Advancing Retinal Disease Diagnosis through Hyperspectral Imaging

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Abstract

In the expanding field of medical diagnostics, hyperspectral imaging (HSI) emerges as a pivotal innovation, particularly for its potential in early detection and monitoring of age-related macular degeneration (AMD). Current methods for reconstructing hyperspectral images of the eye and extracting spectral signatures from these images for diagnosis, face challenges related to speed, accuracy, and applicability to in vivo data. We propose a novel solution leveraging deep learning techniques to enhance image reconstruction and diagnostic algorithms, with the anticipation that our approach will improve AMD detection in-vivo. The results indicate that deep learning methods can enhance computational efficiency and maintain quality of results obtained through traditional methods for image reconstruction and diagnosis for AMD. This study lays the groundwork for future research to refine these techniques and expand their application within clinical settings.

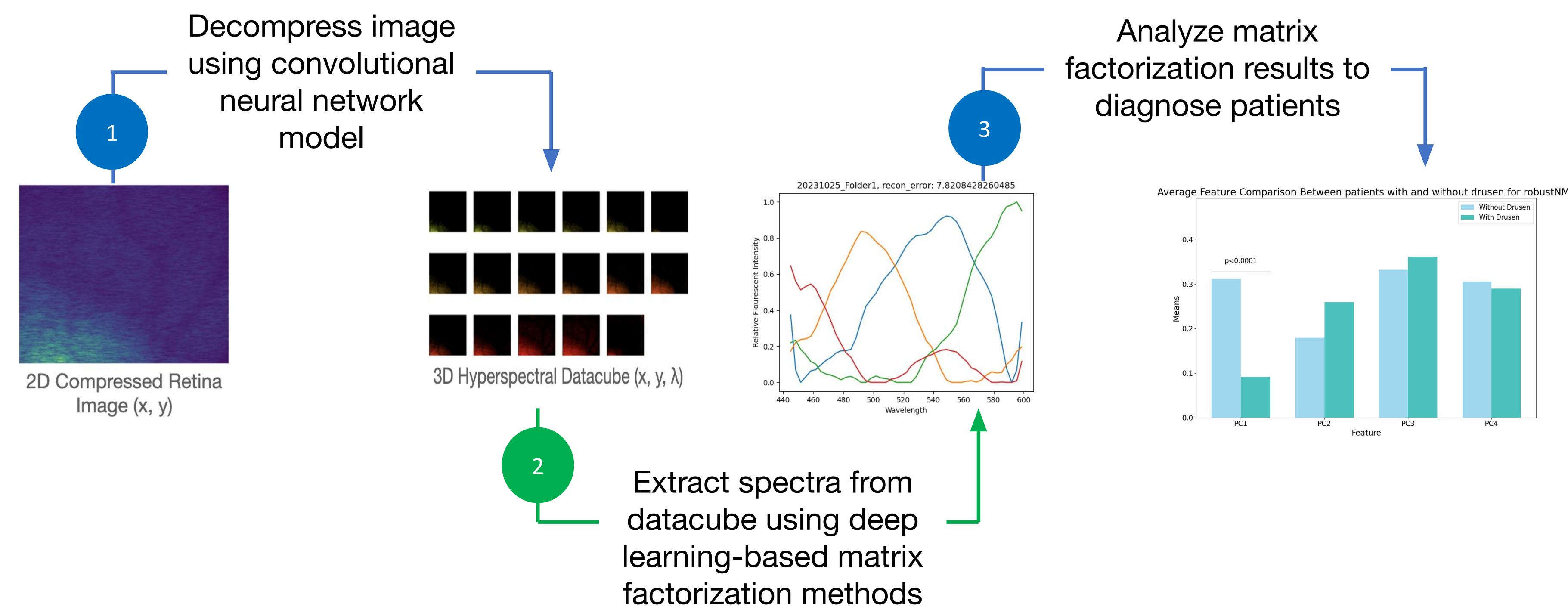


Figure 1. illustrates the process pipeline of preprocessing, analyzing, and diagnosing patients

