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Multi-spectral Image Alignment Analysis of Brain Tissue Dissection During Neurosurgery

Abstract

Multi-spectral imaging is a modality that acquires an image with multiple channels, each representing information from one wavelength instead of its generalised colour value, such as green.

Brain tumours develop and affect the central nervous system inside or near the brain. One of the main treatments for this type of tumour is maximum resection. However, during the procedure, the visual appearance of the tumour might be hard to distinguish against its sorroundings.

A study has shown promising results on tissue segmentation from multi-spectral images[1]. The first step of this process is to match tissue types based on their spectral values. Thus, this project aims to explore alignment methods for multi-spectral images.

Introduction

Imperial College London, in partnership with Charing Cross Hospital, has acquired a novel dataset of microscope colour images and multi-spectral images taken during open surgeries. The operator took these images at different time points throughout the procedure, called scenes.

A neurosurgeon then label the microscope images by identifying and bounding regions in the image to a set of tissues. We then use the labelled images as the ground truth of the scene.

Dataset

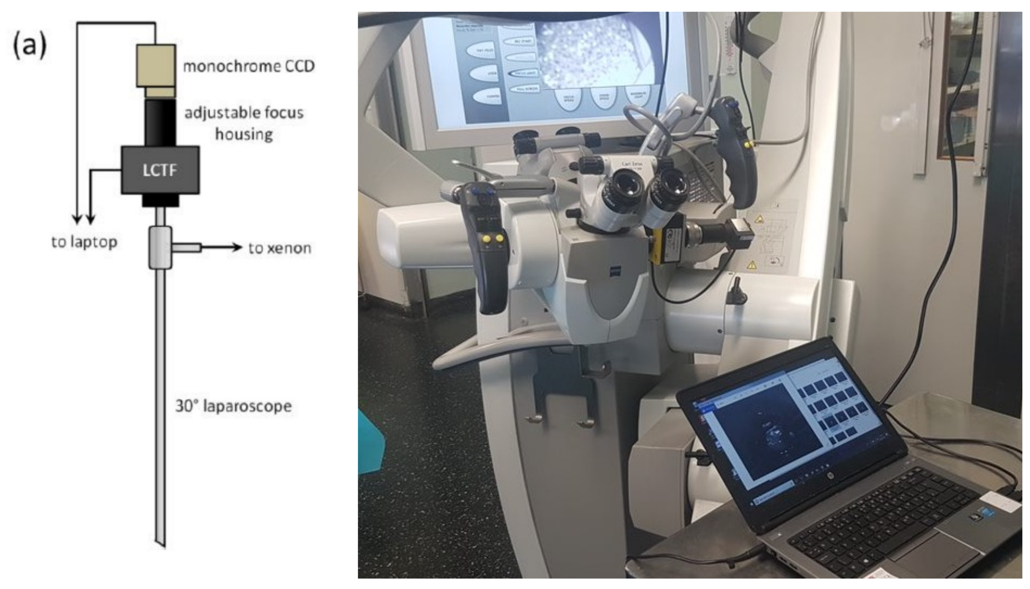
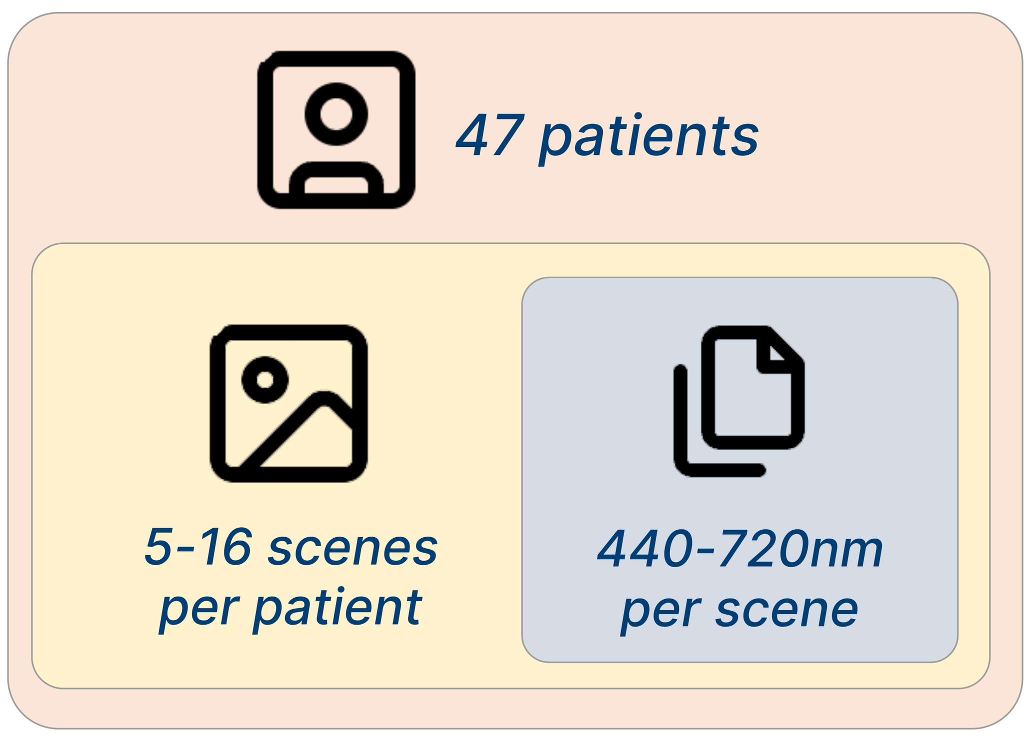


Image capture system diagram (left) and its photo in the operating room (right).



