Combined Multispectral and Fluorescence Imaging for Breast Conserving Surgery

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Introduction

- 1 in 8 women in the UK develop breast cancer at some stage in their lifetime.
- In 2008 approximately 58% elected to have breast conserving surgery or lumpectomy
- One in five women who had breast conserving surgery in England had a reoperation. Reoperation was nearly twice as likely when the tumour had a carcinoma in situ component coded [1].
- In the US, half of re-excisions after initial lumpectomy were performed for margins that are positive [2].

A contemporaneous/intra-operative and sensitive screening tool for positive resection margin will have a huge impact on patient psychology, morbidity, mortality, healthcare cost and disease burden.

The GLOW project carried out at Hamlyn Centre, Imperial College London, demonstrated that NIR ICG Fluorescence Imaging can be used in intra-operative tumour border demarcation [3]. The sensitivity in detecting tumour by hyperspectral imaging requires improvement for DCIS and connective tissue [6]. To this end, we have developed a combined fluorescence and multispectral camera.

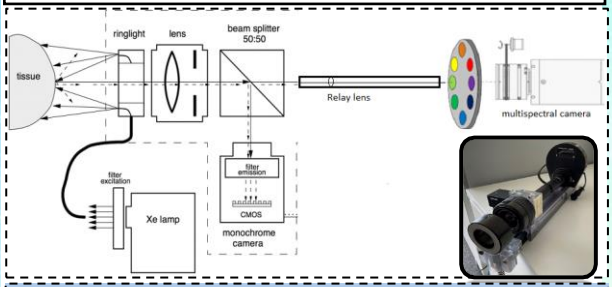

Figure 1: Camera design drawings and features

Method

- A multispectral camera (SpectroCam©, Ocean Optics) was connected to a NIR fluorescence monochrome camera (GS3-U3-15S5M-C FLIR) using a non-polarising 50:50 beam splitter and relay lens of 1:1 magnification *(figure 1).*
- A Xenon lamp (MAX 303 Asahi) provided illumination of the region of interest. The primary image was formed by a manual zoom 35-70mm provided by a SLR Pentax K-mount lens.
- The camera acquisition parameters and image acquisition was carried out using a custom made LabView interface *(figure 3d).*
- The multispectral camera operates with a frame rate of 33fps and the monochrome camera at a variable level set at 45fps. The field of view of the two cameras were matched.
- The camera resolution was tested using a custom-built program incorporating the Rayleigh criterion and USAF1951 targets in MATLAB (MATHWORKS, Massachusetts. USA). Resolution and signal to background noise were explored further over varying working distances and illumination.
- An RGB reconstruction from spectral images was carried out to validate the filters and performance of the camera system using Python OpenCV. *(figure 2).*

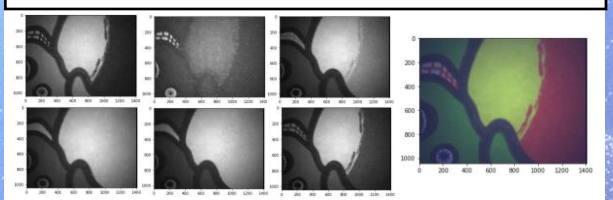

Figure 2: (Left) multispectral image slices (470, 520, 560, 615, 645nm) . (Right) reconstructed colour image

Preliminary results

The camera is currently fit for preliminary validation with specimens. Eight spectral images at distinct wavelength within the visible range are displayed on the interface and compared to a larger image from the fluorescence camera. Functionality is provided to the user to change the exposure time and gain for each filter configuration including the NIR fluorescence camera. The following camera features were extracted from testing as shown in *figure 3*.

Camera Features

- ✓ The camera functions at a working distance of 10 – 40 cm.
- ✓ Safe illumination can be provided between the range of 5 – 15 illumination (lx).
- ✓ The spectral bandwidth is between 400 – 700 nm.
- ✓ The resolution is best at a working distance of 15 – 25 cm with an illumination of 10 lx.
- ✓ At a working distance of 10 cm the illumination from the xenon lamp is absent
- ✓ There is a peak in signal to noise ratio at 15 cm working distance, which plateau out.
- ✓ The diagonal field of view *(figure 3c)* generally increases with increasing working distance.

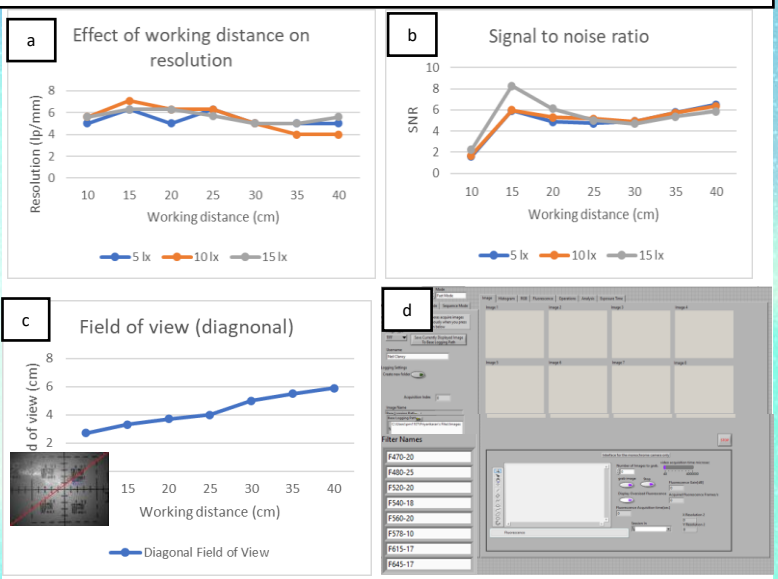

Figure 3– (a): Effect of working distance & illumination on camera resolution; (b): Effect of working distance & illumination on image signal-to-noise; (c): Working distance and the effect on field of view; (d): Custom LabView interface with filter names specified (nm).

Discussion

A Multispectral/ NIR ICG Fluorescence Imaging camera capable of operating at variable frame rates, working distances and illumination is presented and tested for performance.

- The optimum working distance for the camera lies between 20 – 30 cm where the resolution and signal to noise ratio do not change with respect to illumination intensity. *(figure 3a)*
- Better resolution at working distances above 30 cm can be achieved with a 15 lx illumination.
- It is recommended to operate at working distances above 15 cm owing to poor illumination at lower values and to maintain the region of interest in the center of the field of view where aberration and distortion are less.
- Signal to noise ratio can be improved with stronger illumination. *(figure 3b)*

Future Work

The multispectral images can be used to construct oxygenation and hemoglobin concentration maps over tumor region of interest [5] to correct the fluorescence texture metrics [3]. We hope to validate the camera by imaging actual tumor specimens and comparing them with histological ground truth data. It is envisioned that the development of a suitable image overlay technique will evolve as real data is captured and analyzed (we hope to explore quantitative image normalization and deep neural networks for tumor localization and segmentation). Further image registration is also required to prevent movement artifacts. The incorporation of better optics will enhance the camera capabilities after establishment in the clinical environment.

References
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