Retinal vessel segmentation using multi-scale wavelet frame analysis

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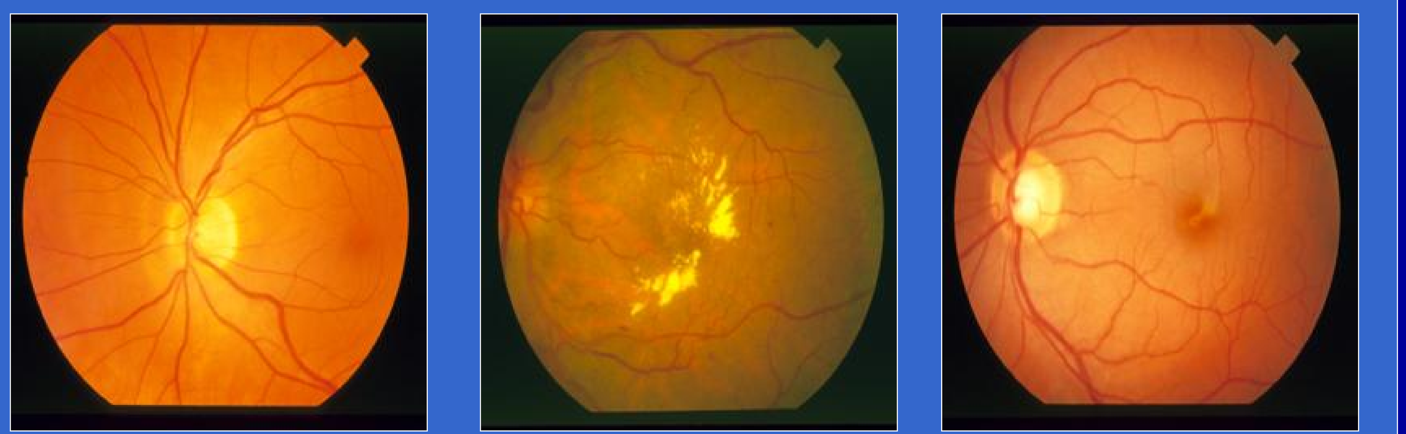
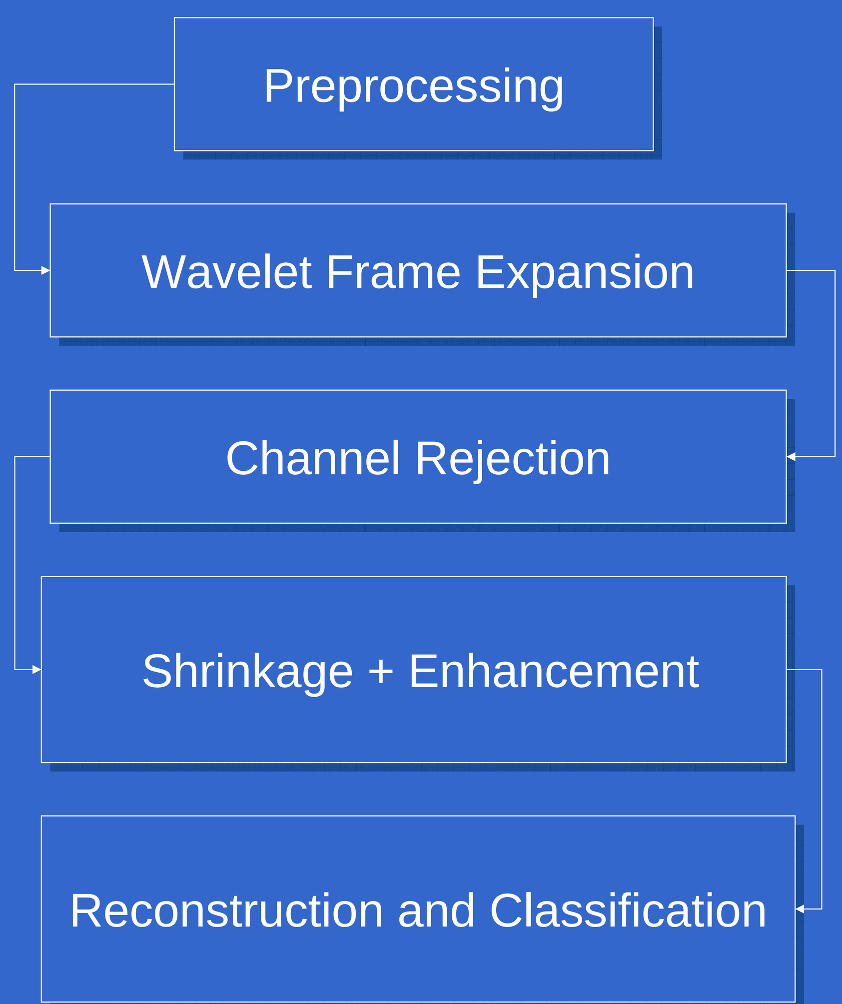
1. INTRODUCTION

