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

Muhammad Farhan Oktavian

Individual Project, MRes Medical Robotics and Image-Guided Intervention

Background

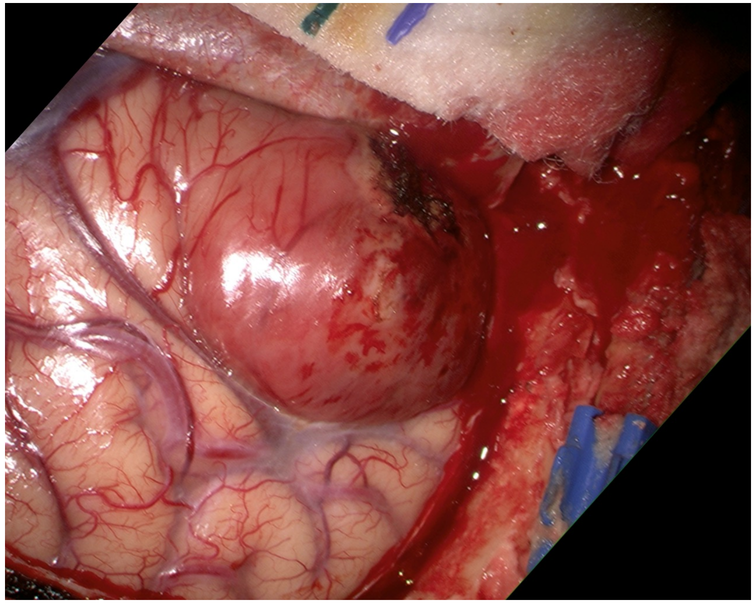
Brain Tumours

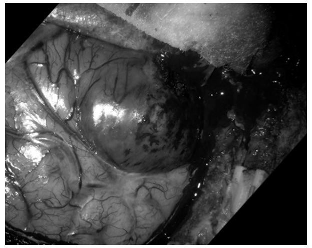
- Tumours affecting the central nervous system that can develop in children and adults.
- Maximal tumour resection through surgical operation is still one the main treatment for brain tumour[1].
- Some tumours are very hard to distinguish[2], as they are visually indifferent to their surrounding tissue, make it difficult to delineate the margin between the tumour and healthy tissue.

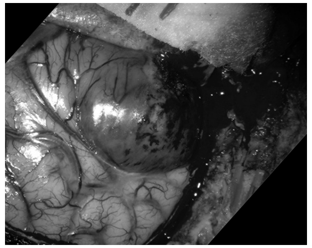
1. N. A. O. Bush, S. M. Chang, and M. S. Berger. Current and future strategies for treatment of glioma. Neurosurg Rev, 40(1):1–14, Jan. 2017. ISSN 1437-2320. doi: 10.1007/s10143-016- 0709-8. URL https://doi.org/10.1007/s10143-016-0709-8.
2. V. P. Collins. Brain tumours: classification and genes. Journal of Neurology, Neurosurgery & Psychiatry, 75(suppl 2):ii2–ii11, June 2004. ISSN 0022-3050, 1468-330X. doi: 10.1136/ jnnp.2004.040337. URL https://jnnp.bmj.com/content/75/suppl 2/ii2. Publisher: BMJ Publishing Group Ltd.

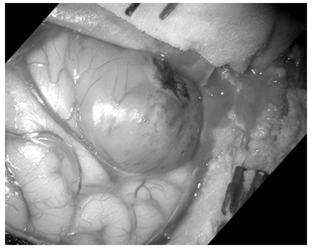
Multi-spectral Images (MSI)

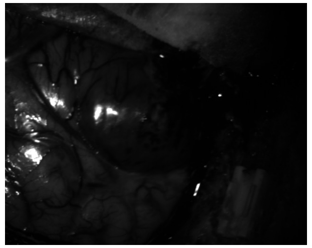
MSI is a stack of images with spatial information on the first two axes (row-column) and spectral information on the third axis (image at wavelength n).


