Improving Reliability of Retinal Vessel Caliber Measurement Using Deep Convolutional Autoencoder

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Research to Prevent Blindness

Background

Over the last decade, many studies have established associations between the caliber of the retinal microvasculature and underlying pathologic conditions. Advancements in retinal imaging and fundus photography (FP) have offered greater opportunity for the assessment of these vessels and greater accuracy in identifying microvascular damage.

Integrative Vessel Analysis (IVAN) is a semi-automated vessel measurement software that has been used in multiple epidemiological studies. However, one of the limitations of IVAN is the necessity of high image quality for reliable measurements. Poor image quality accounts for about 10 – 25% data loss using IVAN.

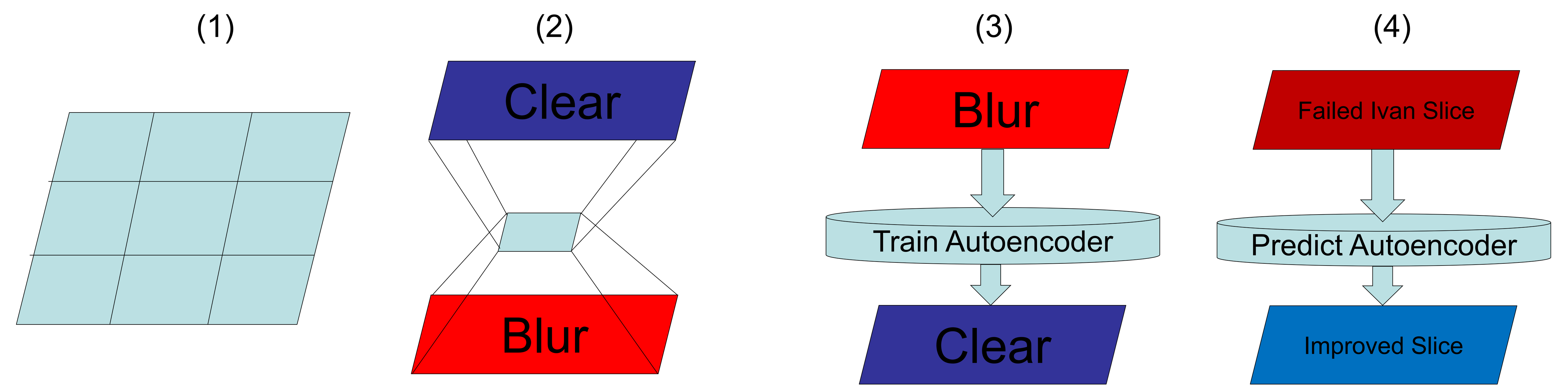
Purpose

This study represents a deep learning autoencoder approach to images and restoring the structural details required for IVAN.

Methods

- The dataset included de-identified CFP (field 1) with vessel measurements in IVAN from the Carotenoids in Age Related Macular Degeneration Study 2 (CAREDS2),
- Mean age of study participants was 68 ± 0.2 years
- To create a 'bad' image, a normal image was shrunk in resolution by a factor of 20 and then inflated back to original size
- A 'bad' image is used as an input with the original image as a target to train a CNN-U-NET (aka Autoencoder)
- Network learns to fill in details from 'bad' images.
- Images unable to be read by IVAN, run through network to improve resolution details