- Fundus imaging is a non-invasive technique for in vivo ophthalmoscopic inspection of retinal disorders. Quantitative information about the vascular network can facilitate clinical diagnosis of retinal diseases [1].
- Goal: Segmentation of the vascular network in fundus images for further quantification and post processing as a binary classification into object and background.
- Approach: We perform an over-complete multi-scale wavelet frame expansion with selective channel rejection in the decomposition tree. Remaining channels undergo wavelet shrinkage and enhancement to separate retinal objects from background.
- Results: Comparison to expert gradings on a pixel by pixel basis show mean sensitivity and specificity of 0.8 and 0.9.

2. MATERIALS & METHODOLOGY

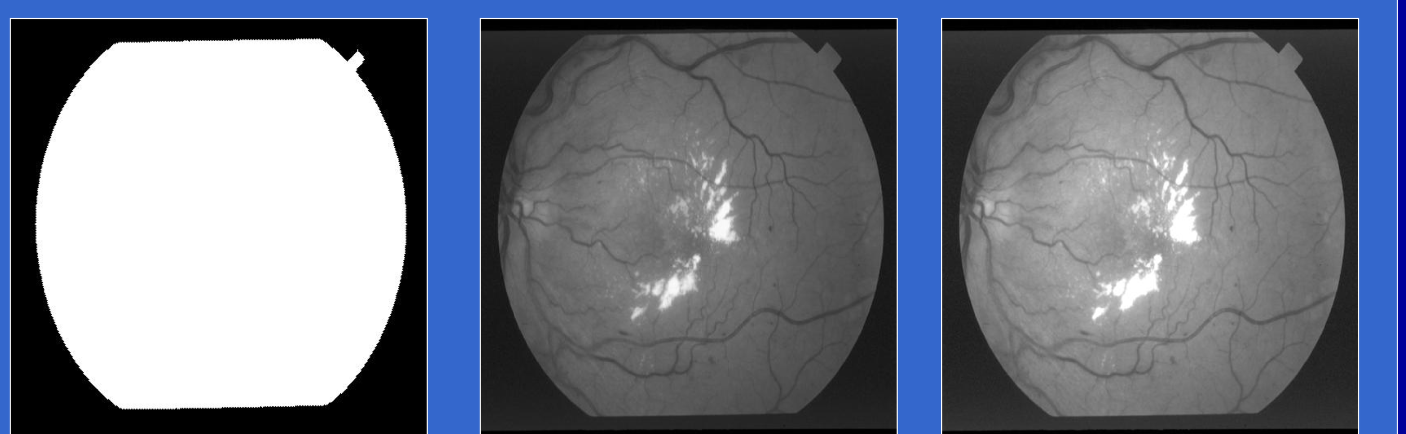
- We use the STARE [2] database for testing and evaluating our segmentation algorithm consisting of 20 datasets. The images are captured by a TopCon TRV-50 camera with 35 degree field of view.





