Retinal Blood Vessels Extraction Using Morphological Operations

Veronika Kurilová, Jarmila Pavlovičová, Miloš Oravec, Radoslav Rakár, Igor Marček

Faculty of Electrical Engineering and Information Technology
Slovak University of Technology in Bratislava , Slovakia

STU FEI

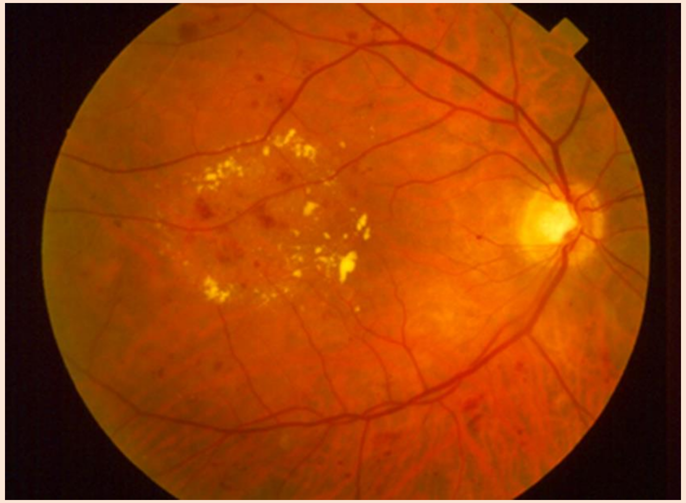
22nd Int. Conference on System, Signals and Image Processing, 2015, London, United Kingdom, 10-12 Sept. 2015

Outline

- Introduction - **Diagnostic in ophtalmology**
- State-of-the-art
- Image Database – **Messidor**
- Previous work
- Image processing - **Mathematical morphology**
- Our approach of - **Retinal Blood Vessel Extraction**
- Results
- Conclusion and future work

Diagnostic in ophtalmology

- **direct diagnostic by ophthalmologist**
- **screening**
  - **automatic evaluation of images**
    - **reduction of resources**
    - **monitoring of detected foundings**



Screening of Diabetic Retinopathy (DR)

- diabetic retinopathy – the leading cause of **blindness**
- early medication can decrease the risk of severe vision loss by > 90%
- there are **no universally accepted criteria** for the detection of DR using digital imaging
- British Diabetic Association **reccomends** minimum **80% sensitivity** and **95% specificity** for screening methods*

* British Diabetic Association. Retinal photographic screening for diabetic eye disease. A British Diabetic Association Report. London: British Diabetic Association; 1997

State-of-the-art - Extraction of blood vessels

Methods based on

- edge detection
- Canny detector or LoG operator
- wavelet transform
- classification algorithms using neural networks
- filtering algorithms
- morphological algorithms

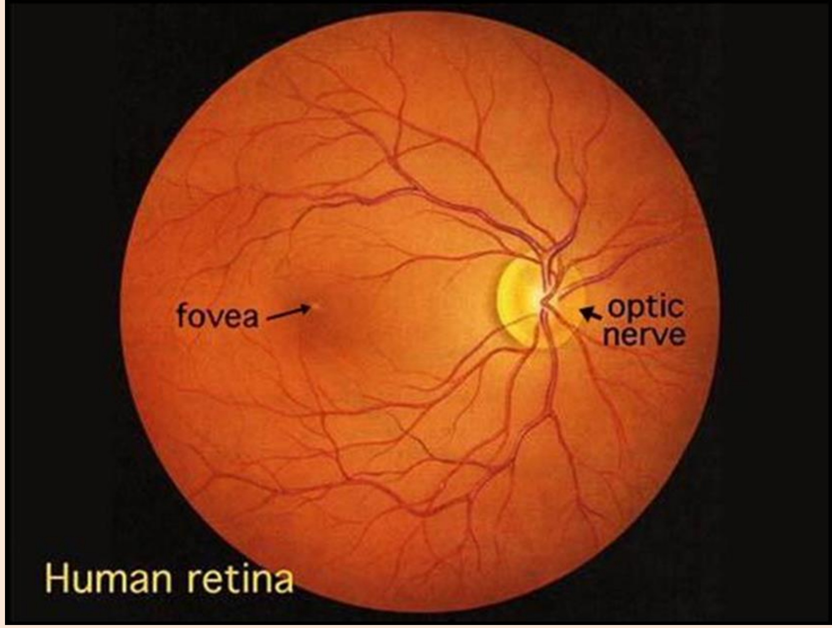
In [*] - the comparison based on sensitivity and accuracy of five existing methods is presented **on DRIVE database**

Sensitivity values ≅ 0,7 – 0,8

Accuracy values ≅ 0,94

* Miri, M.S.; Mahloojifar, A., "Retinal Image Analysis Using Curvelet Transform and Multistructure Elements Morphology by Reconstruction," Biomedical Eng., IEEE Trans. on, Vol. 58, Iss. 5, pp. 1183 – 1192, 2011