Background

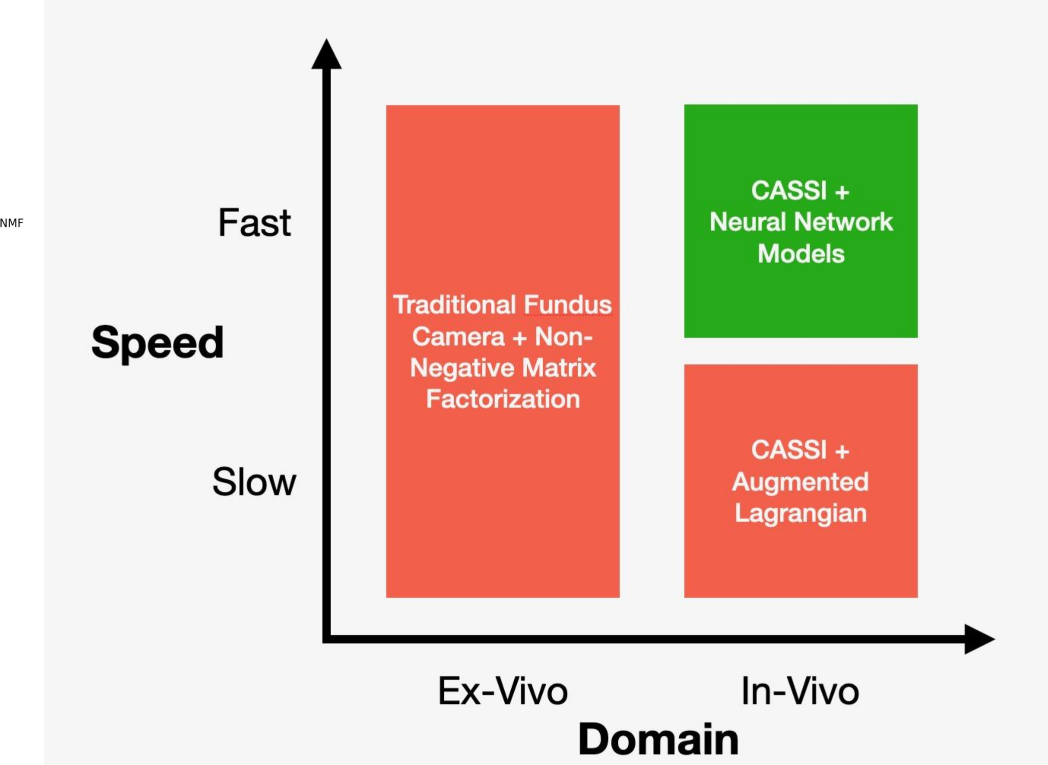


Figure 2. depicts the niche addressed by this research.

Part A: Hyperspectral Image Reconstruction

Methods

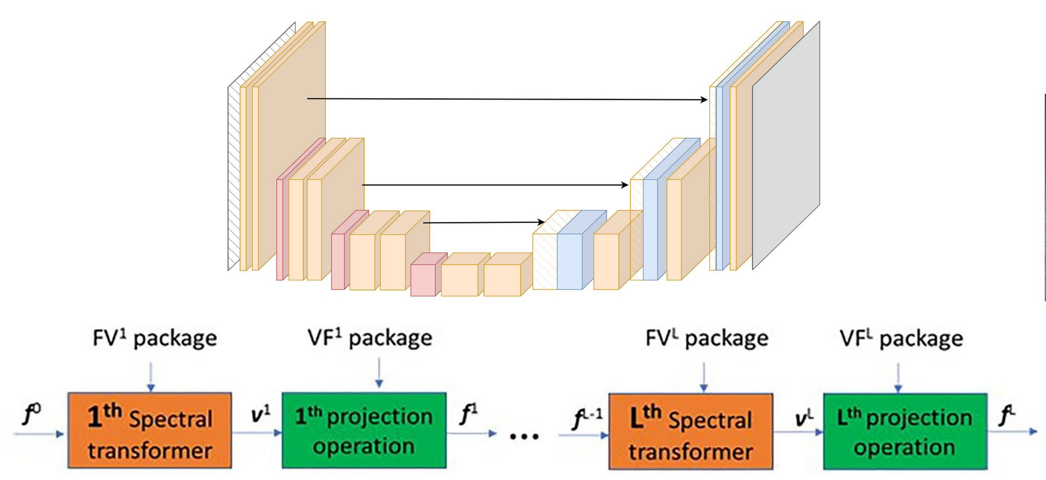


Figure 3. U-Net (top) and Deep Unfolding (bottom) architectures.