2.1 Preprocessing

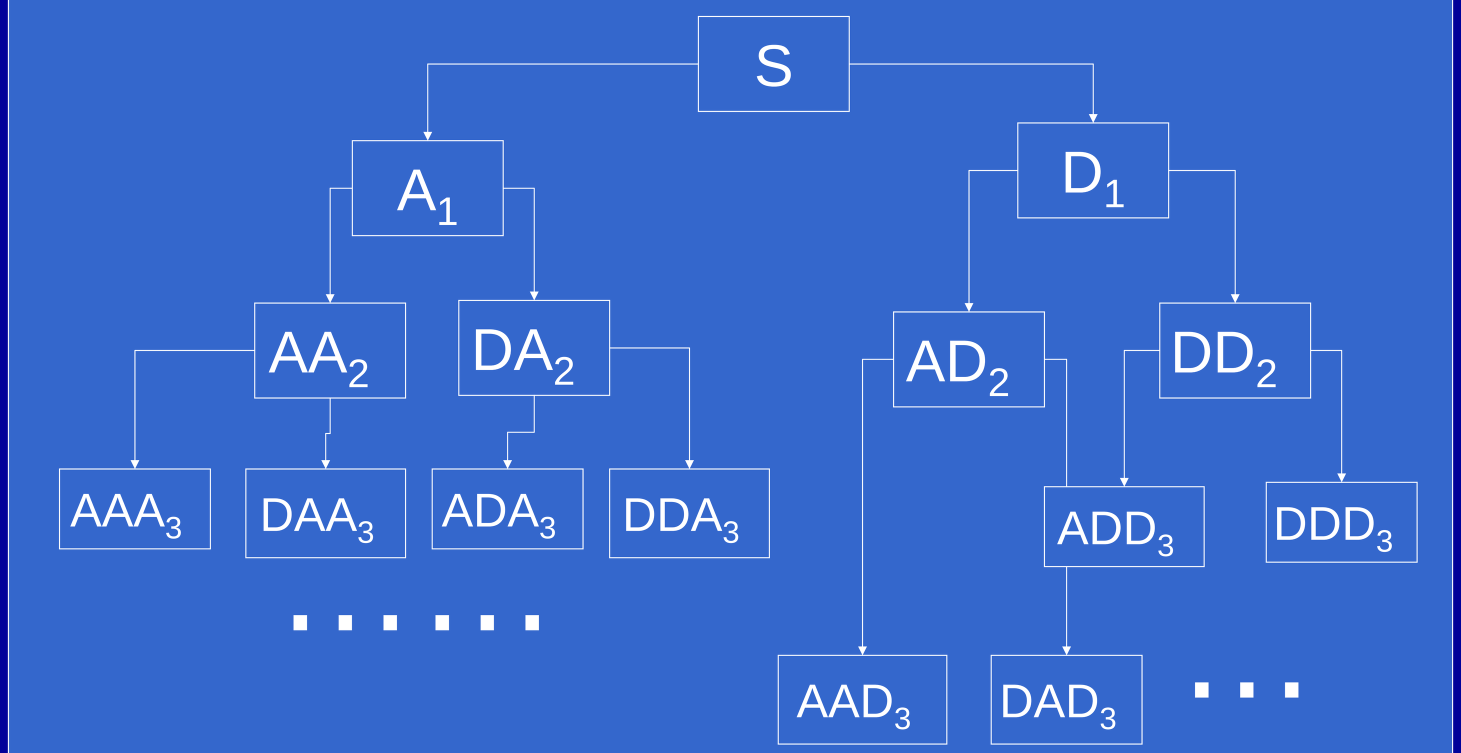
- We first define a ROI (left) and preprocess all fundus images by working on the RGB green channel (middle) followed by standard contrast enhancement (right).