Retinal image database Messidor *



- 1200 colour fundus images
- by 3CCD fundus camera Topcon TRC NW6
- 45° visual field
- images of healthy subjects and subjects with diabetic retinopathy
- 8 bits colour depth
- 1440x960 to 2304x1536 pixels resolution

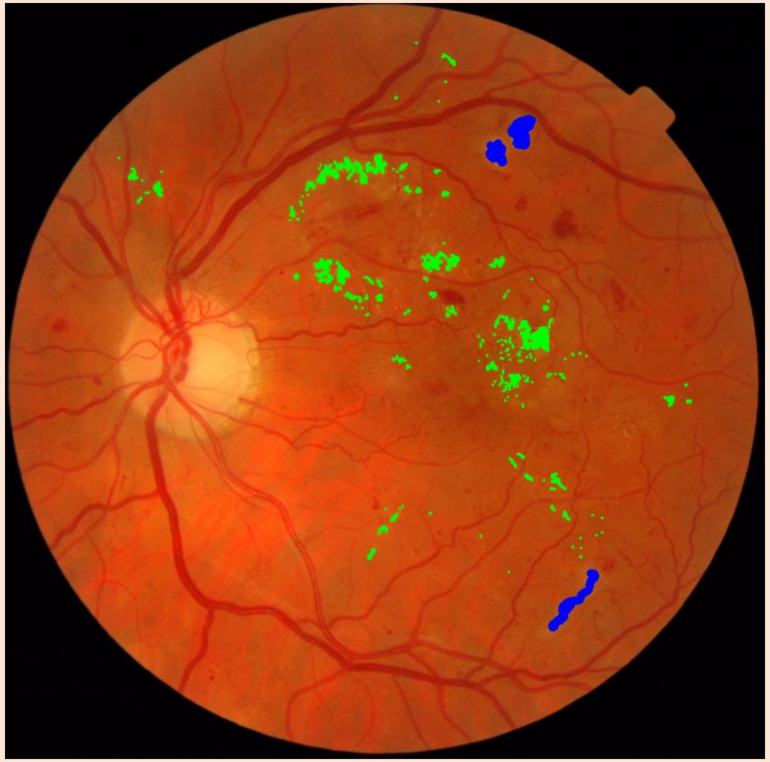
* MESSIDOR, "Methodes d'Evaluation de Systemes de Segmentationet d'Indexation Dediees a l'Ophtalmologie Retinienne," from http://messidor.crihan.fr., 2007

Retinal image database Messidor

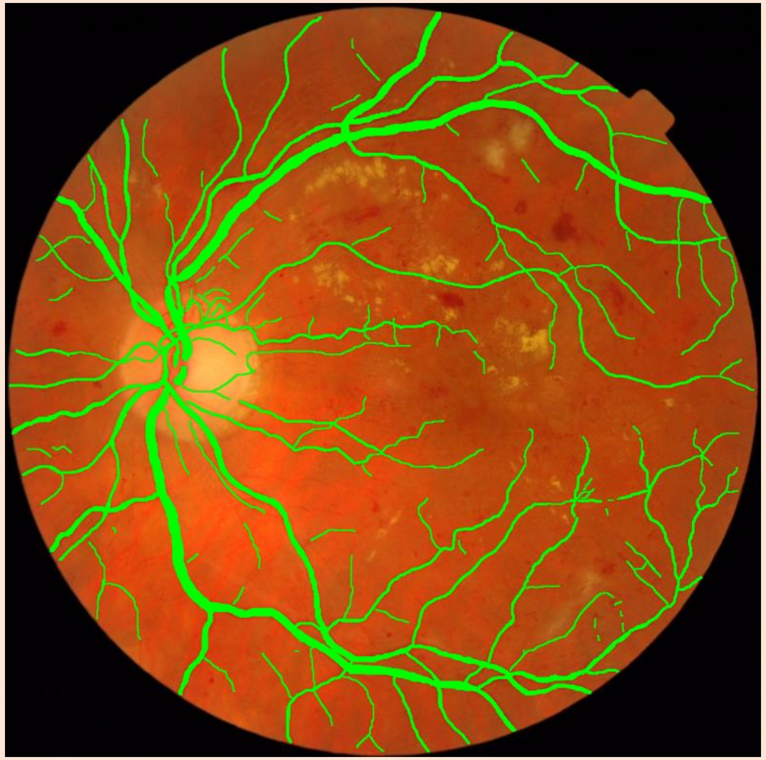
original

in our analysis:

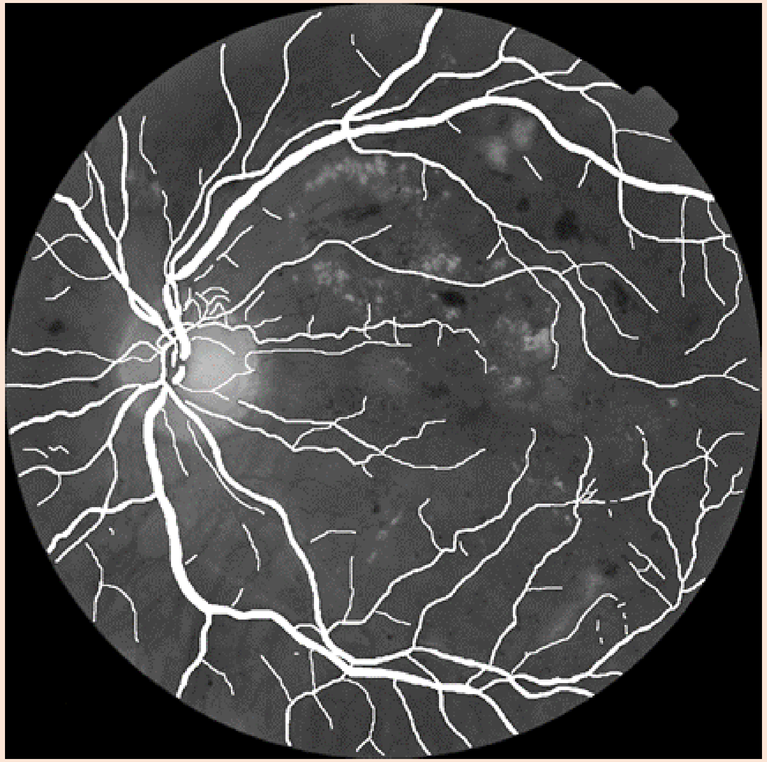
- 1373x1372 pixel array
- green channel



lesions marked by ophthalmologist



blood vessels marked by ophthalmologist



green channel

Previous work

- image normalization - luminance normalization, contrast enhancement
- optic disc suppresion (Hough transform, FRST)
- **retinal blood vessels suppresion – mathematical morphology**
- soft exudates feature extraction on fundus images
- soft exudates classification by NN (trained for 16 selected features)

Image normalization

$I(x,y)=f(I^0(x,y))=C(x,y)I^0(x,y)+L(x,y)$

$I(x,y)$ – original image

$I^0(x,y)$ – ideal image

$f(I^0(x,y))$ – transformed image

$C(x,y)$ – contrast variation parameter

$L(x,y)$ – luminance variation

$L'(x,y), \hat{C}(x,y)$ - estimation of parameters based on μ and σ of background

- **luminance normalization**
- **contrast enhancement**

$$\hat{I}^0(x,y) = \frac{I(x,y) - L'(x,y)}{\hat{C}(x,y)}$$

M. FORACCHIA, E. GRISAN, A.RUGGERI. Luminosity and Contrast Normalization in Retinal Images. Medical Image Analysis, 2004, vol. 9, pp. 179-190

Morphological operations for blood vessel detection

- *dilation, erosion, opening, closing*
- *white top hat – bright details*

$$WTH = X - (X \circ B)$$

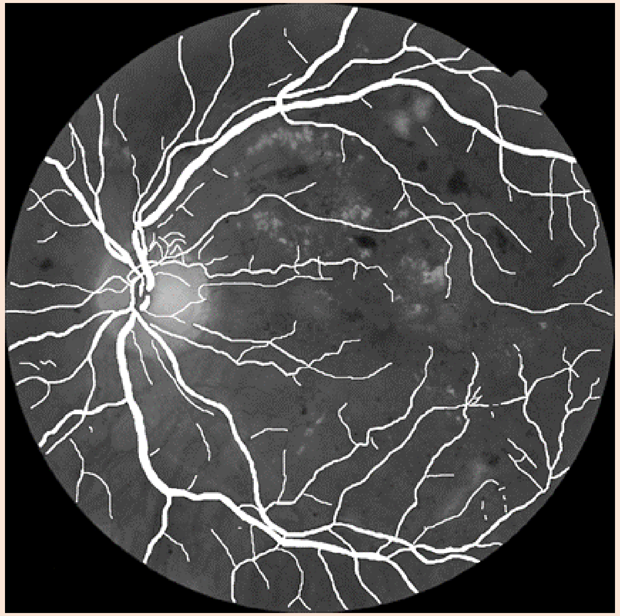
- black *top hat – dark details*

$$BTH = (X \bullet B) - X$$

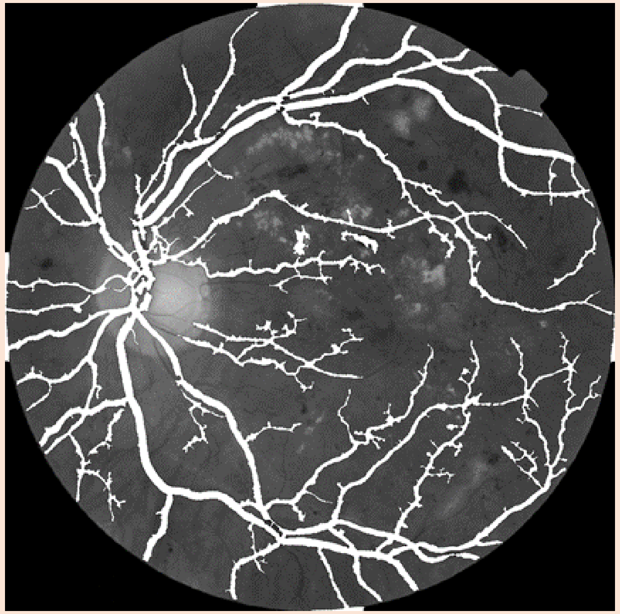
- *morphological reconstruction –the intensity fluctuations removal*

