Quantitative Spectral Imaging of the Retina

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Purpose

Hyperspectral imaging of the retina presents a unique opportunity for direct and quantitative mapping of retinal biochemistry - particularly of the vasculature where blood oximetry is enabled by the strong change of absorption spectra with oxygenation. This is particularly pertinent both to research and to clinical investigation and diagnosis of retinal diseases such as diabetes, glaucoma and age-related macular degeneration. Spectral processing methods such as linear spectral unmixing[1] enable semi-quantitative depiction of retinal oximetry as shown in figure 1, but there is a clinical requirement for more accurate oximetry within retinal blood vessels.

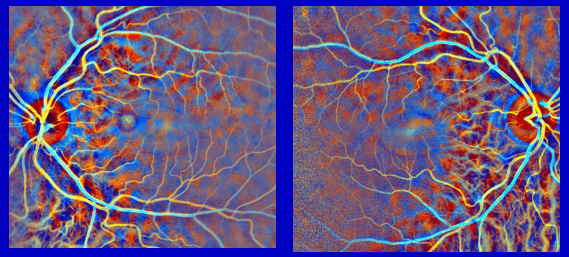
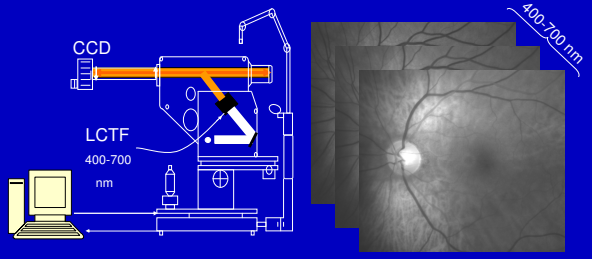


Figure 1 linear spectral unmixing

Methods

A liquid crystal tuneable filter has been incorporated into a conventional fundus camera to enable computer-controlled, random-access spectral filtering of the source with 10nm spectral resolution (figure 2). The available output image has been reimaged to enable the full 60° field of view to be retained when used with a cooled low-noise CCD. A computer running under LabView is used for instrument control and data acquisition.

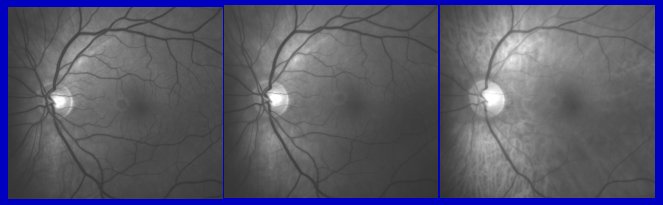


Fundus camera

Raw retinal images

Figure 2

Due to non-uniform illumination and random movement of the eye ball and reflections from lens surface recorded images need to be calibrated and co-registered to correct for rotational and translational offsets introduced between images. A typical set of images is shown in figure 3 for wavelengths between 580 nm and 600 nm.



580 nm 590 nm 600 nm

Figure 3

The process for calculation of blood oxymetry is illustrated as shown in figure 4. This involves a non-linear fit of a physical model for light propagation to each narrow-band image[2]. An interpolated estimate of the illumination at the retina obviates the need for calibration (figure 5).

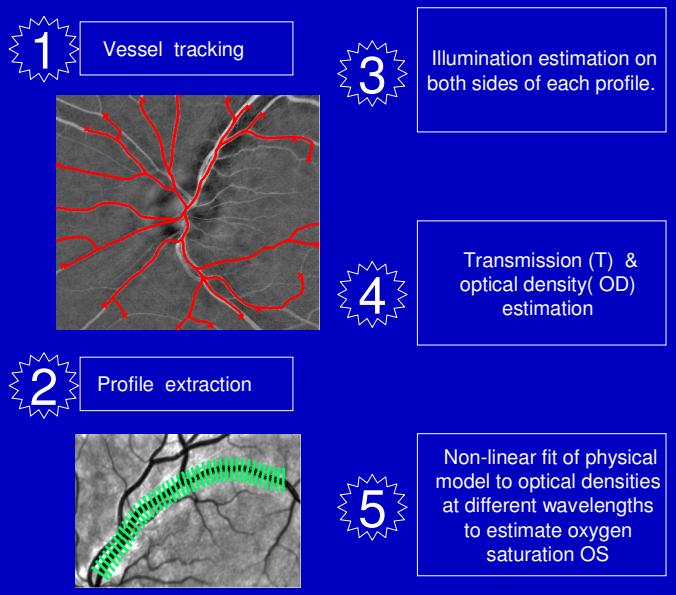


Figure 4

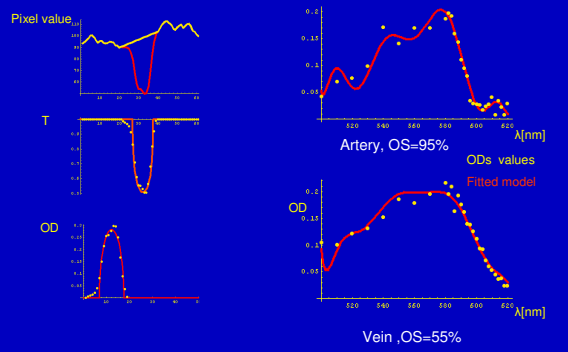


Figure 5

Results

The oxymetry map (figure 6) can be rapidly calculated for a comprehensive fraction of the retinal vasculature. Random variations in oxygenation along a blood vessel of assumed constant oxygenation are typically less than 4%.

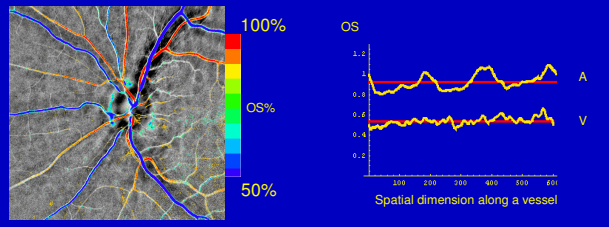


Figure 6

Conclusion

This technique enables a highly flexible approach to acquiring a wide-field spectral data cube for research and clinical exploration. The use of vessel tracking and fitting of an analytical mathematical model to the transverse profiles suppresses the misregistration and calibration artefacts that are normally an issue for time-sequential techniques. For clinical application a wide-field snapshot technique[3] is desirable: the investigative data recorded here has informed the optimisation and design of the novel snapshot system spectral retinal imager[4].Future work using this instrument will assess clinical interpretation and refinement of the mathematical model for light propagation.

References

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[4] G.Muyo, A.Corman,I.Alabboud,D.J.Mordant,A.I.McNaught,A.R.Harvey, En Face Snapshot Spectral Imaging Of The Retina ,ARVO 2582-B659,ARVO 2007.

COMMERCIAL RELATIONSHIP a: QinetiQ, AstraZeneca, b :Alcon; Allergan; MSD; Pfizer.