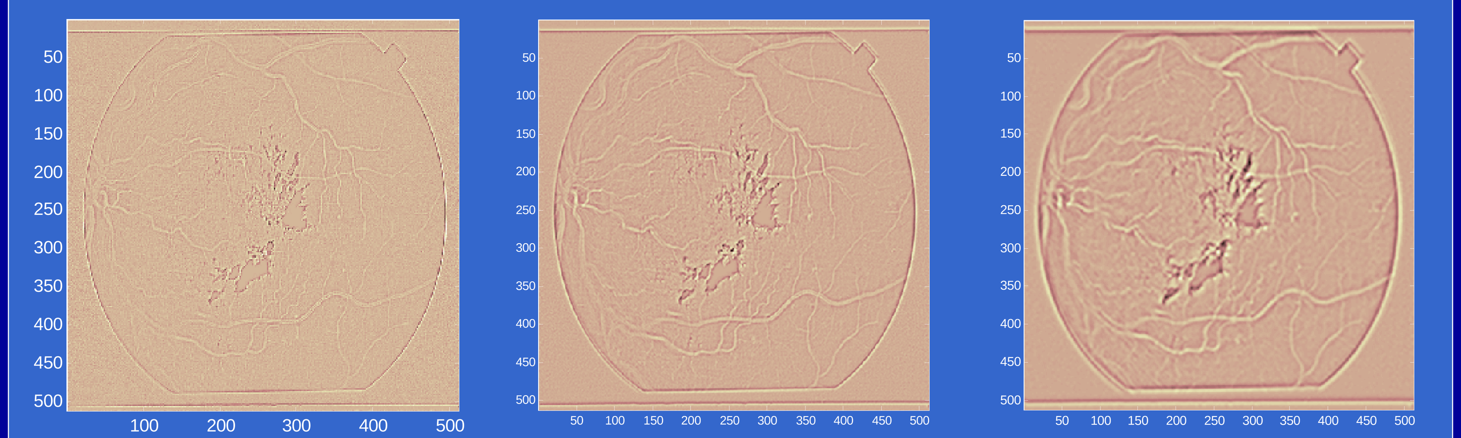
2. MATERIALS & METHODOLOGY

2.2 Multi-Scale Wavelet Frame Analysis

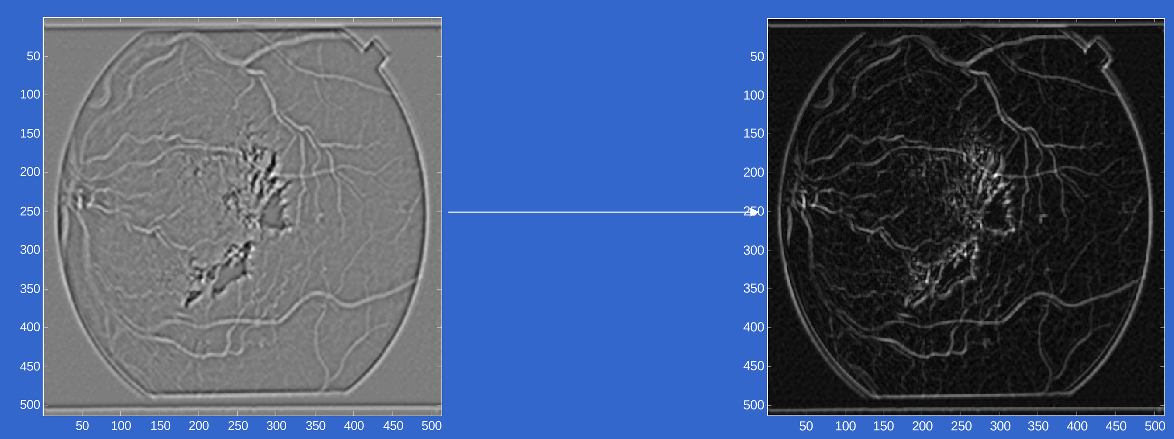
- Decompose the image S into a spatial-scale frequency decomposition using multi-scale wavelet frames [3]. We perform wavelet frame decomposition, i.e. we split S iteratively into approximation and detail components. In our experiments we used a 4 level decomposition.



- To remove the retinal background and its inherent illumination variability we reject all approximation channels of the low-pass signal within the decomposition tree (A_{1-4}). Based on visual appearance we select appropriate wavelet frames that constitute salient feature information of the vascular network and join the detail components together for simplified analysis. Joint detail components for level 1-3 are shown below. Level 4 detail components ($D \ldots D_4$) are also rejected since the vascular network is out of scale.

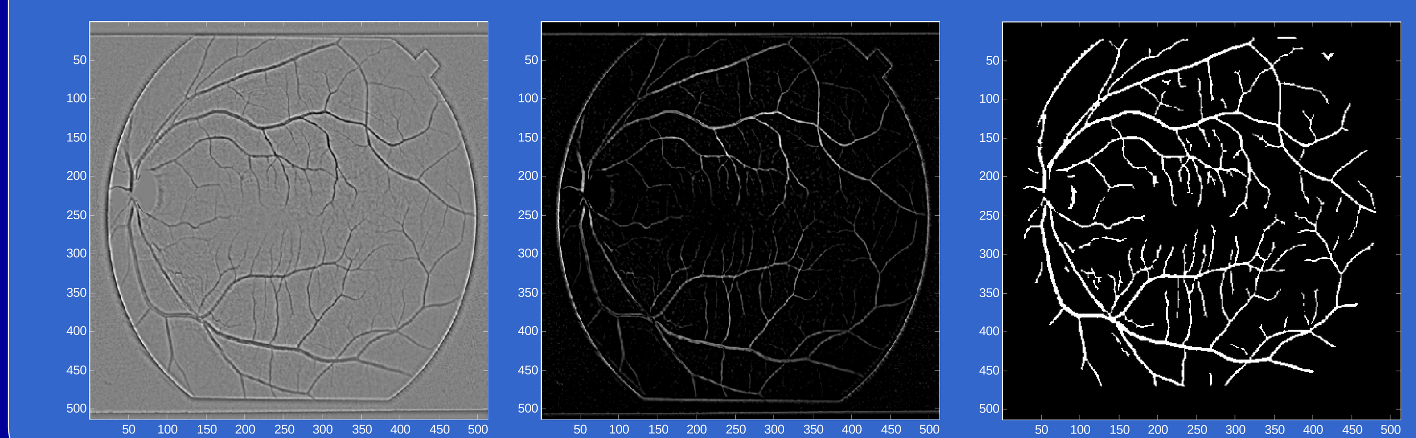


- We are not interested in the detail channels since they give edge information of the vessel tree. Rather the sum of approximations or individual approximation channels from channel details give relevant feature information of the vasculature. We perform noise removal on level 2 (above) and enhancement in level 3 (below)