Morphological Blood Vessel Detection – Approach I

1) Green channel extracion
2) Morphological closing, SE disc size 10
3) Sum of images 1) and 2)
4) Morphological closing, SE disc size 4
5) Contrast adjustment
6) Morphological closing SE disc size 10
7) Subtraction of the image 5) from image 6)
8) Binary conversion of the image
9) Morphological closing, SE disc size 2



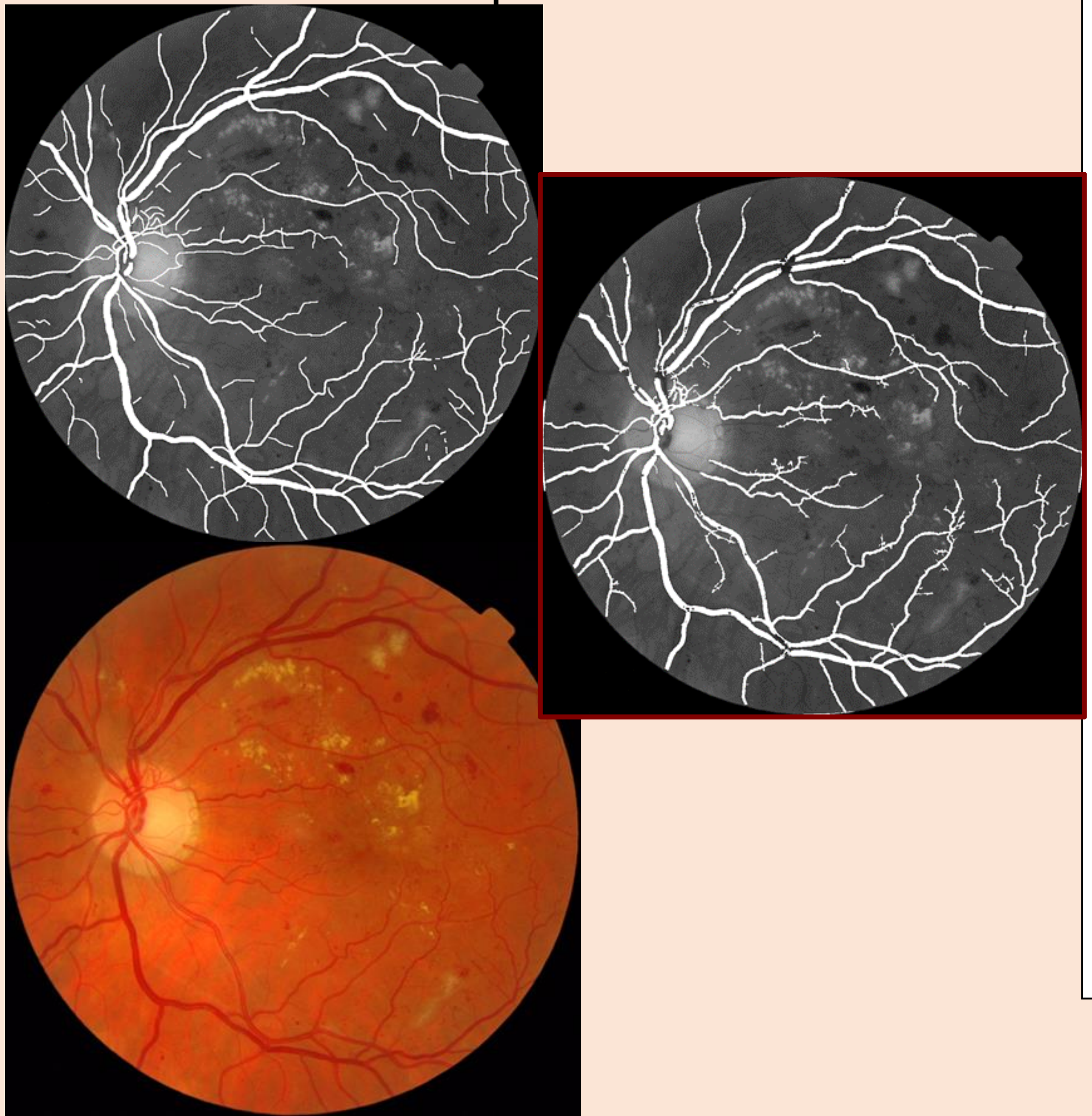
ophtalmologist



Approach I

Morphological Blood Vessel Detection - Approach II

- **two-channel processing**
- combination of profitable results

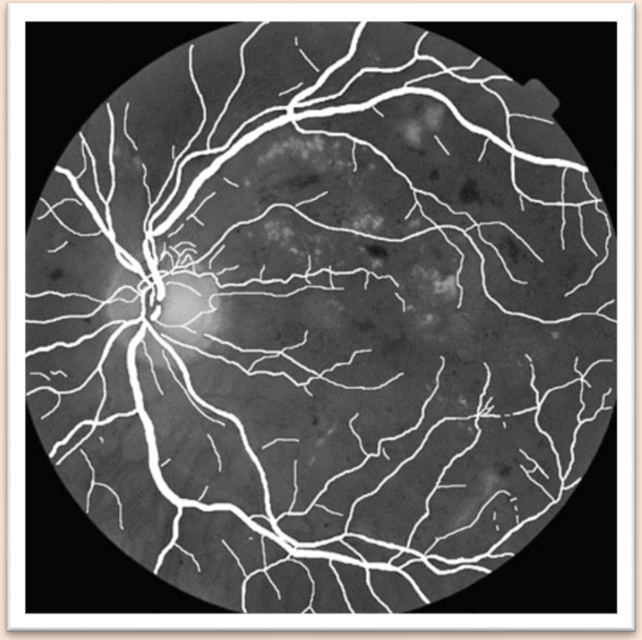


1) Image pre-processing
2) Morphological opening
3) Morphological reconstruction

4) Image sharpening SE Disc, size 5	4) Image sharpening SE Disc, size 6
5) Morphological closing SE Octagon, size 12	5) Morphological closing SE Disc, size 6
6) Subtraction of image 5) from 4)	6) Subtraction of image 5) from 4)
7) Graythresholding	7) Graythresholding
8) Morpfological opening SE linear, size 10	8) Morpfological opening SE linear, size 10
9) Area opening function	9) Area opening function

10) Combination of results
11) Postprocessing

Results



Approach I