Colour Image

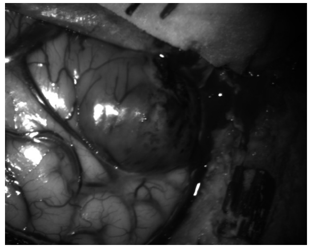

Blue Channel


Green Channel


Red Channel


500nm

. . .


600nm

. . .


700nm

Brain Tissue Image Acquisition

- 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.
- A neurosurgeon then label the microscope images by identifying and bounding regions in the image to a set of tissues.

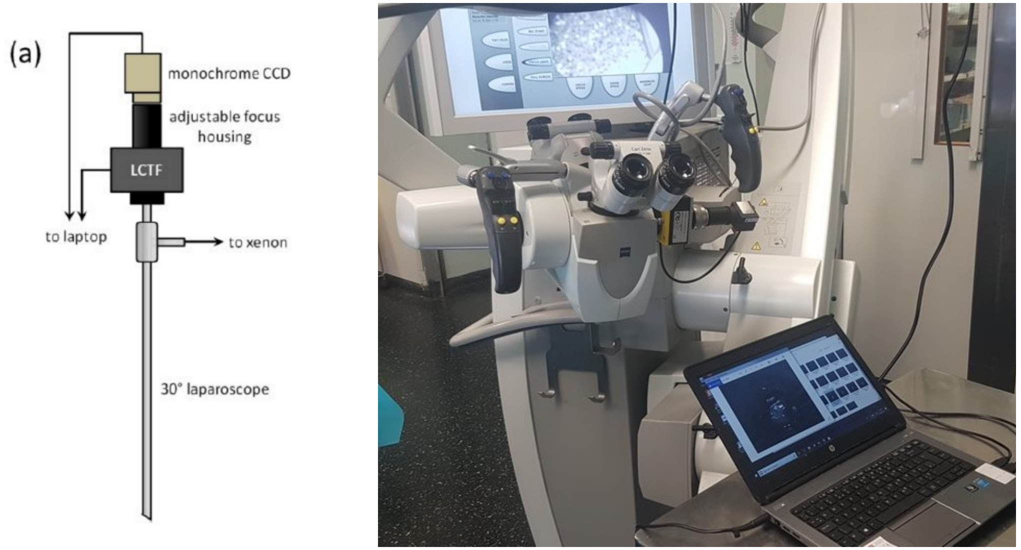
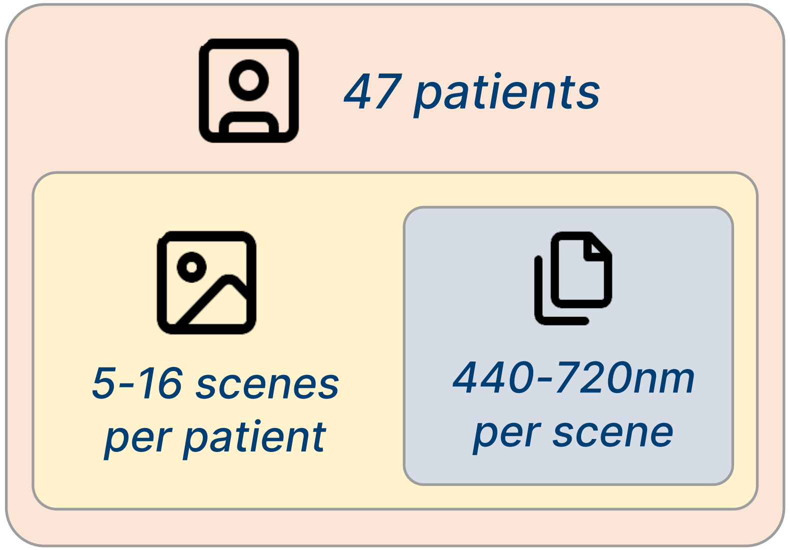


