# Enhanced vessel continuity in optical coherence tomography angiography *en face* projections of the superficial vascular plexus via deep learning

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## PURPOSE

- Averaging is known to improve vessel continuity in ocular Optical Coherence Tomography Angiography (OCTA) *en face* images but is time consuming, since it involves repeatedly scanning the patient. Alternatively, improving continuity in individual images is possible by using a Hessian "vesselness" filter[3]. Although this can improve continuity, it can compromise fidelity to the anatomy.
- This work investigates the use of a convolutional neural network (CNN) on individual scans to improve continuity without this loss of accuracy.

## METHODS

- A CNN with a patch-based U-net architecture was trained on OCTA images of the superficial capillary plexus, using averages of repeated scans of the same subject as ground truth.
- A PLEX® Elite 9000 SS-OCT System (ZEISS, Dublin, CA) was used to acquire 4 repeated 6x6 mm OCTA scans of each of 12 subjects, 6 normals and 6 with vascular pathology. Superficial angiography slabs from these repetitions were averaged, providing 12 high quality images, using one of the individual repetitions as the reference for each average.
- The trained CNN was used to process each reference slab, providing a "pseudo-average" frame.
- In parallel, for comparison, a Hessian filter was applied to these reference scans to improve vessel continuity.
- Each averaged image was then correlated with its corresponding CNN-processed image, the Hessian processed image, and the original reference image, so that similarity to the average image could be quantified.

## RESULTS

Correlations with 4-frame average image

| subject | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | mean | stdev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| original image | 0.851 | 0.855 | 0.868 | 0.867 | 0.86 | 0.86 | 0.878 | 0.877 | 0.881 | 0.869 | 0.885 | 0.877 | | 0.869 | 0.0109 |
| CNN_output | 0.864 | 0.849 | 0.867 | 0.869 | 0.86 | 0.859 | 0.861 | 0.875 | 0.88 | 0.872 | 0.88 | 0.866 | | 0.867 | 0.00909 |
| Hessian output | 0.78 | 0.781 | 0.81 | 0.809 | 0.788 | 0.788 | 0.796 | 0.803 | 0.806 | 0.773 | 0.79 | 0.793 | | 0.793 | 0.0121 |

