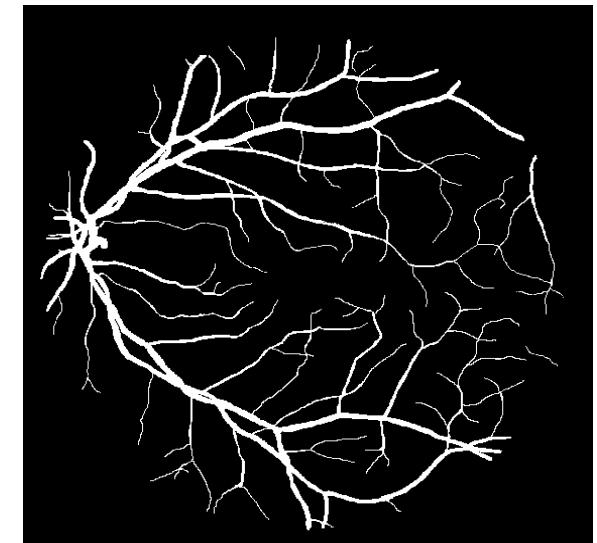
- 40 retinal images
- Mask of FOV
- Ground Truth – Segmented by human observer



Original Image



FOV Mask



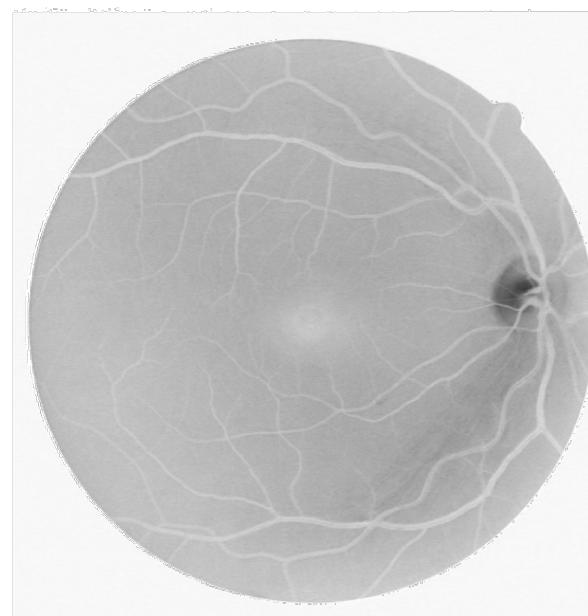
Ground Truth



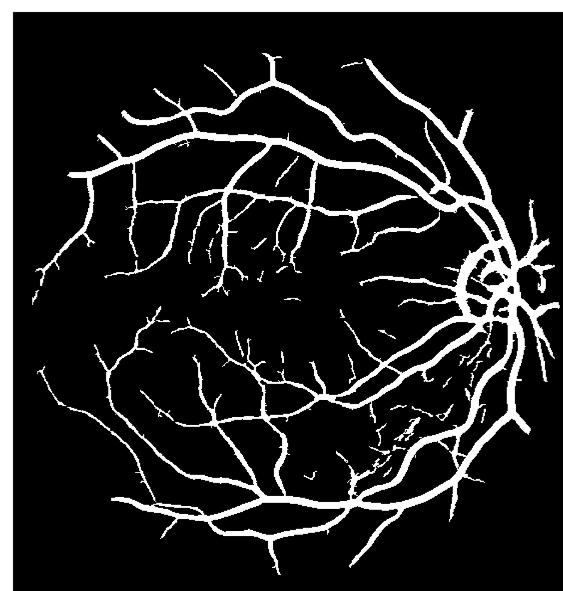
Results



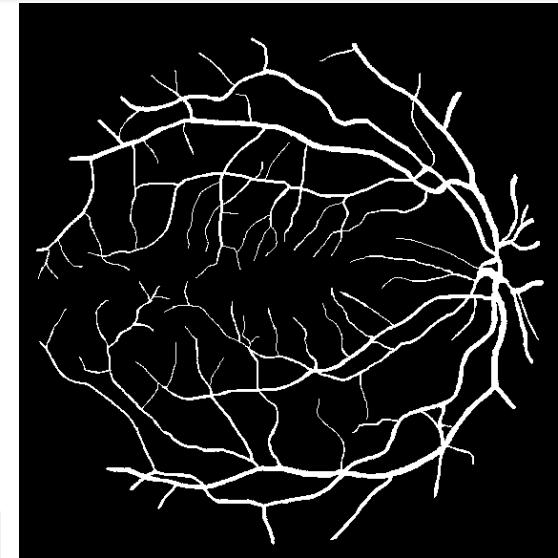
Original Image



Inverted green channel image



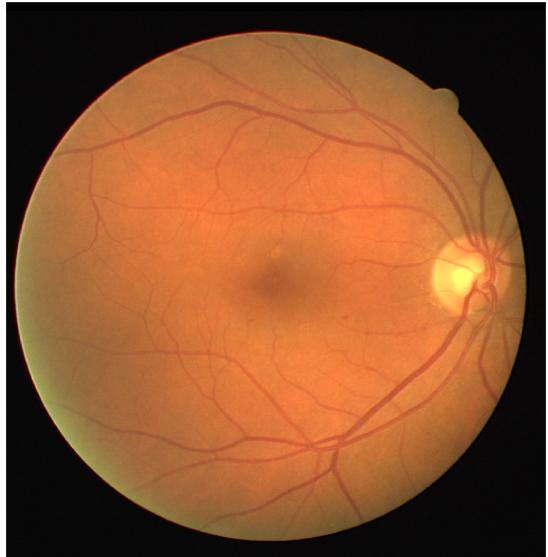
Proposed Method



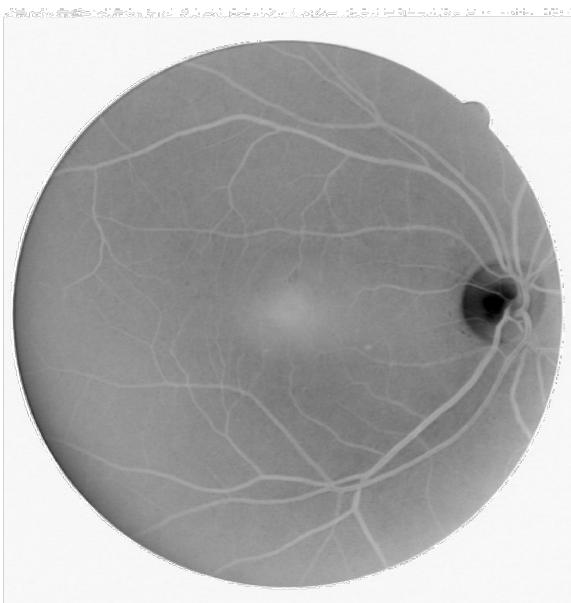
Ground Truth



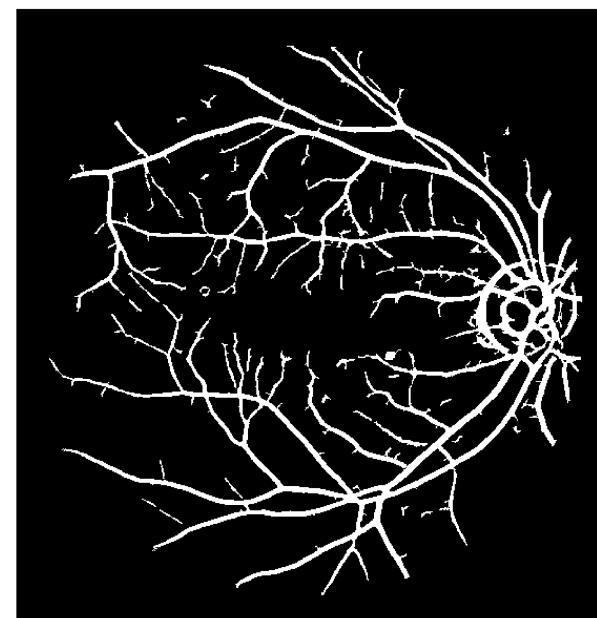
Results



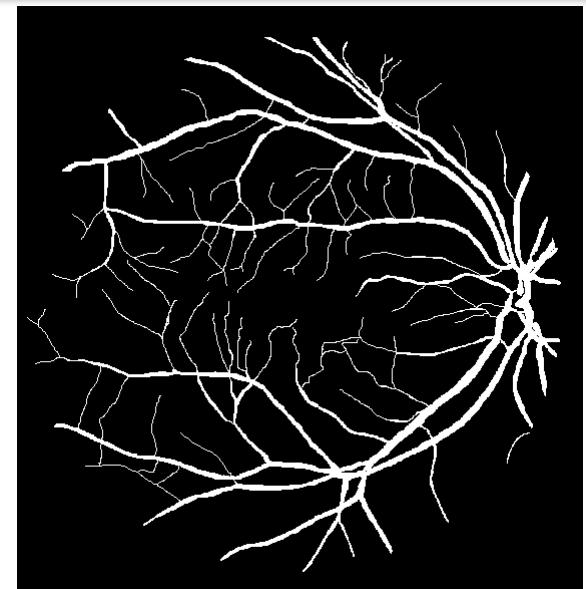
Original Image



Inverted green channel image



Proposed Method



Ground Truth



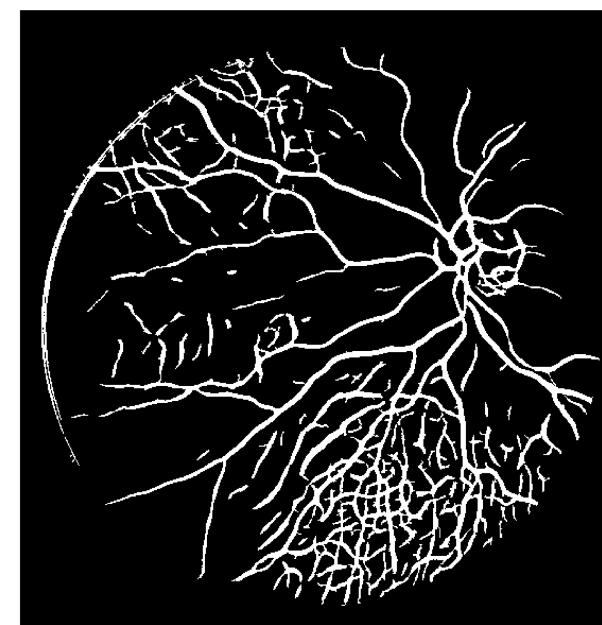
Results



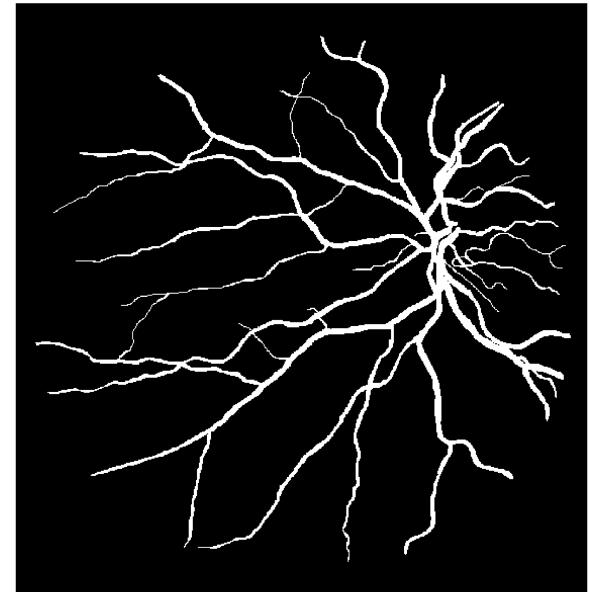
Original Image



Inverted green channel image



Proposed Method