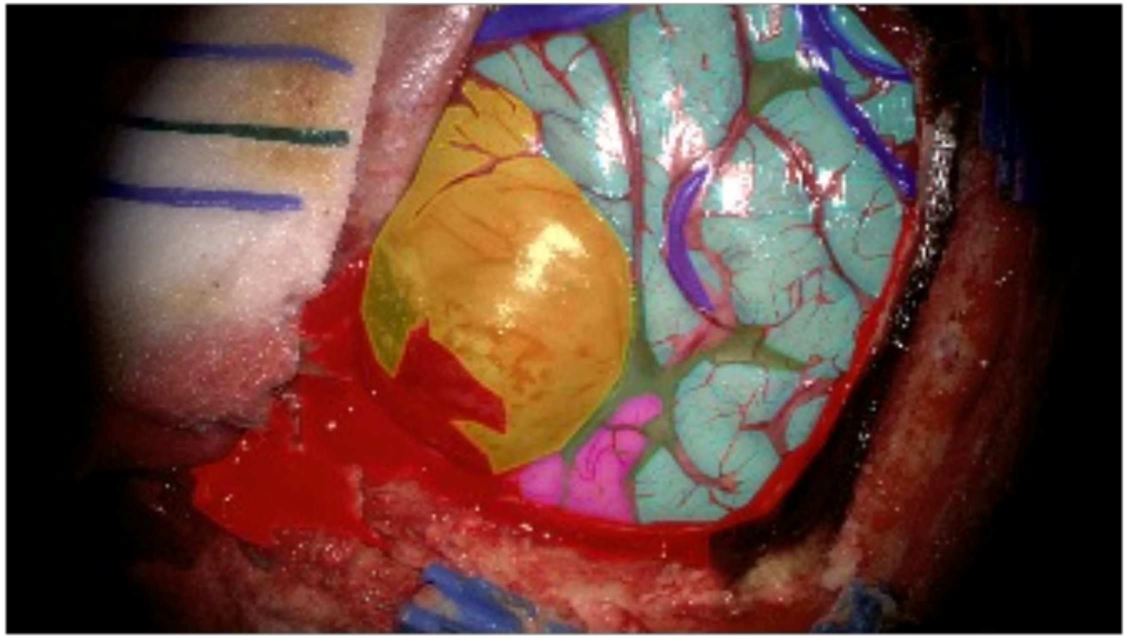
Image capture system diagram (left) and its photo in the operating room (right).



Size and description of the dataset.

Aim and Motivation

How can we prepare the raw image and label data into a usable format for further analysis?