Size and description of the dataset.

[1] S. Seidlitz et al., *Robust deep learning-based semantic organ segmentation in hyperspectral images*, Medical Image Analysis, vol. 80, p. 102488, Aug. 2022, doi: 10.1016/j.media.2022.102488.
[2] X. Du et al., *Robust surface tracking combining features, intensity and illumination compensation*, Int J CARS, vol. 10, no. 12, pp. 1915–1926, Dec. 2015, doi: 10.1007/s11548-015-1243-9.
[3] Hu. Zepeng, *Report on Multispectral Image Analysis of Brain Tissue Dissection*, 2023, Unpublished.
[4] W. Xue, L. Zhang, X. Mou, and A. C. Bovik, *Gradient Magnitude Similarity Deviation: A Highly Efficient Perceptual Image Quality Index*, IEEE Transactions on Image Processing, vol. 23, no. 2, pp. 684–695, Feb. 2014, doi: 10.1109/TIP.2013.2293423.

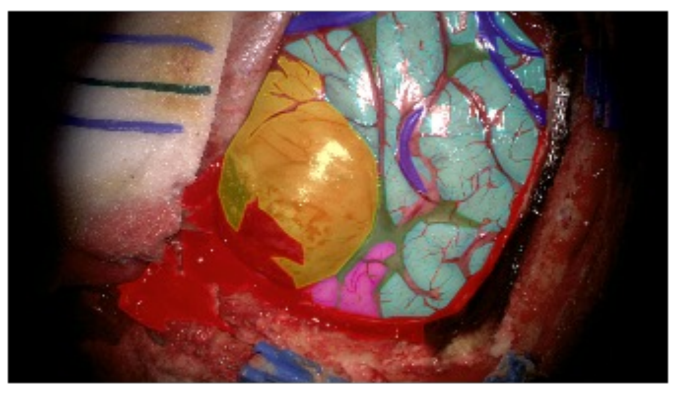
Objective

Ground Truth Images

- Creating the label uses colour images from the microscope camera.
- Each tissue region is identified and assigned to its name.

Alignment

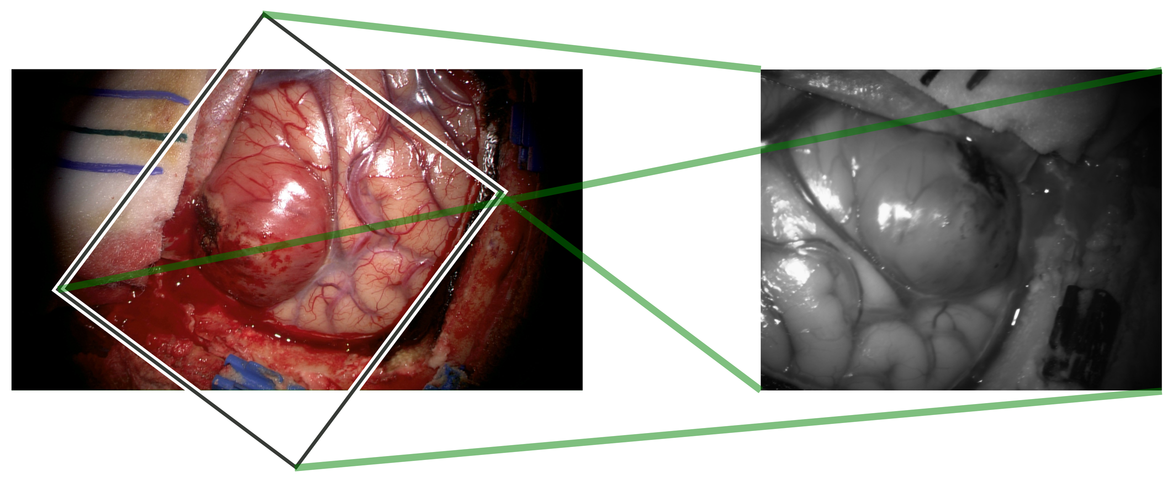
If we match the labels to the spectral images, we will be able to analyse tissues based on their spectral values. However, the labelled microscope images and the multi-spectral images have different perspectives. Therefore, we need to align the images to get accurate label matching.