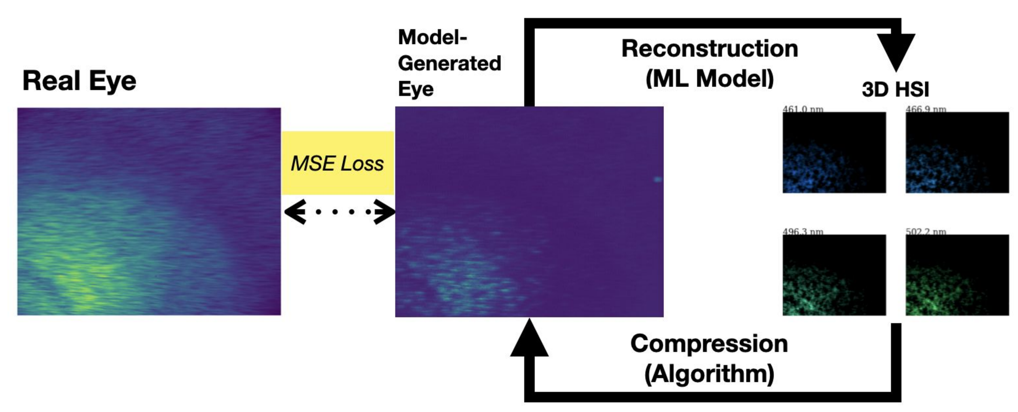


Figure 4. Self-supervised training workflow.

Models Evaluated:

1. U-Net + Supervised (Traditional)
2. U-Net + Self-Supervised
3. Deep Unfolding + Self-Supervised

Results

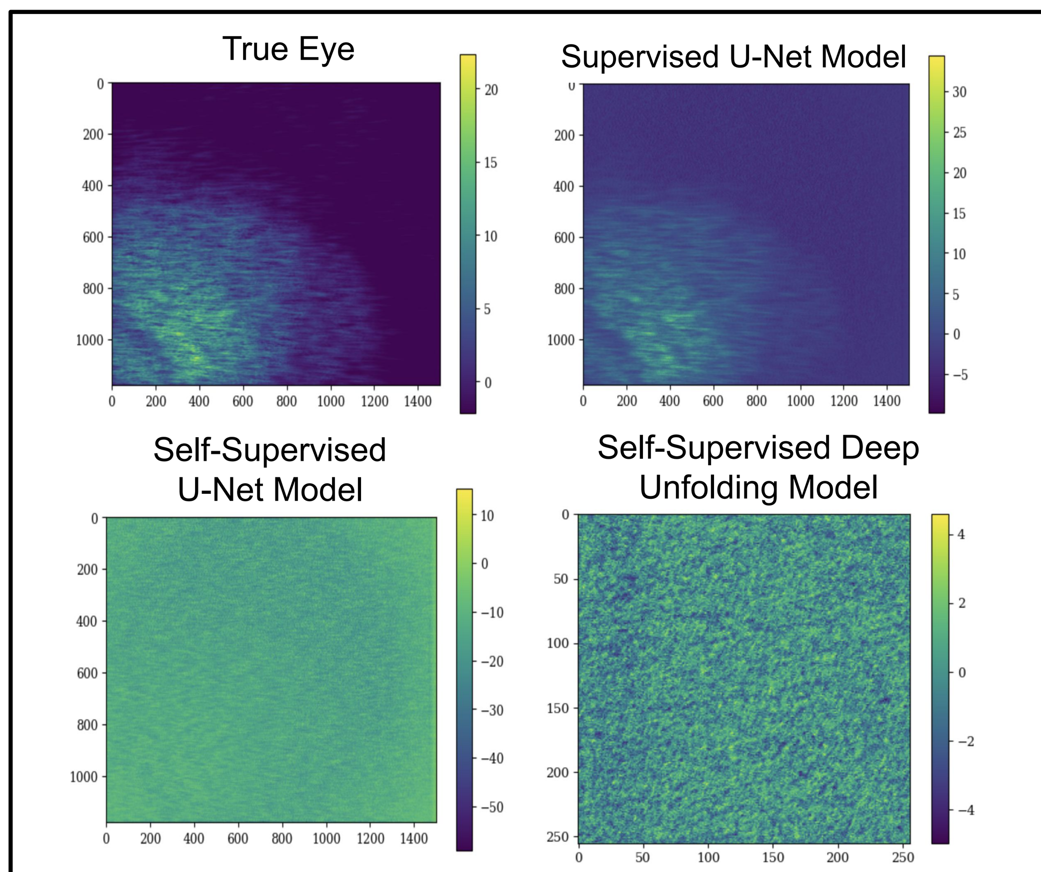


Figure 5. True and predicted eye images.

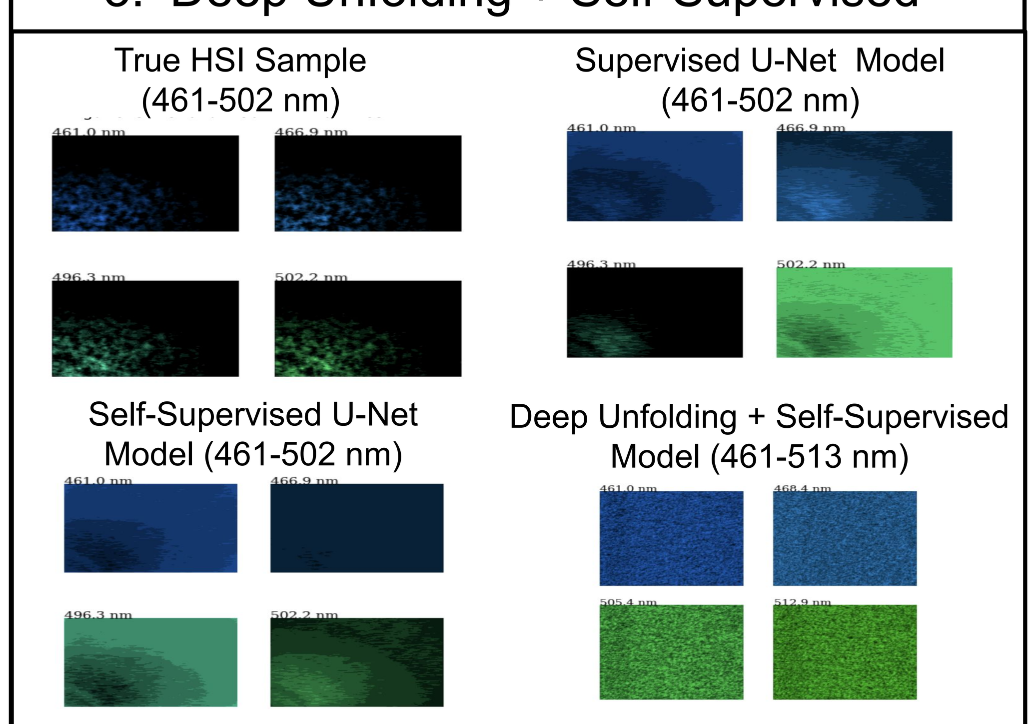


Figure 6. True (Augmented Lagrangian) and predicted eye HSIs.