Model Development



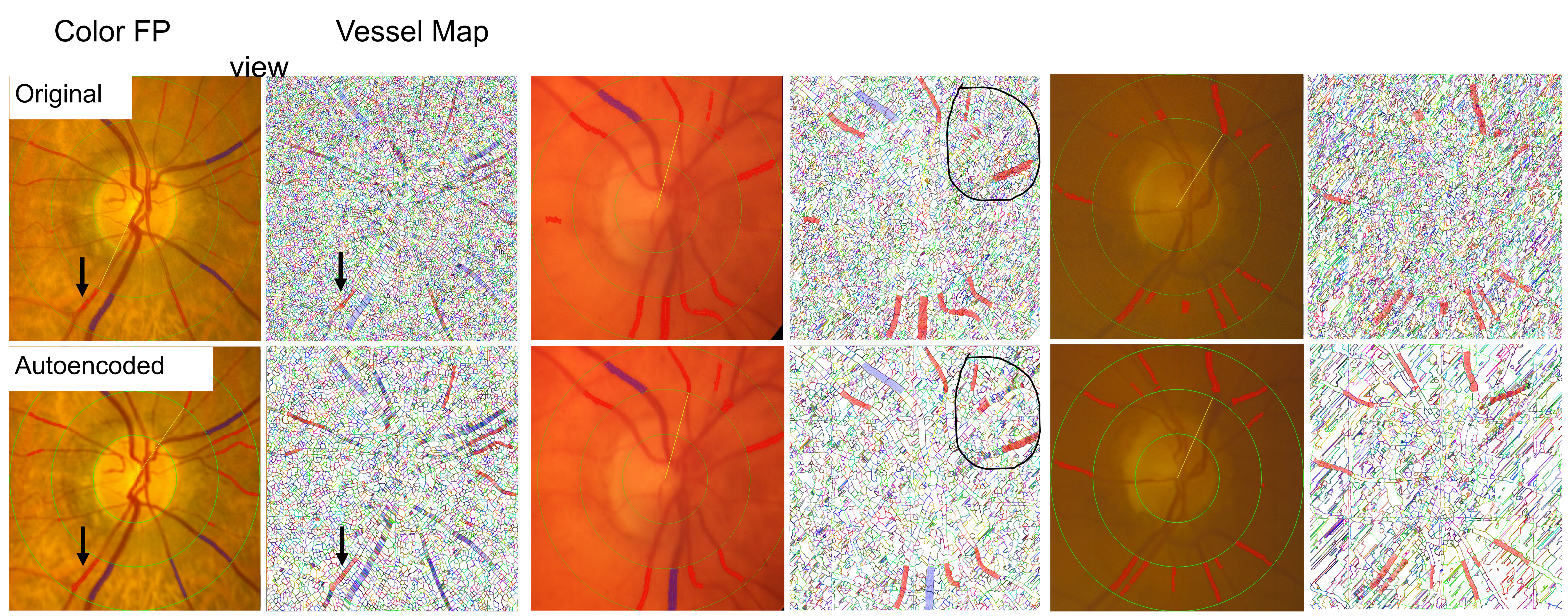
(1) Images Ivan can measure (2k x 2k pixels) are chopped into sizes a CNN can handle 400x400.

(2) Slices are degraded by lowering resolution and then resizing back to original resolution to create a blurry image

(3) Network learns to reconstruct clear image from blurry image

(4) Take failed Ivan slice and try to improve. (not pictured—improved slices stitched together for full size image in IVAN

Vessel Measurement



The original image was good quality except one major arteriole vessel not mapped correctly (arrow). The autoencoder sharply mapped the blurry double vessel without affecting other vessel resolution.

The original image was poorly focused resulting in several ungradable vessels (circled area). The autoencoder improved the overall image resolution enabling these vessels to be reliably measured.

The original image was poorly focused resulting in most of the vessels ungradable. The autoencoder oversimplified vascular details (map view), making it difficult to decide if this image could be graded reliably or not.

Results

- 12 images considered ungradable by IVAN were processed through the autoencoder
  - 9 images resulted in improved IVAN now able to measure vessels
  - 2 images remained ungradable due to vessel anatomy
  - 1 image remained ungradable due to focus
- A comparison of 'good; images run through the network (n = 10) vessel caliber pre and post autoencoder showed a mean difference of 6.03 microns (p = 0.41) for central retinal artery equivalent (CRAE) and 1.12 (p = 0.90) for central retinal vein equivalent (CRVE).
- The mean sigma for CRAE and CRVE was 3.26 and 3.83 respectively in the original dataset and 4.13 and 4.76 in the autoencoder dataset

Conclusions

A deep convolutional autoencoder improves the vascular details on retinal images and enables IVAN measurements, reducing data loss due to inferior quality photographs. Vessel diameter is not altered due to autoencoder enhancement and can be reliably used in longitudinal data.

References

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