Final Report prepared for Retina Australia

For the Retina Australia Grant received in 2015
Project: ***"Hyperspectral funduscopy for non-invasive detection of retinal ischemia"***
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Lay summary of the project

Retinal ischemia is a leading cause of vision impairment and blindness among adults. While there are number of treatments methods that interrupt the ischemic cascade, there are no clinically effective methods for reversing retinal ischemia. Thus, effective treatment requires early detection of the disease. The aim of this project was to use hyperspectral fundus imaging for non-invasive identification of retinal ischemia. Hyperspectral imaging (HSI) uses narrow band optical wavelengths to obtain the detailed spectrum of the image at each of the pixels. Unlike commonly used photography techniques, it does not quantify the colours in three discrete channels. This is a relatively new technology and allows the user to record the true colours of each pixel in a range that is often defined in terms of the wavelength of the light. It was hypothesized that differences between normal and ischemic regions in retina will be observable using hyperspectral imaging which can be used as an alternative technique to the invasive fluorescein angiography (FA). Unlike other retinal imaging, this technique uses a set of narrow band optical wavelengths to obtain the detailed spectrum of the image at each of the pixels making it suitable for detection of Microvasculopathy.
For this purpose, at first a hyperspectral camera was required to be integrated with fundus imaging equipment and images of the volunteers to be taken. Analysis of the images was to be performed to study retinal perfusion and classify the regions into perfused (non-ischemic) and non-perfused (ischemic) regions.

Objectives and Achievements

1) Integration of Hyperspectral camera with fundus camera

The first part of the project was the hardware integration. The OCI-OEM-2000 hyperspectral camera by Bayspec (BaySpec, Inc. USA) was used in this project. This is a 28 band C-mount, snapshot hyperspecral imager with wavelengths ranging between 600-1000 nm (visible and near infrared region) and spectral resolution of less than 10nm. This camera was mounted along the top optical path of a Topcon TRC50-VT through a relay lens system. A C-mount to

Topcon adaptor was used to couple the relay lens with the hyperspectral camera and to match the focal points.

Substantial modifications were made to the Topcon optics in the illumination pathway for providing a wide band illumination and also for optoelectronic synchronization. The built-in xenon flash in the Topcon camera was replaced with a wide band halogen light source controlled by an electric shutter to illuminate inside the eye for duration of 30ms. A Topcon 35 mm film camera was connected to the front optical path of the fundus camera. It was used as the view finder, required by the photographer to look through the patient's eyes and do the focusing and other adjustments. A software package was built in MATLAB (Mattworks ® USA) for real-time streaming of the hyperspectral images and analysis. Figure 1 shows the camera configuration and setup.

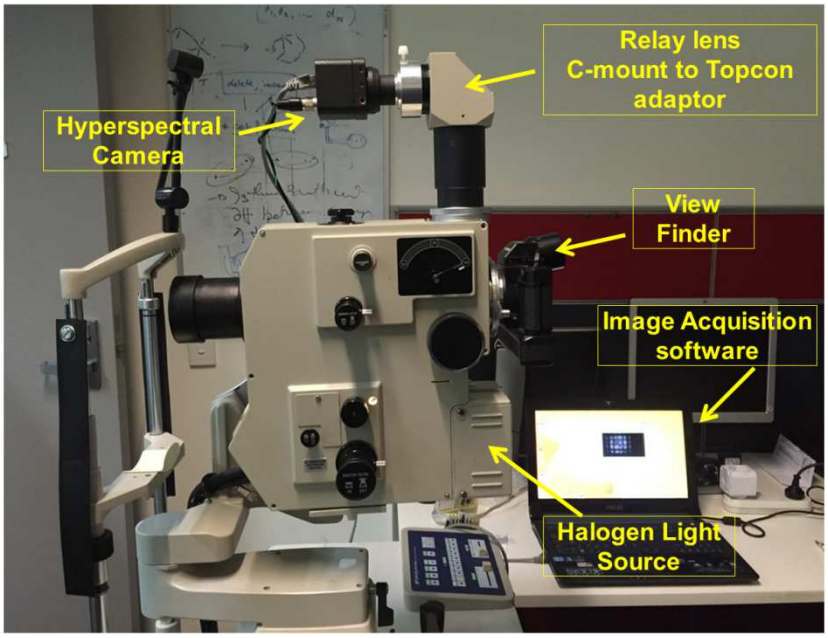

Figure 1: Hyperspectral fundus imager (Camera Setup)