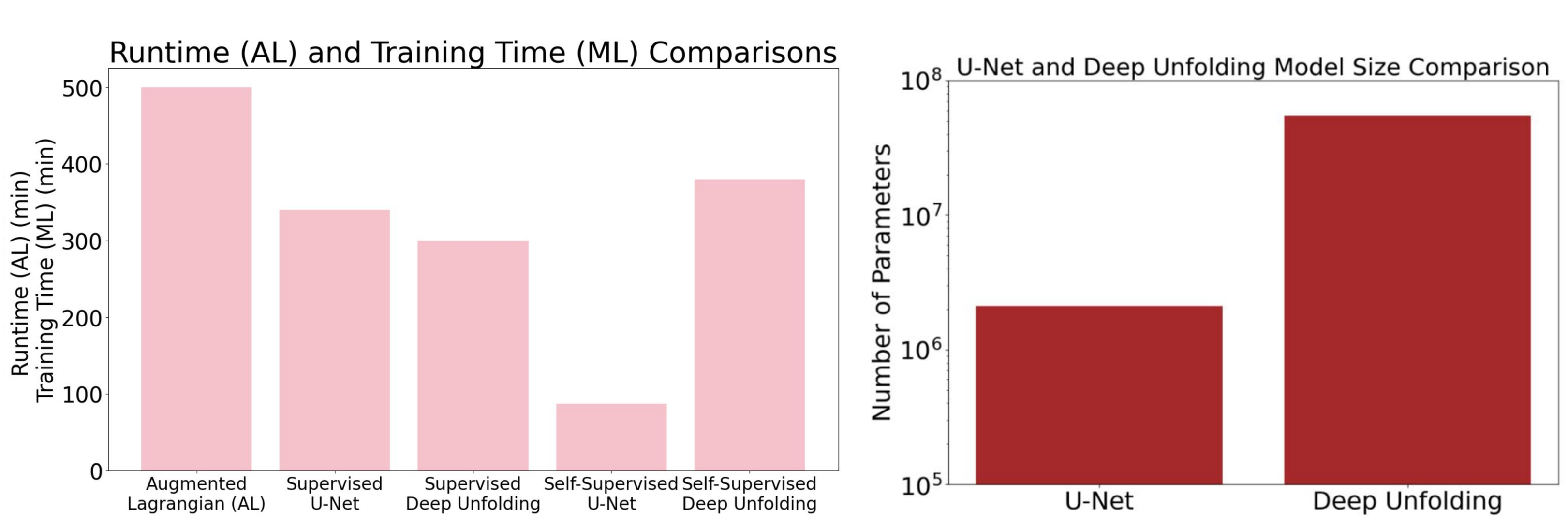
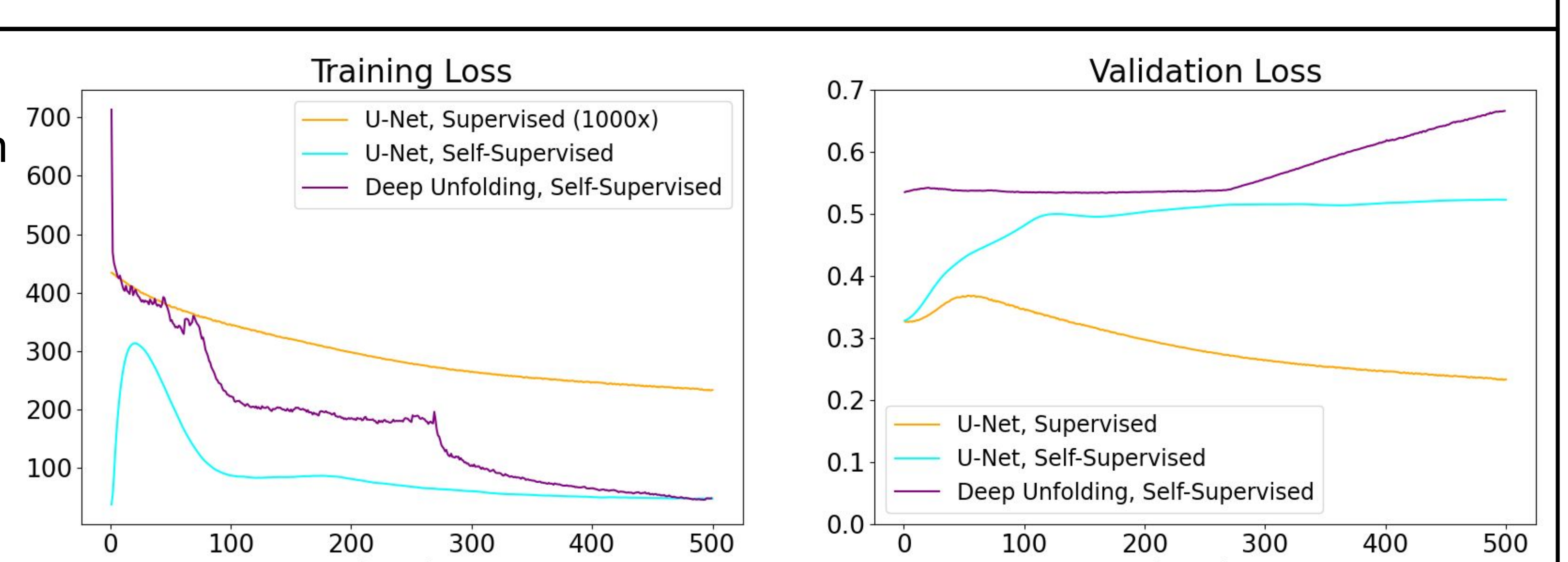