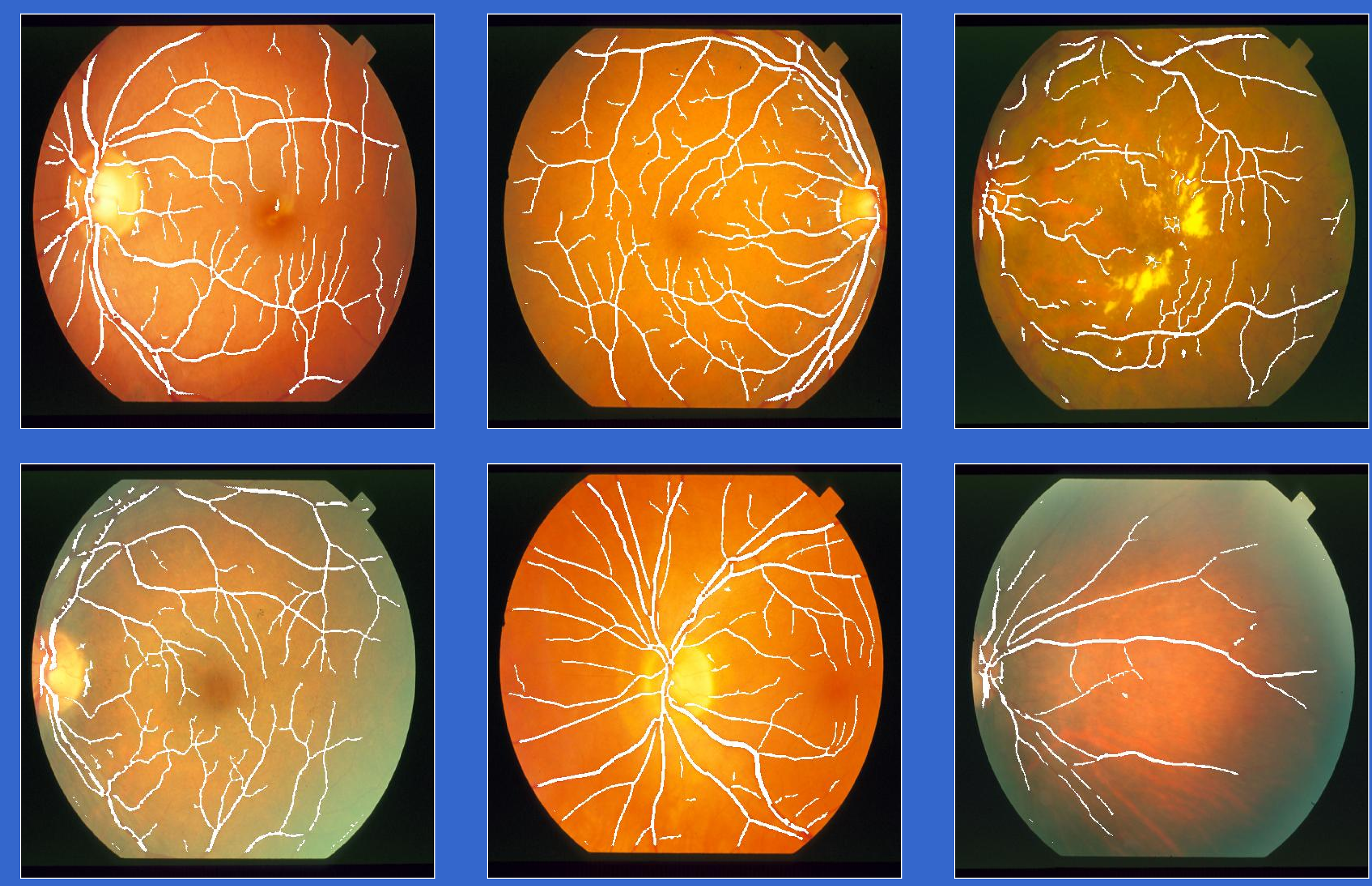
2.3 Reconstruction and Classification

- The final step is reconstructing the decomposition tree with the modified wavelet frames by computing the inverse wavelet frame transform recursively. The obtained reconstruction aids as a vessel likelihood map that we input into the k-means algorithm with k=2.