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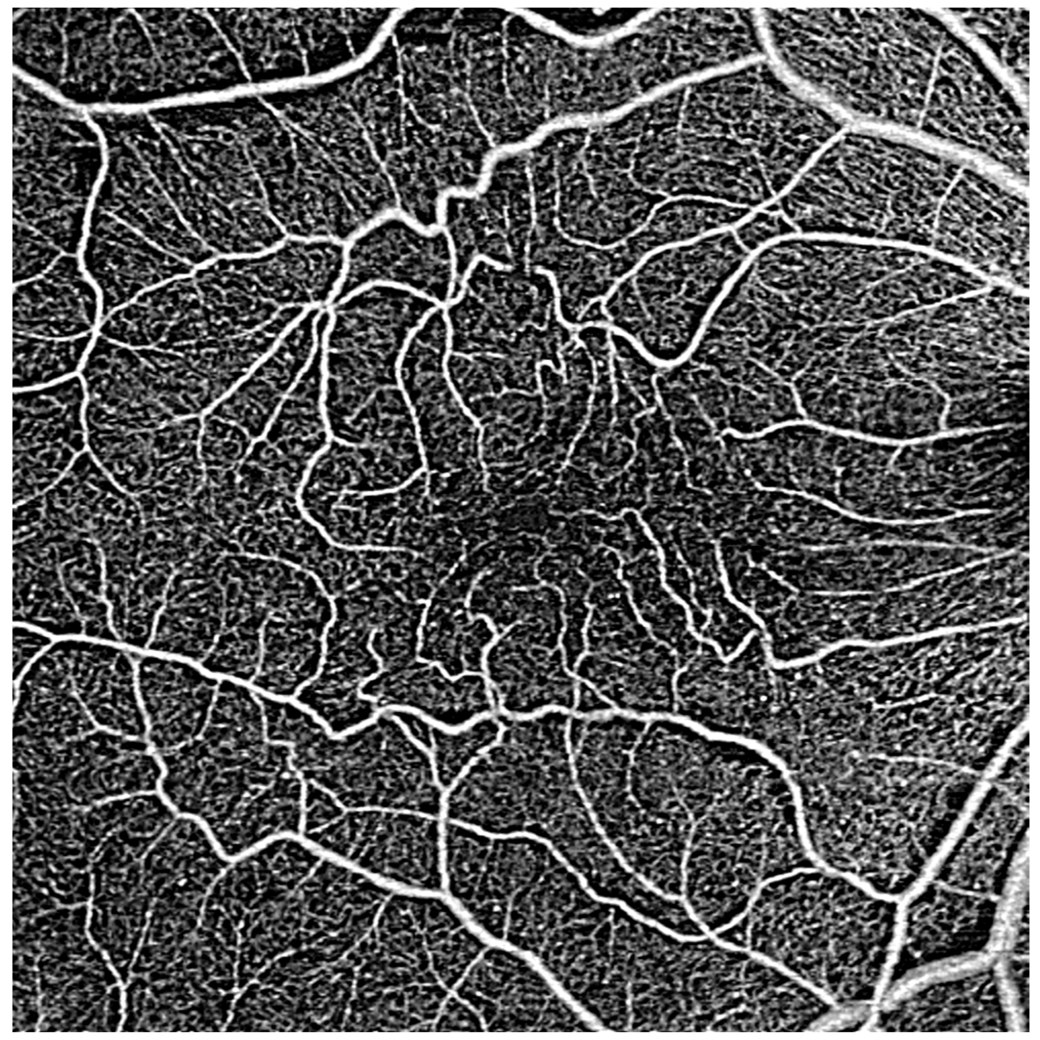
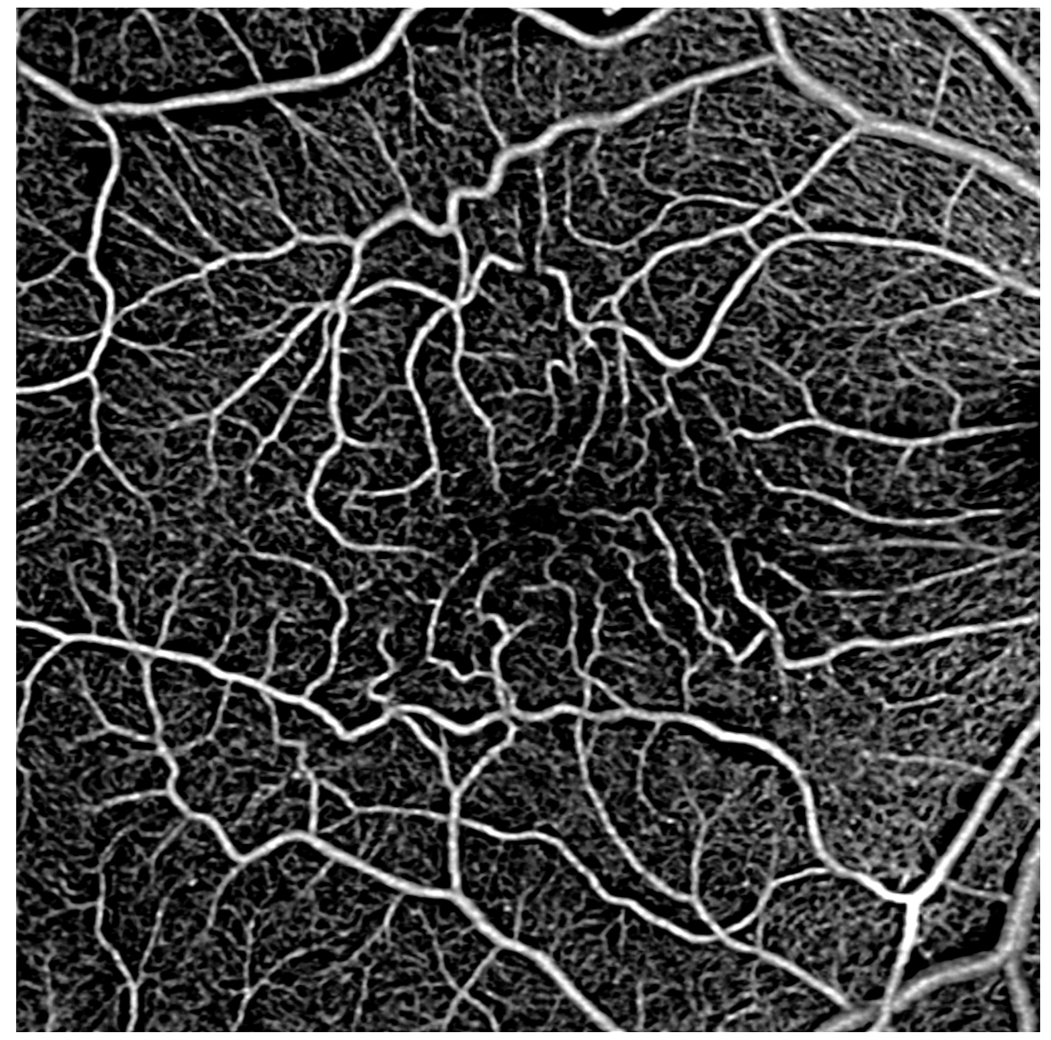
References:

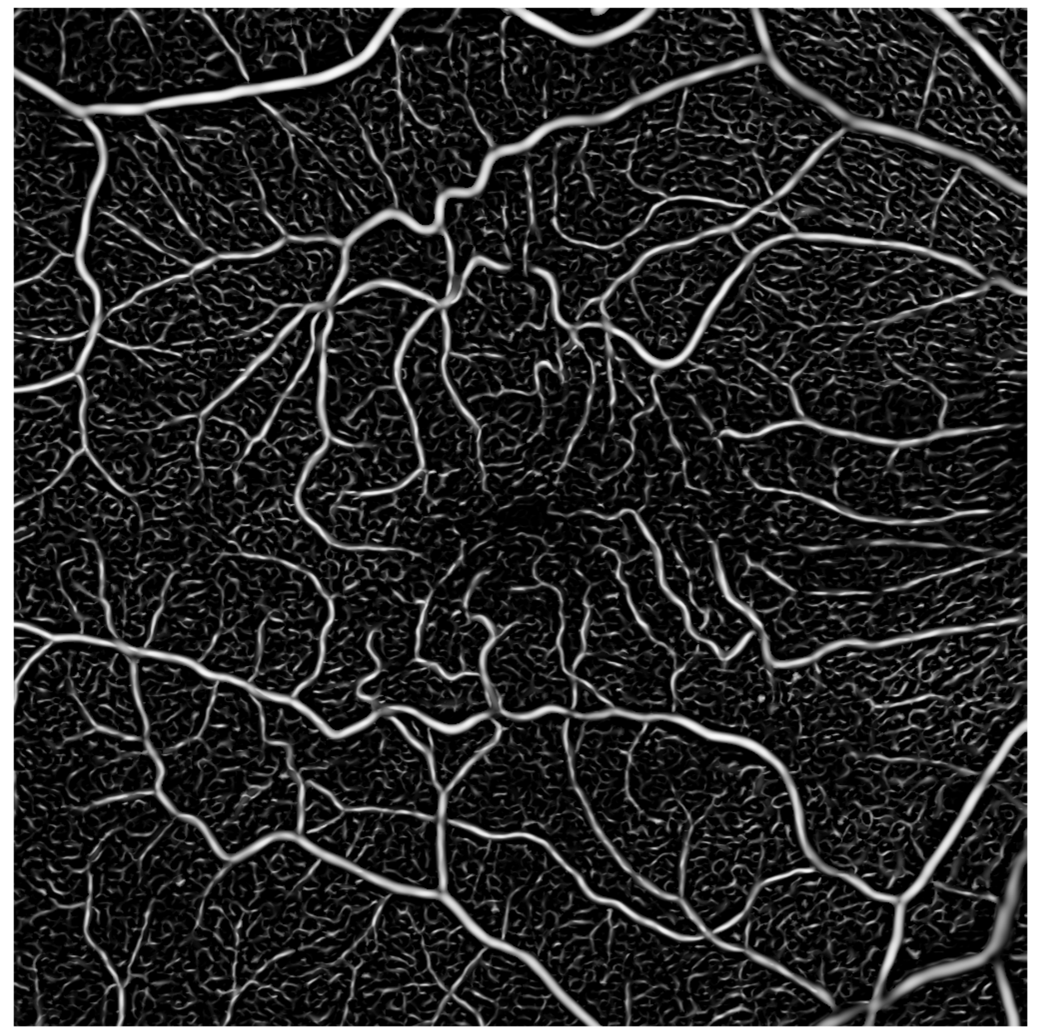
[3]Frangi, A. F., Niessen, W. J., Vincken, K. L., and Viergever, M. A., "Multiscale vessel enhancement filtering," in [Medical Image Computing and Computer-Assisted Intervention - Miccai'98], Wells, W. M., Colchester, A., and Delp, S., eds., 1496, 130–137, Springer-Verlag Berlin, Berlin (1998)