accuracy of hand-marked pixels

TP (pixels)	**84.86%**
FPR (pixels)	4.16%
FN (pixels)	**15.14%**

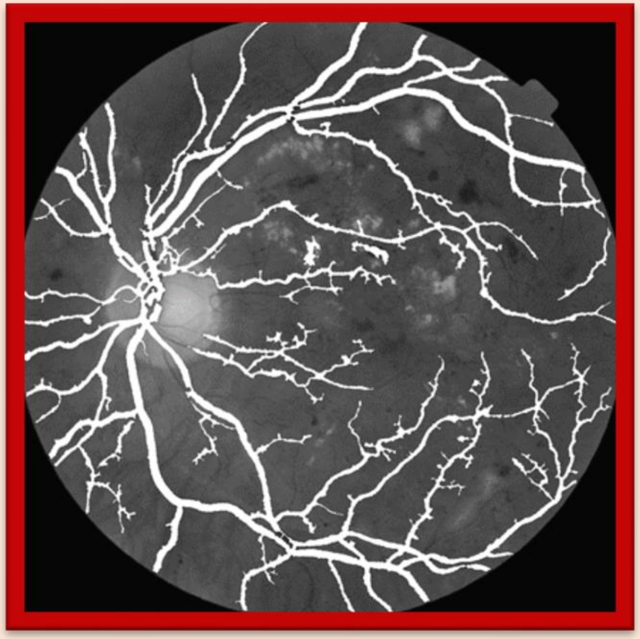
ophtalmologist: 160 092 pixels

Approach I : 207748 pixels

TP: 135 856

FP: 71 892

FN: 24 236



Approach II
two-channel processing

accuracy of hand-marked pixels

	80.52%
FPR (pixels)	**1.82%**
FN (pixels)	19,48%

ophtalmologist: 160 092 pixels

Approach II : 160465 pixels

TP: 128 901

FP: 31 564

FN: 31 191

Results of Approach I

Image	Sensitivity (TPR)	Specificity (TNR)	Accuracy (ACC)
1	77.70%	98.03%	96.94%
2	72.68%	96.54%	94.90%
3	**84.86%**	**95.84%**	**94.90%**
Average	78.41%	95.85%	95.58%

Results of Approach II

2 - Channel Processing

Image	Sensitivity (TPR)	Specificity (TNR)	Accuracy (ACC)
1	**80.72%**	**97.55%**	**96.64%**
2	77.29%	95.43%	94.17%
3	**80.52%**	**97.24%**	**95.82%**
Average	79.51%	96.74%	95.55%

$$TPR = TP/(TP + FN)$$

$$TNR = TN/(FP + TN)$$

$$ACC = (TP + TN)/(TP + TN + FN + FP)$$

$$FPR = FP/(FP + TN)$$

Conclusion

Our approaches - sensitivity (TPR) **79.51%** and accuracy **95.55% in average;**
- higher in most cases despite of used datab. Messidor (higher resolution of images then DRIVE)

