Fast computational hyperspectral imaging

Post doctoral fellowship / Engineer position (Lyon, France)

Objective : We are actively seeking a postdoctoral fellow or an engineer to spearhead the development of a high-speed computational imaging system tailored for hyperspectral imaging. This cutting-edge camera need to be developed to detect Protoporphyrin fluorescence signal, specifically in the context of glioma resection. The role, funded by ANR, will encompass the full spectrum of responsibilities, from conceptualization and simulation to system design, practical implementation, and comprehensive characterization. This exciting opportunity will involve the acquisition of hypercubes from *ex-vivo* and *in-vivo* glioma samples directly within the hospital's operating room setting.

Keywords : Hyperspectral imaging, geometrical optics, spectrometer, fluorescence, single-pixel imaging, Python, glioma.

Background : Our research group is dedicated to advancing computational imaging systems that harness the synergy of hardware and software innovations [1, 2], with a specific focus on acquiring hyperspectral data cubes characterized by two spatial dimensions and one spectral dimension. To this end, we've developed an in-house hyperspectral imaging setup (as depicted in Figure 1a) comprised of a digital micromirror device (DMD), a spectrometer, and a camera.

In this setup, the spectrometer captures a series of spectra associated with predefined light patterns loaded onto the DMD, allowing us to reconstruct the hyperspectral data cube. This innovative system design stems from our main objective: optimizing glioma resection to enhance the life expectancy of patients. Currently, glioma removal involves a surgical procedure that entails opening the cranial cavity and extracting the tumor. During this operation, neurosurgeons employ a fluorescence microscope to observe the emission of Protoporphyrin IX (PpIX), a fluorophore selectively present in tumor cells.

However, the current fluorescence microscope can only provide information about the total fluorescence intensity. Our research team has demonstrated that by leveraging the complete PpIX spectrum present in gliomas, it is possible to distinguish the boundaries between tumor tissue and healthy tissue [3]. Consequently, our initial setup is transported to the neurosurgical block's operating room, allowing us to acquire hyperspectral data cubes from biopsies taken during the procedure (as illustrated in Figure 1b -1).

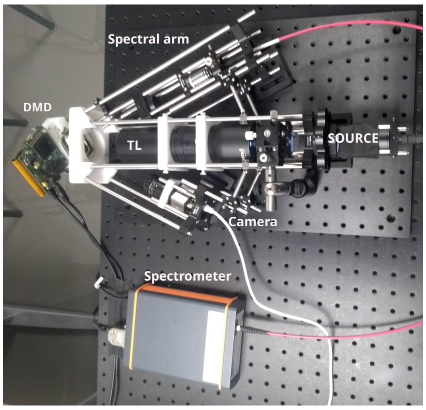
These biopsies exhibit distinct spectral characteristics (as depicted in Figure 1b -2/3) at various locations, enabling us to pinpoint the boundary separating healthy and tumoral cells. This innovative approach holds great promise for improving the precision and effectiveness of glioma resection procedures.

Challenge : Currently, the total acquisition time is suitable for biopsy samples but proves impractical for in-vivo imaging not to mention the lake of spatial resolution. In response, our research group has developed compressive imaging strategies aimed at reducing the number of patterns required for acquisition, thereby decreasing the total acquisition time. This innovative approach involves deep neural networks to reconstruct the hyperspectral cube corresponding to the observed scene. Over time, we have proposed various deep network architectures [4], each designed to optimize the hyperspectral reconstruction process. These networks have proven to be very effective in denoising experimental data obtained with our hyperspectral imaging device.

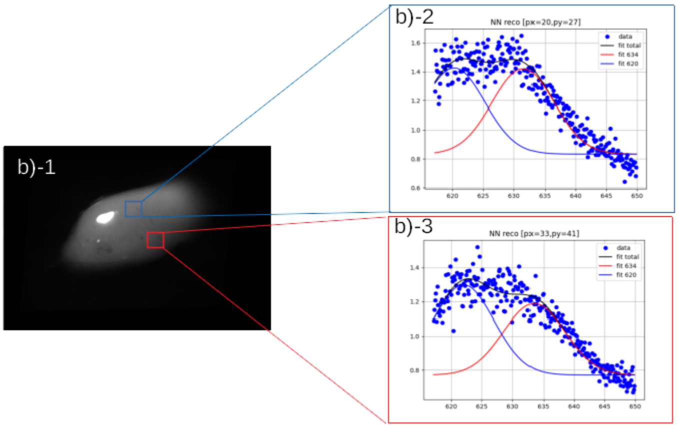
While this represents a significant advancement, it remains insufficient for clinical in-vivo applications. Hardware development are needed to enhance the speed by developing a second setup.

The main tasks of the project include :

- the taking charge of the existing optical setup and making improvements
- the development of the second optical setup
- the development of the instrumentation control software (based on the SPAS package [5])



(a) Picture of our hyperspectral device (DMD: digital micromirror device, TL: telecentric lens).



(b) -1 photo of the biopsy. b)-2 and -3 Spectra and fit of two states of the PpIX at different locations of the biopsy.

- the use of advanced reconstruction algorithm based on deep learning (based on the spyrit package[6])
- the characterization of the imaging device (e.g., sensitivity, spatial and spectral resolution)

Project details The project comprises two main concurrent tasks :

- **Optical Setup Enhancement and Biopsy Imaging :** The first task involves taking charge of the existing optical setup and making improvements, both in software and hardware where necessary. The upgraded setup will be used to acquire hyperspectral data cubes from biopsies within the operating room of the hospital. These acquired cubes will be analyzed and compared to the anapathological analysis. This comparison aims to distinguish tumor cells from healthy ones, providing valuable insights for clinical applications.

- **Development of a 2D Sensor Spectrometer :** The second task focuses on the creation of an entirely new optical setup aimed at accelerating the hyperspectral data acquisition process. The current spectral arm, which employs a commercial spectrometer with a 1D sensor, will be replaced by a custom-made 2D sensor spectrometer. This new configuration will consist of a grating, prism, and camera, enabling the simultaneous capture of the full spectrum of multiple image lines. In contrast to the current device, which acquires lines sequentially using a linear sensor, this advancement is expected to dramatically increase imaging speed. As an example, a 64x64 image can be acquired 64 times faster than with the existing setup. The acquisition software will be updated to handle 2D patterns corresponding to 1D Hadamard patterns that repeat in one direction. The successful candidate will be responsible for constructing the 2D spectrometer, involving the use of a cylindrical lens to compress one spatial dimension and a prism or grating (or a combination of both) to disperse and diffract light onto the 2D sensor.

These two tasks represent the core components of our project, with the potential to significantly enhance our hyperspectral imaging capabilities and their practical applications in the medical field.

Skills : We are seeking an enthusiastic and self-motivated candidate with a strong background in optical setup design. Proficiency in Python programming is a prerequisite for this role, as it will be essential for developing the 2D sensor.

Salary : between €2000 and €2400 net monthly depending on the experience

duration : 18 months.

How to apply : Send CV and motivation letter to mahieu@creatis.insa-lyon.fr and Bruno.Montcel@creatis.insa-lyon.fr

References

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[5] https://github.com/openspyrit/spas.

[6] https://github.com/openspyrit/spyrit.