Labelled microscope images

- Blood
- Blood Vessel
- Arachnoid
- Tumour Core
- Cortical Surface
- Tumour Margins
- White Matter

Perspective Differences



Microscope perspective

Spectral perspective

Registration

Tackling Periodic Movement (Stack Registration)

- Exposure for each spectral image is either 50 or 200ms.
- This is enough time for the brain to expand or contract during acquisition of a scene.
- A hybrid deformable registration based on progressively finite newton and Lucas-Kanade's optical flow is used to register spectral images within a scene [2].

Inferring Ideal Target

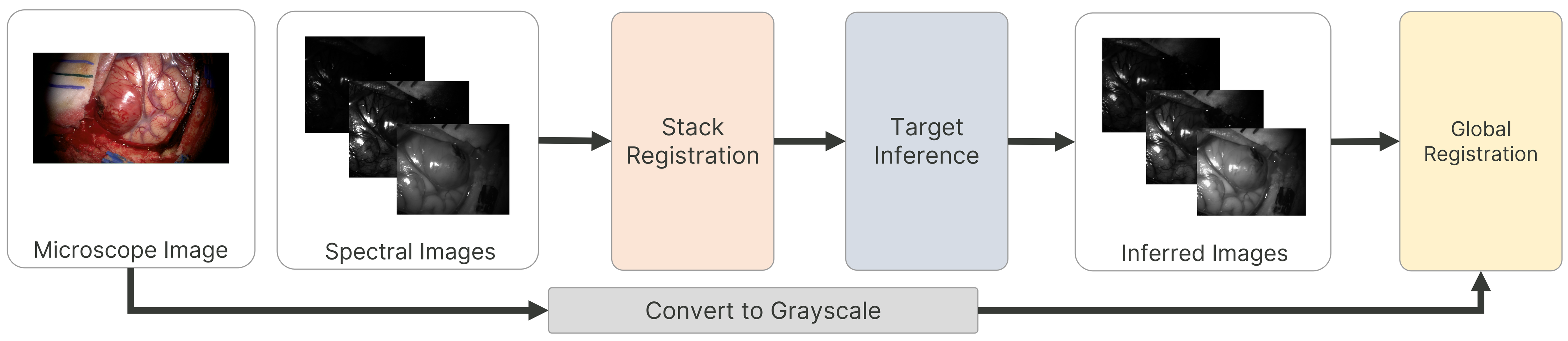
- Spectral image intensity vary across wavelengths, there is no one "ideal" wavelength.
- A latent variable model is used to infer blue, green and red images of the stack [3].

440-720nm images

Inferred blue, green and red images.

Estimating the Transformation (Global Registration)

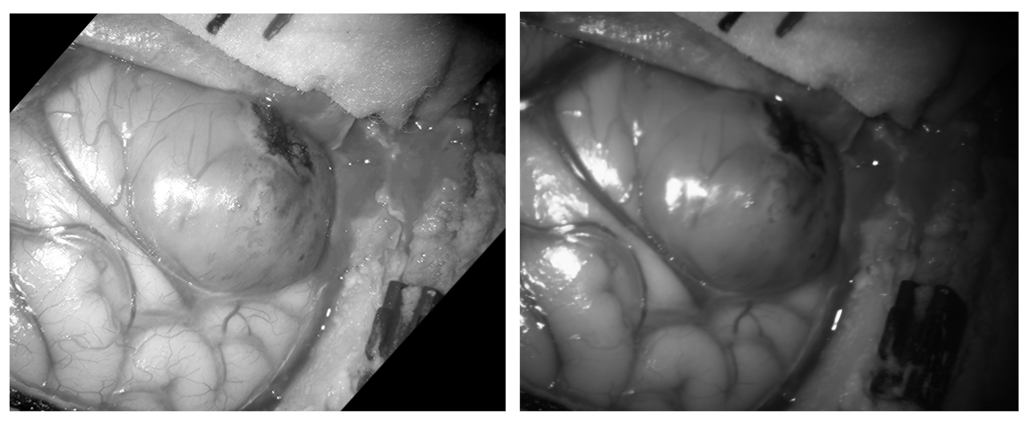
This project evaluates two main registration methods, **projective** transformation based on homography matrix and **affine** transformation based on least-squares solution of features. The overall method of registration is as follows



Preliminary Results

Channel	GMSD*[4]		SSIM^		PSNR^	
	Proj	Affine	Proj	Affine	Proj	Affine
Red	0.102	**0.096**	0.445	**0.475**	13.828	**14.53**
Green	0.126	**0.124**	0.358	**0.359**	**12.846**	12.750
Blue	0.132	**0.131**	0.233	**0.248**	12.063	**13.080**
Overall	0.120	**0.117**	0.345	**0.360**	12.912	**13.455**

* lower is better
^ higher is better



Registered microscope image (left) and its corresponding spectral image target (right).

Future Plans

- *Implement second finer deformable registration from the microscope to spectral image.*
- *Implement and evaluate segmentation method:*
  - *Classical Learning (SVM, KNN)*
  - *Deep Learning (ResNet, U-Net, ConvNeXt)*