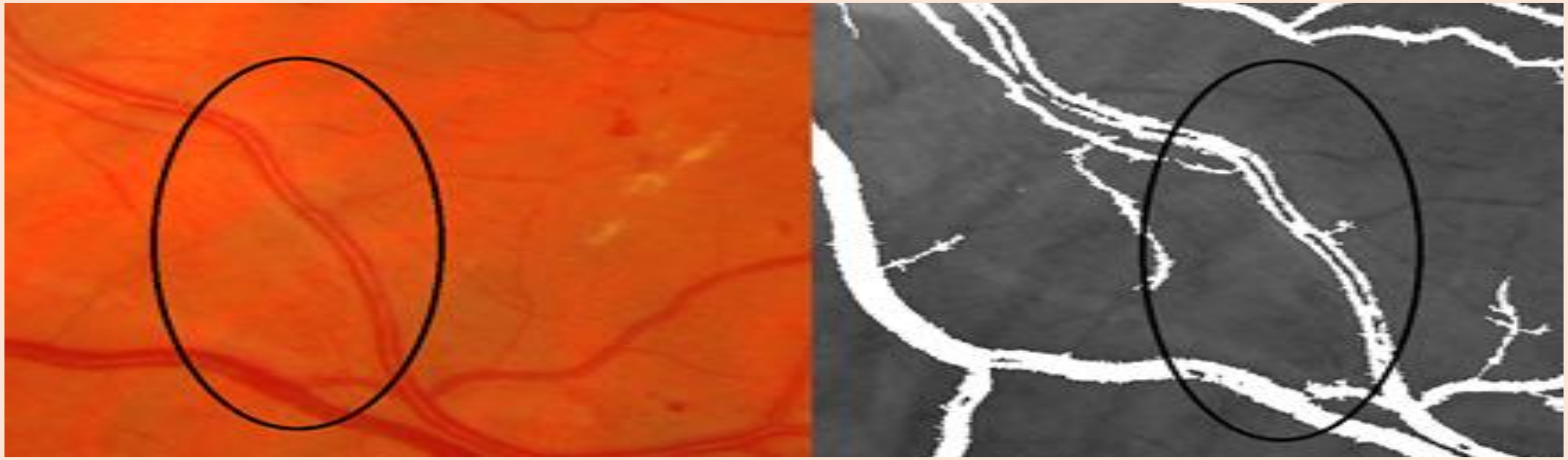
COMPARISON OF PERFORMANCE BETWEEN THE RECENT STUDIES

DRIVE database

Method	TPR	FPR	Average Accuracy
Mendonça *et al.* [3]	0.7344	0.0236	0.9452
Staal *et al.* [22]	0.6780	0.0170	0.9441
Martinez-Perez *et al.* [23]	0.7246	0.0345	0.9344
Niemeijer *et al.* [20]	0.6898	0.0304	0.9416
Our method	**0.7352**	**0.0205**	**0.9458**

Miri, M.S.; Mahloojifar, A., “Retinal Image Analysis Using Curvelet Transform and Multistructure Elements Morphology by Reconstruction,” Biomedical Eng., IEEE Trans. on, Vol. 58, Iss. 5, pp. 1183 – 1192, 2011

Conclusion - Specific false positive detections



- the border of bigger retinal arteries looks darker than its lumen
- have no negative influence to pathological retinal findings detection

- some degree of noise on the border of blood vessels

Conclusion

Presented methods

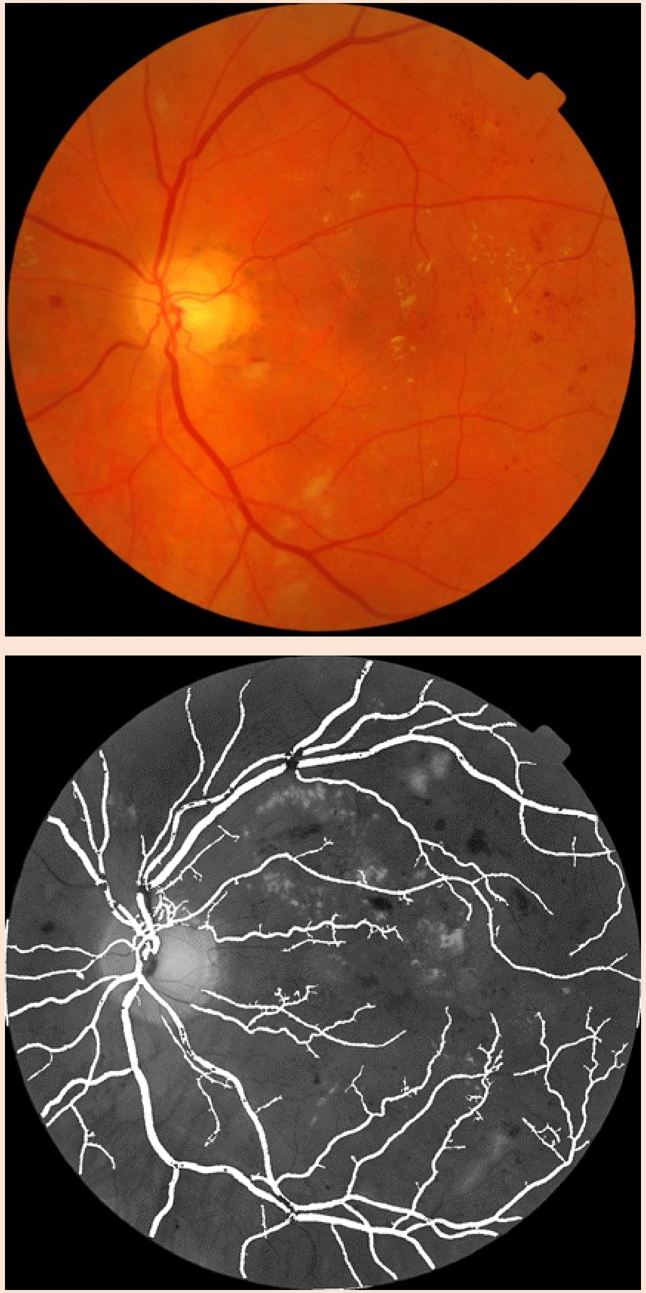
- fast and easy to implement
- suitable for physiological and also pathological images of any size
- satisfies the recommendation of min. specificity for screening (95%)
- sensitivity near recomended 80 %
- *Two-channel processing* - higher values of sensitivity and specificity in average