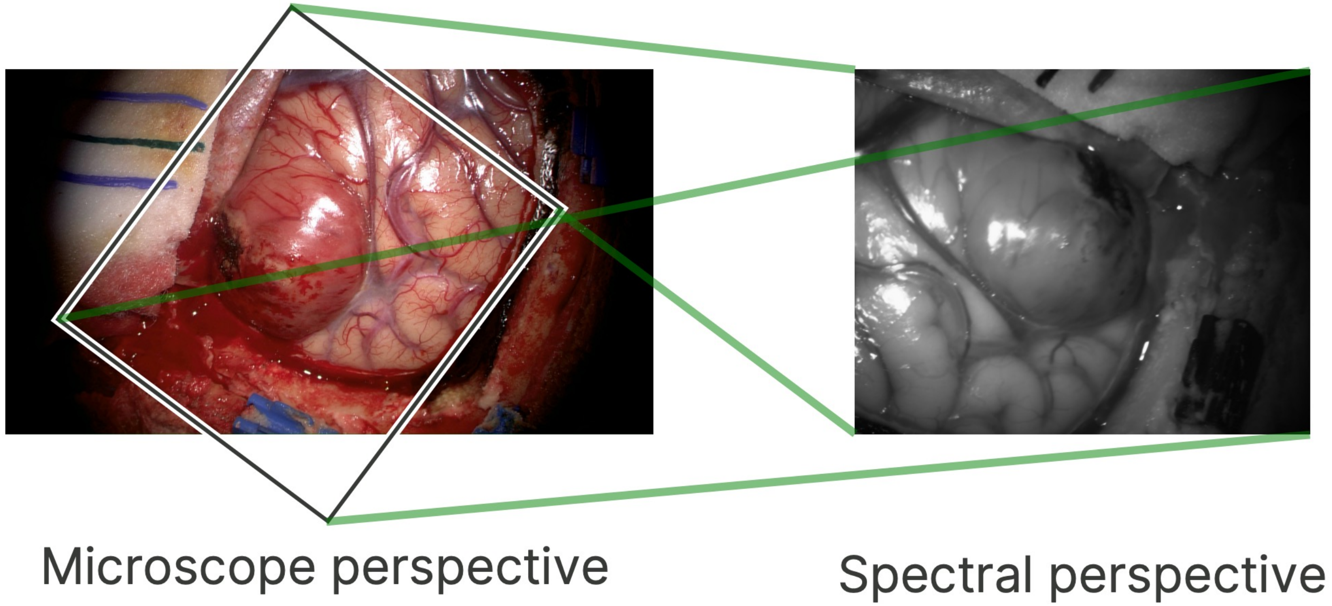
Labelled microscope images

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

Challenges

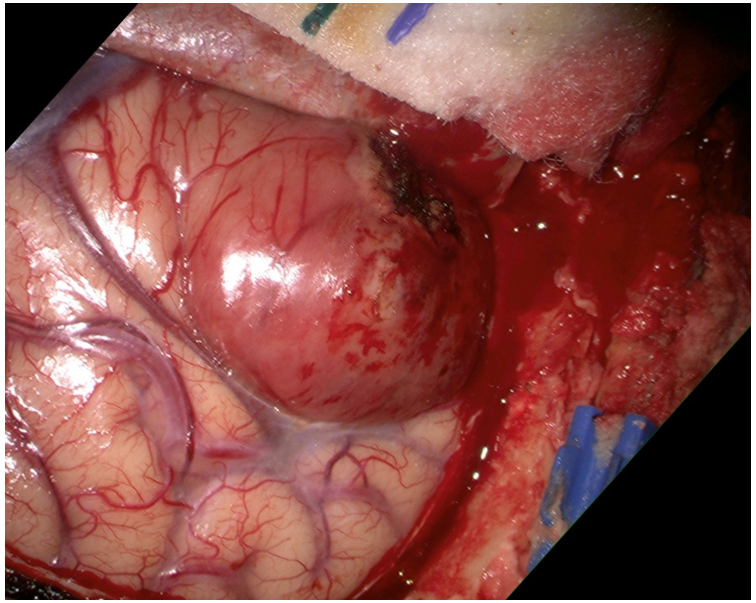
Perspective Differences

- Colour and multi-spectral images from the same scene were taken using two different cameras, which resulted in perspective difference.
- Since the tissues are labelled based on the colour image, we need to align the images, so that the label also correspond to the multi-spectral images.

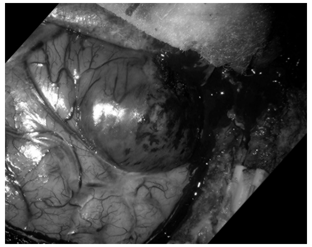


Colour and Contrast

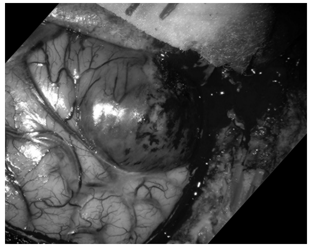
- While coloured image are made up of red, green and blue channels, these channels cannot be directly mapped to a single wavelength.
- Since they have different contrast value distribution, a perfectly aligned colour and spectral image would have a non-zero similarity error.