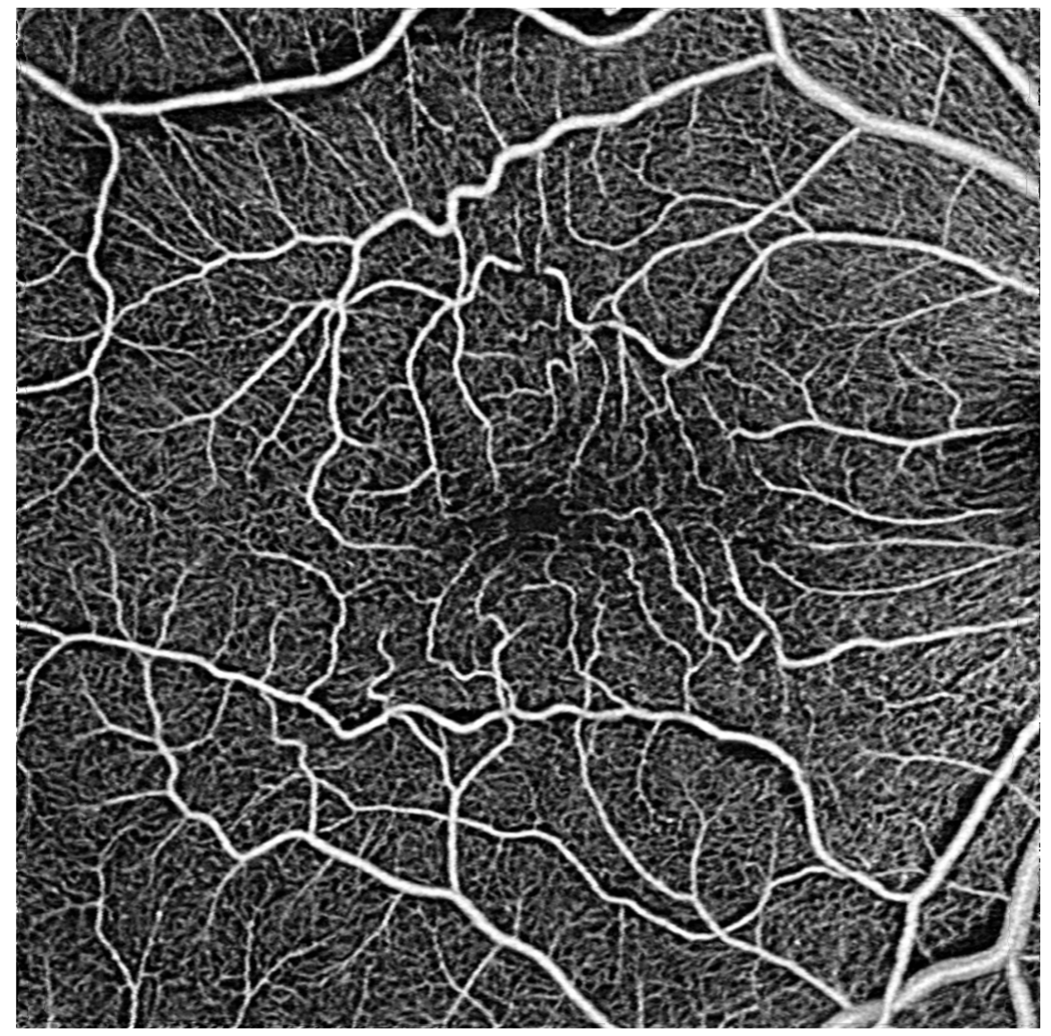
Unprocessed single acquisition



CNN output



Hessian filter output



4-frame average

The averaged image has improved vessel continuity, but required a series of 4 scans. Both the CNN output and the Hessian filter improve the vessel continuity from a single scan, but the CNN provides better fidelity to the averaged image than does the Hessian filter.

## CONCLUSION

Convolutional neural network based image processing can improve vessel continuity without the loss of fidelity associated with Hessian filters.