The significance of the above configuration is that it allows snapshot acquisition in only 30 ms and without much sampling errors due to artefacts such as the eye movements. It also provides a wide spectral band with high spectral resolutions (28 channels). However, it provides much smaller field of view and lower spatial resolution compared to the conventional fundus cameras. Therefore further system enhancement in the above area is required to enable high definition hyperspectral imaging of the retina and allow for application of the device in clinical setting.

2) Image processing for study of retinal perfusion

While work was in progress for fixing the above limitations, we used hyperspectral images from a newly developed fundus camera (Photon HR Camera, Optina^{TM}, QC, Canada) to implement and test the image processing algorithm. In order to understand the changes that occur in perfused and non-perfused regions in retina, we created a bassline characteristic and feature sets for healthy subjects with normal retinal perfusion. We developed an algorithm for feature extraction and for differentiation between ischemic and non-ischemic regions using the baseline characteristics as reference.

To create the baseline, hyperspectral retinal images of healthy subjects were collected and examined by an experienced grader from Center for Eye Research Australia (CERA). A pseudo RGB image feature sets were constructed from the hyperspectral cube using principal component analysis (PCA). Figure 2 shows example of a hyperspectral image of a healthy retina with normal perfusion and the constructed pseudo RGB feature set. The images were subdivided into several small Regions of Interest (ROI) and the Gray Level Co-occurrence Matrix (GLCM) was obtained for each ROI corresponding to each wavelength to obtain a number of textural information. The contrast, homogeneity, correlation, and energy feature sets were extracted from the GLCM matrix corresponding to a normally perfused tissue.

We also developed an algorithm for quantification of changes in the blood oxygen saturation of retinal arterioles and venules and extraction of Hb and HbO_2 levels as measure of retinal perfusion and feature to detect ischemic region.

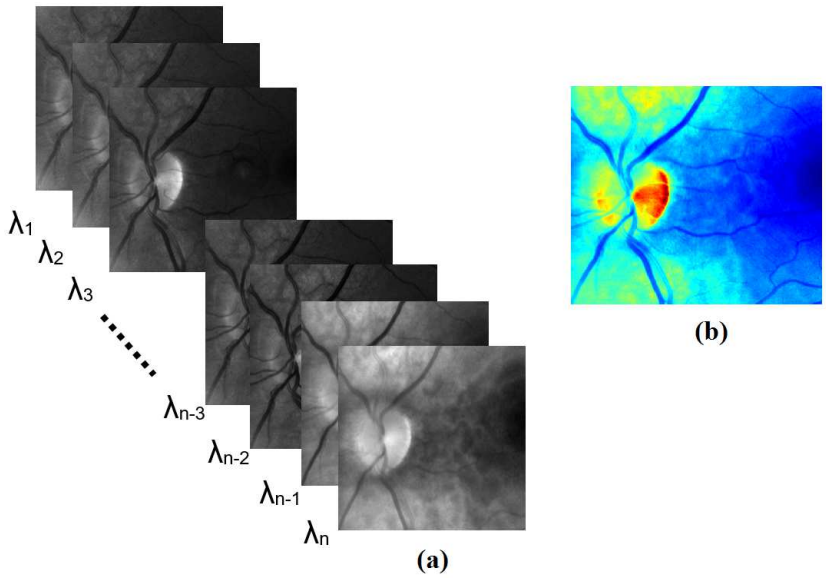

Figure 2: Example of a Hyperspectral fundus image (a) Hyperspectral cube – channels corresponding to each wavelength (b) Pseudo RGB image obtained using PCA

In summary, in this pilot study, we built a prototype hyperspectral fundus camera and identified the baseline characteristics and feature sets (i.e. Texture and Oxygenation level) corresponding to retinal perfusion and to identify non-perfused regions. The outcome of this work will be considered for publication in near future. This work has determined that hyperspectral imaging has the potential for improved assessment of the retinal vasculature disorders. Further development and experiments are essential to test and validate the hypothesis.