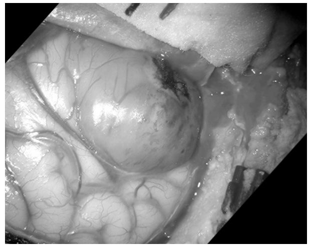
Colour Image



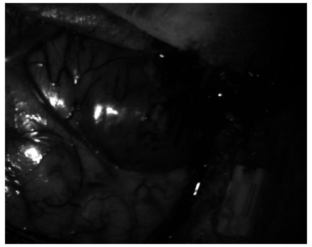
Blue Channel



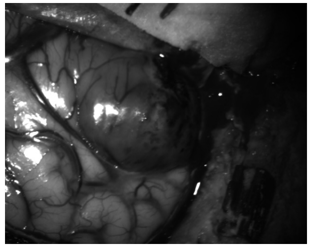
Green Channel



Red Channel



500nm



600nm

700nm

Organ Displacement

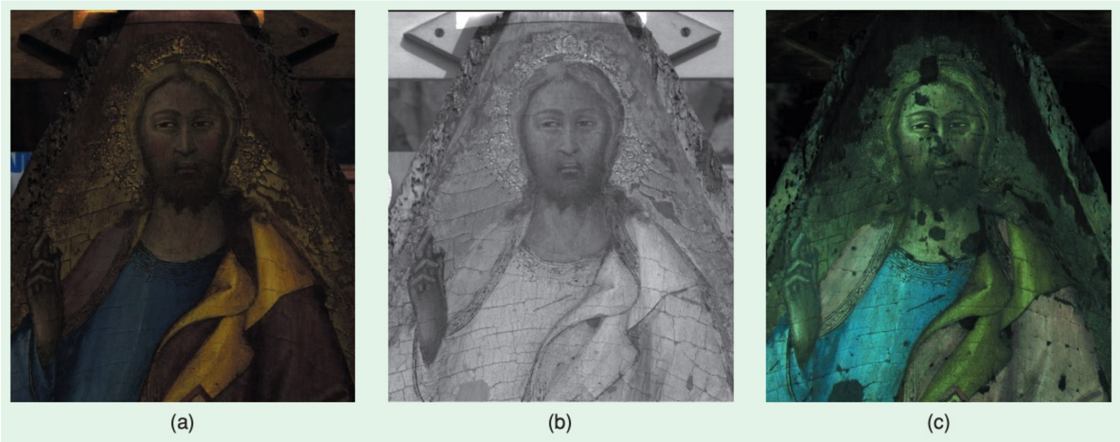
- Exposure for each spectral image is either 50 or 200ms.
- This is enough time for the brain to expand or contract during acquisition of a scene.

PLACEHOLDER
[moving tissues]

Literature Review

Multi-spectral Imaging Use Case

- Determining food quality and safety[3].
- Sensing geographical terrain[4].
- Identifying paints used on paintings[5].



(a) the reconstructed (from the eight available bands) visible image

(b) one of the near IR images

(c) the reconstructed (from the eight available bands) UV induced visible fluorescence image.