Figure 7. Comparison of model run and train times (left). Comparison of model size (right).

Figure 8. Training loss and validation loss of U-Net Supervised,U-Net Self-Supervised and Deep Unfolding Self-Supervised Models



Conclusions

- Integration of hyperspectral imaging and machine learning holds promise for early AMD diagnosis.
- Increasing the training population can enhance model accuracy for early AMD diagnosis.
- Computational models enable early intervention in AMD, addressing the absence of a cure.
- Ongoing efforts in adapting NMF algorithms for in-vivo data aim for precision in diagnostic outcomes.

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Part B: Spectral Extraction from Hyperspectral Images

- Converted hyperspectral data cubes into matrices through mode-3 matricization.
- Extracted spectra from matrices using an iterative non-negative matrix factorization (NNMF) algorithm and a deep-learning based NNMF algorithm
- Performed functional-PCA on the unit-2 normalized spectra to compare the Robust-NMF and EADNMF algorithms as well as the spectra of patients with and without drusen lesions.
- Compared the runtime of the Robust-NMF and EADNMF algorithms for spectral extraction.

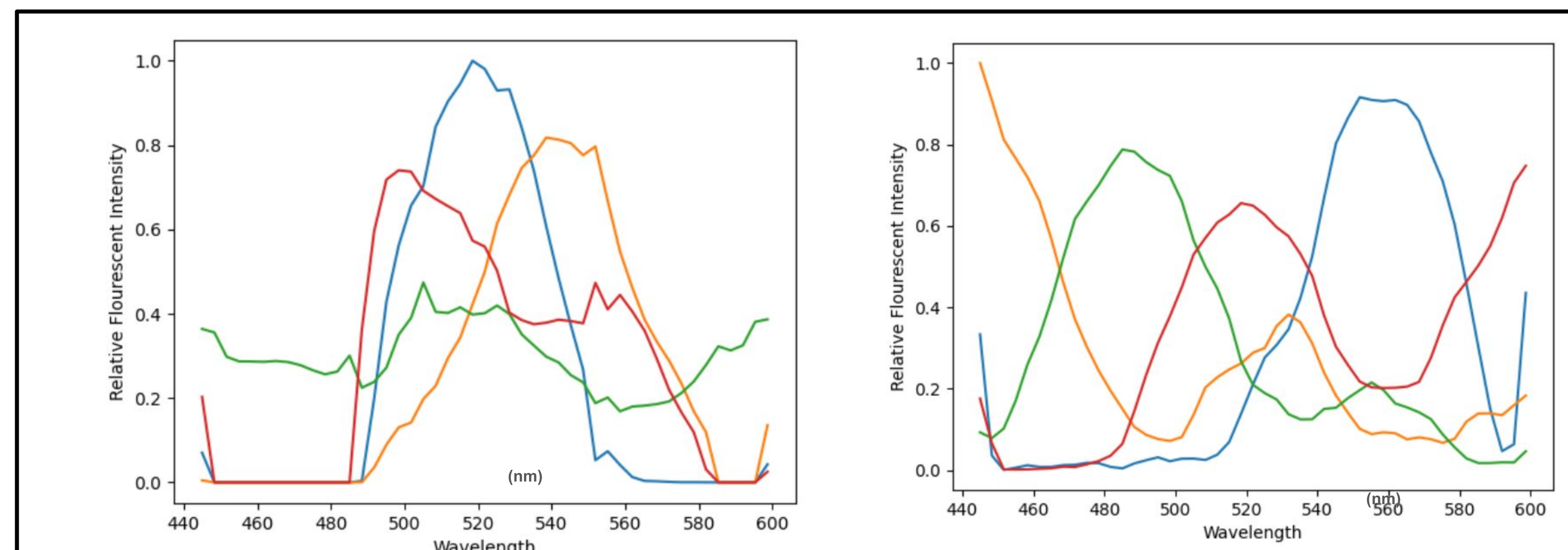

Figure 11. Representative spectra for a patient without (left) and with (right) drusen extracted using EADNMF. Potential drusen spectra shown in blue in the image on the right.

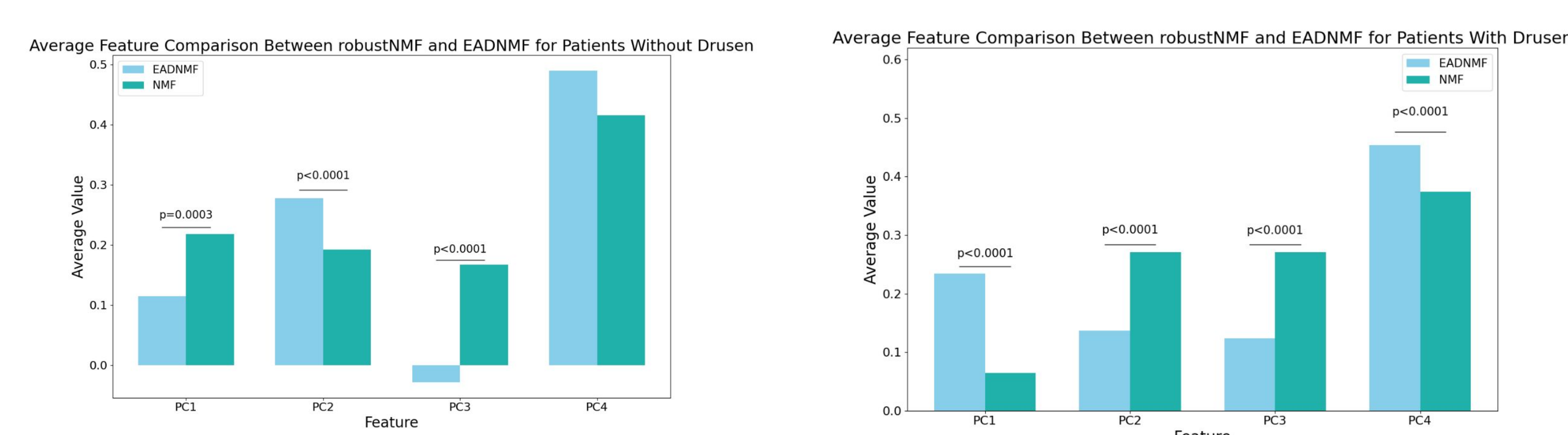

Figure 12. Averagecomparison feature between spectra extracted through robustNMF and EADNMF for patients with (left) and without (right) drusen lesions.