Improvements need to be developed in

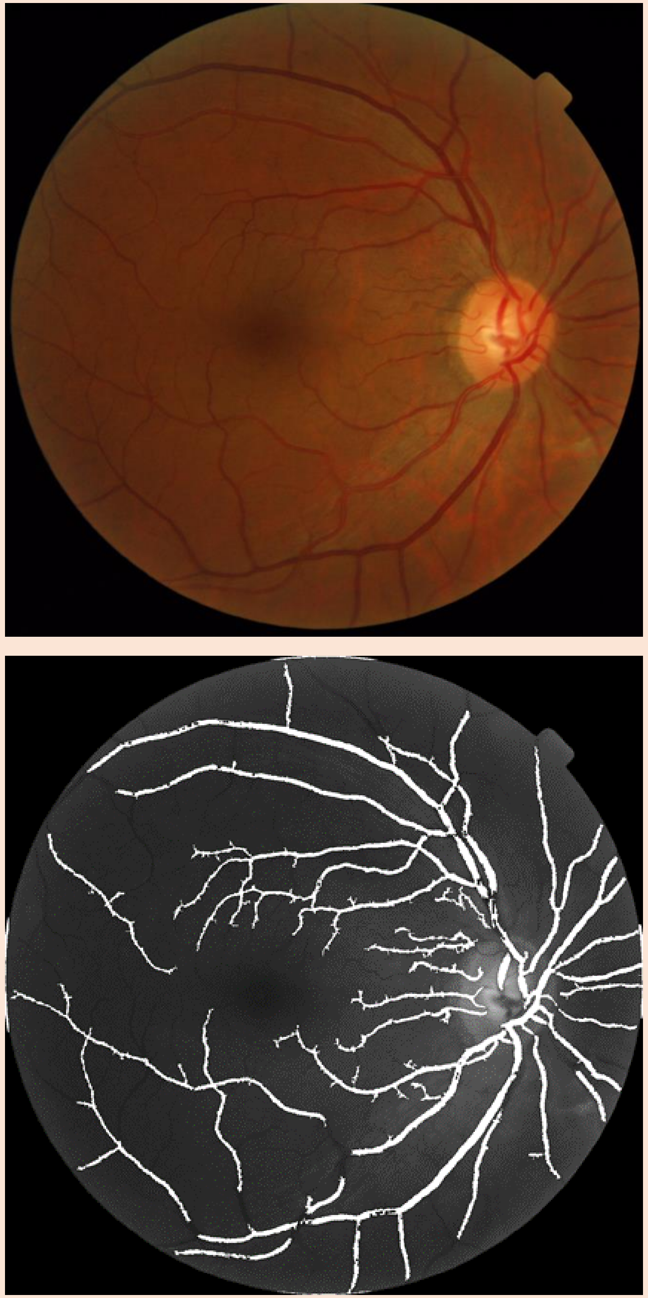
- image normalization
- number of false positive detections