Source 5

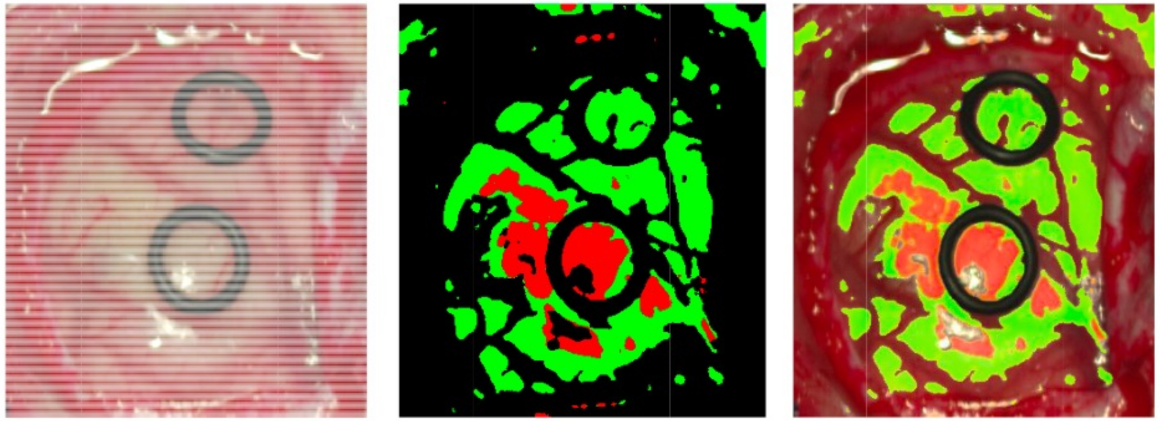
3. J. Qin, K. Chao, M. S. Kim, R. Lu, and T. F. Burks. Hyperspectral and multispectral imaging for evaluating food safety and quality. Journal of Food Engineering, 118(2):157–171, Sept. 2013. ISSN 0260-8774. doi: 10.1016/j.jfoodeng.2013.04.001. URL https://www.sciencedirect.com/ science/article/pii/S0260877413001659.

4. J. A. J. Berni, P. J. Zarco-Tejada, L. Suarez, and E. Fereres. Thermal and Narrowband Multispectral Remote Sensing for Vegetation Monitoring From an Unmanned Aerial Vehicle. IEEE Transactions on Geoscience and Remote Sensing, 47(3):722–738, Mar. 2009. ISSN 1558- 0644. doi: 10.1109/TGRS.2008.2010457. Conference Name: IEEE Transactions on Geoscience and Remote Sensing.

5. A. Pelagotti, A. D. Mastio, A. D. Rosa, and A. Piva. Multispectral imaging of paintings. IEEE Signal Processing Magazine, 25(4):27–36, July 2008. ISSN 1558-0792. doi: 10.1109/ MSP.2008.923095. Conference Name: IEEE Signal Processing Magazine.

Use in Medicine

- Classifying brain tumour tissue based on near-infrared wavelength[6].
- Classifying internal organ tissues on pigs[7].



(a) (b) (c)