Ground Truth



Results

$$TPR = \frac{\# \text{ correctly classified vessel pixels}}{\# \text{ vessel pixels in GroundTruth}}$$

$$FPR = \frac{\# \text{ Non - vessel pixels classified as vessel}}{\# \text{ Non - vessel pixels in FOV in GroundTruth}}$$

$$Acc = \frac{\# \text{ Correctly classified pixels}}{\# \text{ pixels in FOV}}$$

Method	TPR	FPR	Accuracy
2nd Human observer	0.7761	0.0275	0.9473
Staal	0.7194	0.0227	0.9442
Soares	0.7283	0.0212	0.9466
Mendonça	0.7344	0.0236	0.9452
Matched filter	0.6168	0.0259	0.9284
Jiang	-	-	0.9212
Zana	-	-	0.9377
Martinez-Perez	0.7246	0.0345	0.9344
Garg	-	-	0.9361
Perfetti	-	-	0.9261
Cinsdikici	-	-	0.9293
Al-Rawi	-	-	0.9510
MF-FDOG	0.7083	0.0458	0.9236



References

- Chaudhuri, Subhasis, et al. "Detection of blood vessels in retinal images using two-dimensional matched filters." *IEEE Transactions on medical imaging* 8.3 (1989): 263-269.
- J.J. Staal, M.D. Abramoff, M. Niemeijer, M.A. Viergever, B. van Ginneken, Ridge based vessel segmentation in color images of the retina, *IEEE Trans. Med. Imaging* (2004) 501–509.
- J.V.B. Soares, J.J.G. Leandro, R.M. Cesar Jr., H.F. Jelinek, M.J. Cree, Retinal vessel segmentation using the 2-d gabor wavelet and supervised classification, *IEEE Trans. Med. Imaging* 25 (2006) 1214–1222.
- A.M. Mendonca, A. Campilho, Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction, *IEEE Trans. Med. Imaging* 25 (9) (2006) 1200–1213.
- M.E. Martinez-Perez, A.D. Hughes, S.A. Thom, A.A. Bharath, K.H. Parker, Segmentation of blood vessels from red-free and fluorescein retinal images, *Med. Image Anal.* 11 (1) (2007) 47–61.