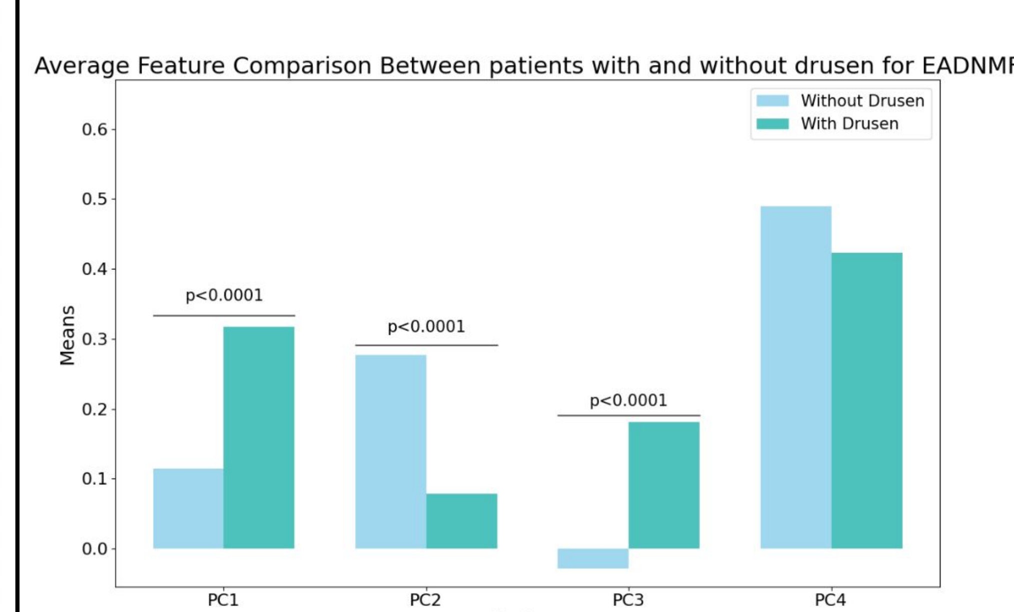

Figure 13. Average feature comparison between spectra extracted from patients with and without drusen lesions with EADNMF.

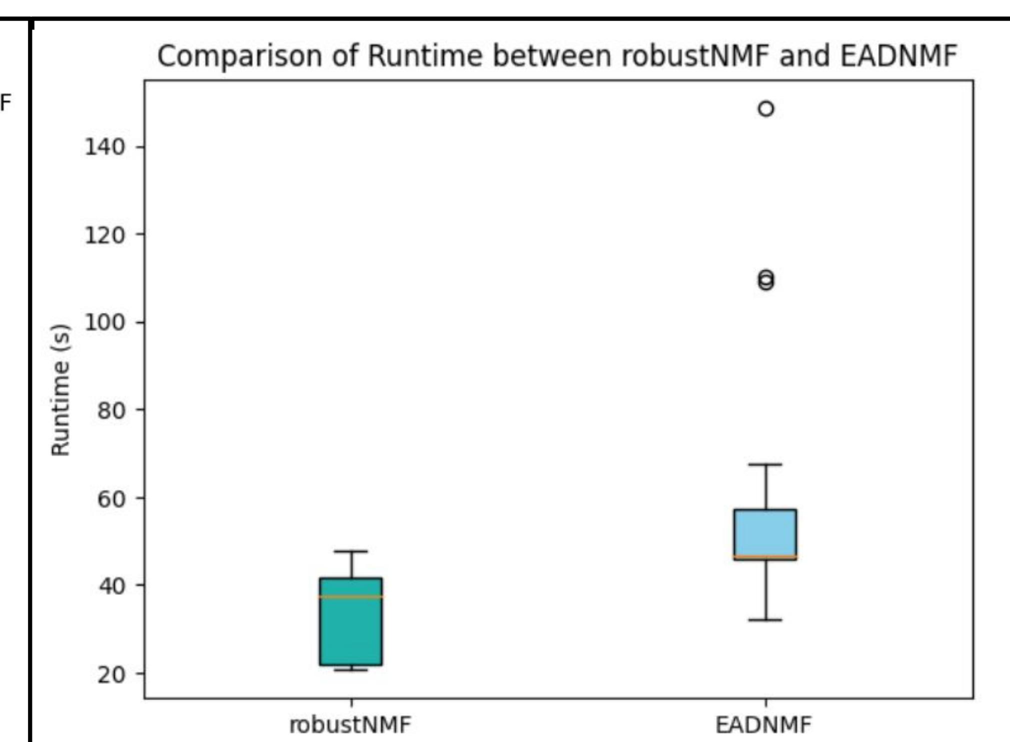

Figure 14. Runtime over all patients for spectra extraction using robustNMF and EADNMF

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