(a) Synthetic RGB image

(b) Classification map

(c) Classification on top of RGB image

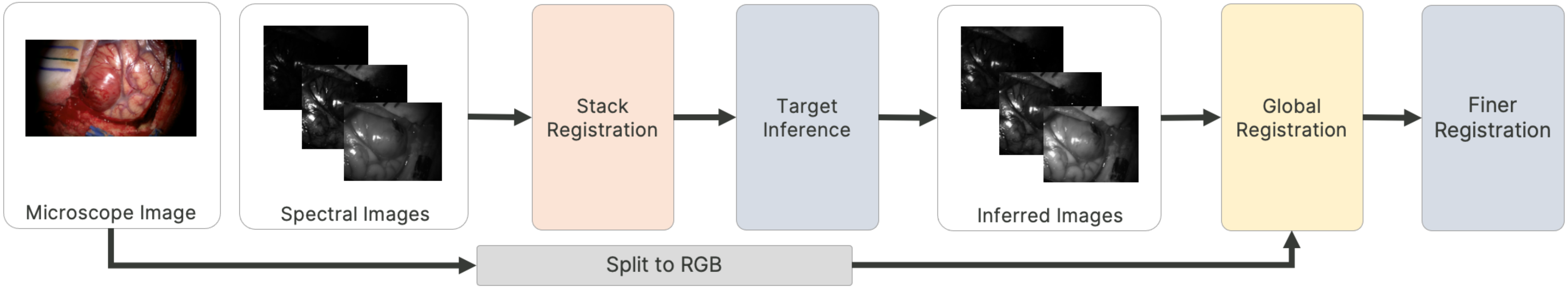
Source 6

6. H. Fabelo, S. Ortega, S. Kabwama, G. M. Callico, D. Bulters, A. Szolna, J. F. Pineiro, and R. Sarmiento. HELICoiD project: a new use of hyperspectral imaging for brain cancer detection in real-time during neurosurgical operations. In Hyperspectral Imaging Sensors: Innovative Applications and Sensor Standards 2016, volume 9860, page 986002. SPIE, May 2016. doi: 10.1117/12.2223075. URL https://www.spiedigitallibrary.org/conferenceproceedings-of-spie/9860/986002/HELICoiD-project--a-new-use-of-hyperspectralimaging-for/10.1117/12.2223075.full.

7. S. Seidlitz, J. Sellner, J. Odenthal, B. Ozdemir, A. Studier-Fischer, S. Kn¨odler, L. Ayala, T. J. ¨ Adler, H. G. Kenngott, M. Tizabi, M. Wagner, F. Nickel, B. P. M¨uller-Stich, and L. Maier-Hein. Robust deep learning-based semantic organ segmentation in hyperspectral images. Medical Image Analysis, 80:102488, Aug. 2022. ISSN 1361-8415. doi: 10.1016/j.media.2022.102488. URL https://www.sciencedirect.com/science/article/pii/S1361841522001359.

Methodology

Registration



Stack Registration

A hybrid deformable registration based on progressively finite newton and Lucas-Kanade's optical flow is used to register spectral images within a scene[8].

PLACEHOLDER
[before]

PLACEHOLDER
[after]

8. 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.

Global Registration

Inferred RGB Image

- Spectral image intensity vary across wavelengths, there is no one “ideal” wavelength.
- An encoder-decoder model is used to infer blue, green and red images of the stack.

Registration Method

- Inferred RGB images are then aligned with coloured image.
- This project evaluates two main registration methods, projective transformation based on **homography** matrix and **affine** transformation based on least-squares solution of features.

Finer Registration

- At this point, the coloured and spectral image are *roughly* aligned.
- However, there might be some regions of the image that do not match due to organ displacement.
- A deep-learning method called RansacFlow[9] is used to refine the aligned images.

PLACEHOLDER
[unaligned region of image]

9. [citation placeholder].

Tissue Analysis

- Since the spectral images and labels are registered, we can try to analyse tissues based on their spectral values.
- We can use learning models to determine the significance of each wavelength for each tissue.
- There are two main types learning models that are evaluated in this project: hybrid classical (VGG+XGBoost[10]) and deep learning model (UNet[11]).

10. [citation placeholder].
11. [citation placeholder].

Results

Global Registration

	GMSD*[4]		SSIM^		PSNR^	
Channel	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

Global Registration

PLACEHOLDER
[before]

PLACEHOLDER
[after]

Finer Registration

	GMSD*		SSIM^		PSNR^	
Channel	Before	After	Before	After	Before	After
Red	...	...	...	...	...	...
Green	...	...	...	...	...	......
Blue	...	...	...	...	...	...
Overall	...	...	...	...	...	...

* lower is better
^ higher is better

Finer Registration

PLACEHOLDER
[before]

PLACEHOLDER
[after]

Tissue Analysis

Metrics	VGG+XGBoost	UNet
IoU	...	...
Dice	...	...
AUC	...	...

Finer Registration

PLACEHOLDER
[VGG+XGBoost]

PLACEHOLDER
[UNet]

Conclusion

Summary

This projects shows that it is possible to align images from different modalities; between coloured RGB and multi-spectral images. Alignment of these images, along with their labels provide valuable information for tissue analysis.

Future Works

- There is only a limited number of tissue labels present in the dataset. Analysis on the full surgical environment will require more labels for other tissue types and surgical instruments.
- There is still a very low number of image similarity metrics for different image modalities. This makes it quite challenging to objectively evaluate the similarity between images.

Thank You

Questions?