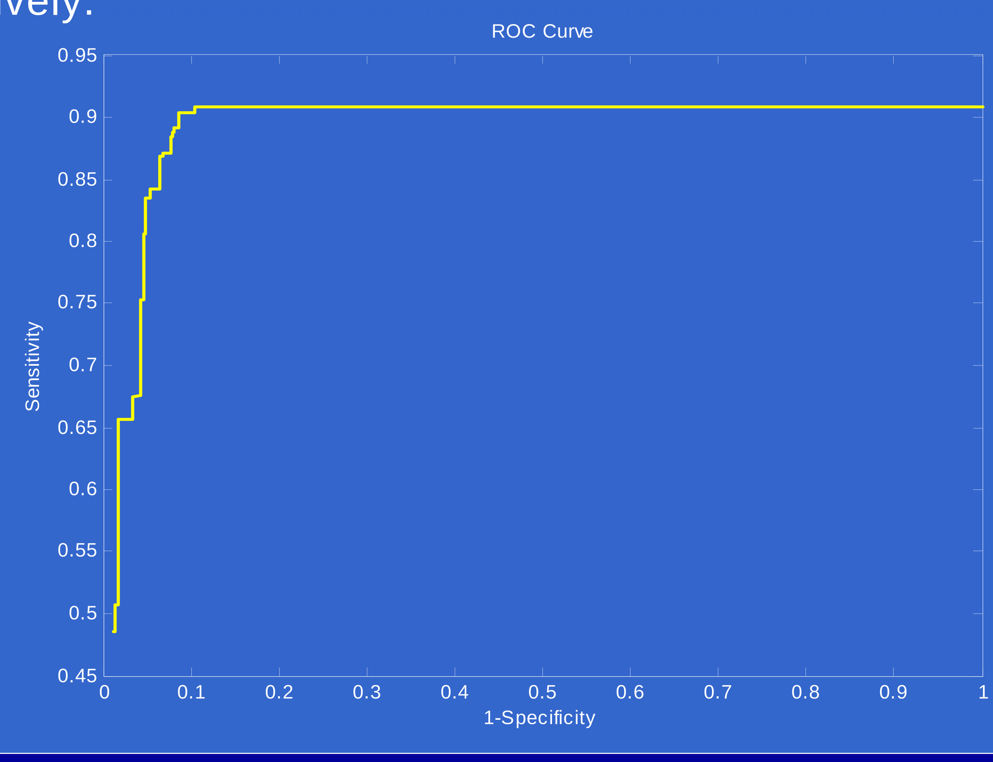


3. RESULTS AND DISCUSSION

- To validate our method we have selected a set of 20 fundus images of the STARE [2] database comprising different levels of segmentation complexity.



- We performed quantitative validation by comparing our segmentation to expert grading and obtained a mean sensitivity of 0.89 and a mean specificity of 0.97 with standard deviations of ± 0.13 and ± 0.02 respectively.



4. ACKNOWLEDGEMENTS

This work was funded by NEI (R01 EY015520-01) (R T Smith), the NYC Community Trust (R T Smith), and unrestricted funds from Research to Prevent Blindness.

5. SUMMARY & CONCLUSIONS

- We have presented a method for retinal vessel segmentation using a multi-scale over-complete wavelet frame analysis with selective channel rejection, shrinkage, and enhancement.
- The efficacy of our analysis depends on sufficient large image data.
- The multi-scale wavelet frame domain is well suited for objects involving analysis of multiple scales. Future work is devoted in learning wavelet coefficients of pathology and abnormal cases to increase segmentation performance.

REFERENCES

1. Cemil Kirbas, Francis Quek: A review of vessel extraction techniques and algorithms. ACM Computing Surveys (CSUR)(2004); Vol. 36; 81-121.
2. Adam Hoover: Locating Blood Vessels in Retinal Images by Piece-wise Threshold Probing of a Matched Filter Response. IEEE Transactions on Medical Imaging. (2000); Vol. 19, no. 3; 203-210.
3. A.F. Laine, J. Fan.: Frame Representations for Texture Segmentation. IEEE Transactions on Image Processing (1996); Vol. 5, no.5; 771-780.