Tested images

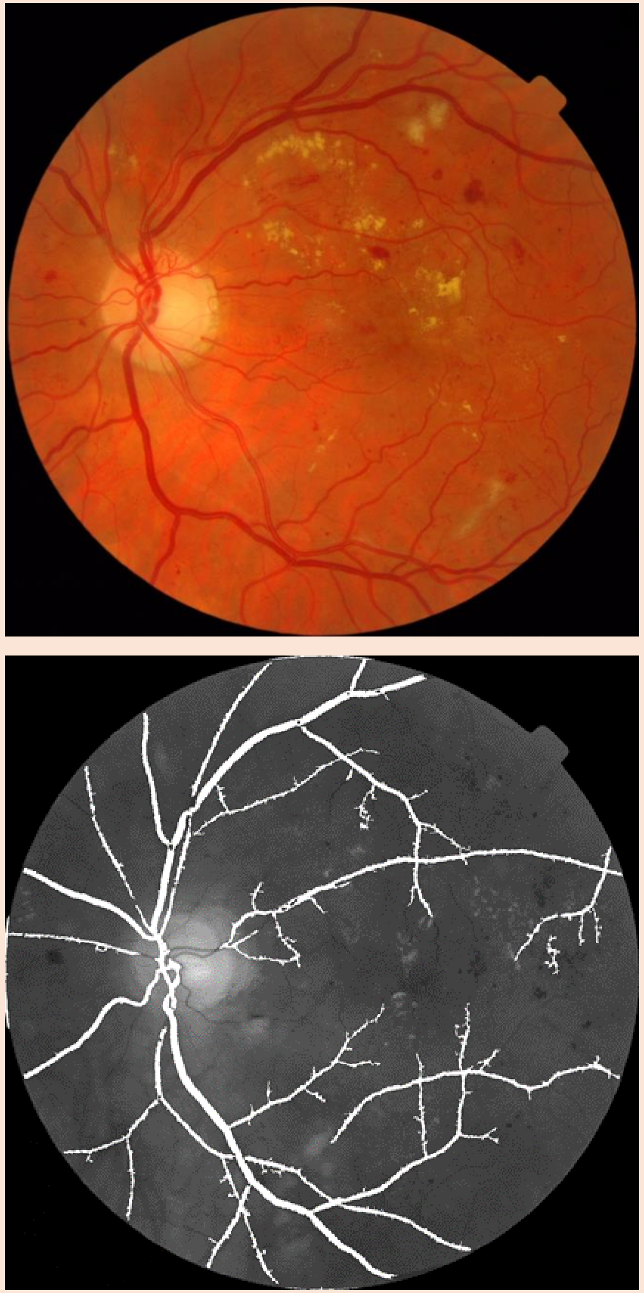
1



2



3



References

- T. Walter, C.J. Klein, "Segmentation of colour fundus images of the human retina: detection of the optic disc and the vascular tree using morphological techniques," Medical Data Analysis, LNCS, vol.2199, pp.282-287, 2001.
- V. Hanúsková, J.Pavlovičová, M.Oravec, R.Blaško, "Diabetic rethinopathy screening by bright lesions extraction from fundus images," Journal of Electrical Engineering, vol. 64, no.5, pp. 311-316, 2013.
- Y. Doaa, H.S. Nahed," Accurate detection of blood vessels improves the detection of exudates in color fundus images, " Computer methods and programs in biomedicine 108, pp.1052-1061, 2012.
- M.Lalonde,L.Gagnony,C.M.Boucherz,"Non-recursive paired tracking for vessel extraction from retinal images,"Conf. Vision Interface, 2000.
- L. Sukkaew, B. Uyyanonvara, "Automated vessels detection on infant retinal images, " ICCAS, Bangkok, 2004.
- J.J.G. Leandro, M.R. Cesar JR, H.F. Jelinek, " Blood vessels segmentation in retina: preliminary assessment of the mathematical morphology and the wavelet transphorm techniques," Computer Graphics and Image Processing, IEEE, pp.84-90, 2001.
- Ch. Yao, H. Chen, "Automated retinal blood vessels segmentation based on simplified PCNN and fast 2D-Otsu algorithm," Journal of Central South University of Technology, issue 4, vol.16, pp.640-646, 2009.
- J. Odstrčilík, "Improvement of vessel segmentation by matched filtering in colour retinal images," World congress on medical physics and biomedical eng., Munich, IFMBE Proc., vol. 25/11, p.p 327-330, 2009.
- F. Zana, J.C. Klein, "Segmentation of vessel-like patterns using mathematical morphology and curvature evaluation," IEEE Transactions on Image Processing, vol.10, no.7, pp. 1010-1019, 2001.
- B. Fang, W. HSU, M.L. Lee, "Reconstruction of vascular structures in retinal images," Image Proc., ICIP 2003, IEEE, pp.157-160, 2003.
- J. Hajer, H. Kamel, E. Noureddine, "Blood vessels segmentation in retina image using mathematical morphology and the STFT analysis," Inf. and comm. technologies, IEEE, 2nd, vol.1, pp.1130-1134, 2006.
- J. Xu, H. Ishikawa, G. Wollstein, J.Schuman," Retinal vessel segmentation in SLO image," Engineering in medicine and biology society, Conference IEEE, Vancouver, pp.2258-2261, 2008.
- Miri, M.S.; Mahloojifar, A., "Retinal Image Analysis Using Curvelet Transform and Multistructure Elements Morphology by Reconstruction," Biomedical Eng., IEEE Trans. on, Vol. 58, Iss. 5, pp. 1183 – 1192, 2011.
- Foracchia,M.,Grisan,E.,Ruggeri,A.,"Luminosity and Contrast Normalization in Retinal Images,"Medical Image Analysis, vol.9, pp.179-190, 2004.
- R. C. Gonzalez), R.E. Woods , Digital Image Processing, 3rd ed., by Pearson Education, Inc., 2008.
- MESSIDOR, "Methodes d'Evaluation de Systemes de Segmentationet d'Indexation Dediees a l'Ophtalmologie Retinienne," from http://messidor.crihan.fr., 2007.