Full-field multispectral Mueller polarimetric imaging for improved surgery of neurological malignancies

Keywords: *Optical imaging - Polarized light; Mueller polarimetric imaging - Signal processing - Cancer surgery - Surgical microscope - Surgical exoscope.*

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Surgery is the crucial step in the treatment of brain tumors, particularly gliomas. While some well-defined tumors, such as metastases, can be removed en bloc, the majority of gliomas, which tend to grow infiltratingly in the white matter inside the brain, are removed piece by piece. During the operation, it is essential for the surgeon to identify and respect the boundary between the tumor and the surrounding healthy brain tissue in order to carry out a radical resection of the pathological parts while preserving neurological function. However, solid tumor tissue is often difficult to differentiate from infiltrated white matter during surgery, even using a state-of-the-art intraoperative microscope. Patients in whom a piece of the tumor is left in place due to poor visualization of the tumor margin have a worse prognosis than those in whom the entire tumor is removed, as the tumors invariably grow back from the remnants. In addition, information on the neurological function of a given area of white matter exposed during surgery is very limited.

Several experimental methods such as fluorescence imaging, ultrasound and magnetic resonance imaging used intraoperatively have been studied for their ability to distinguish brain tumors tissue from healthy parts of the brain. In summary, the efforts to visualize tumor cells and reliably identify the interface between healthy and pathological areas during surgery have so far failed for many intrinsic brain tumors.

Mueller polarimetric imaging is a technique using the polarization of light, which has been widely used for the exploration of biological tissues, optically very complex systems where scattering and anisotropy effects are present at the same time. This technique is very sensitive to microstructural changes in biological tissues generated by pathological conditions. In recent years, it has shown great promise for improving the detection of cancerous lesions, as well as for accurately defining the resection margins of pathological areas during surgery. Biomedical research activities at LPICM focus on the development of innovative Mueller polarimetric imaging systems to improve the management of different types of cancer ex vivo and in vivo. In particular, a multispectral Mueller Polarimetric Colposcope has been built to improve the imaging of cervical cancer in vivo. Recently, a first prototype of Mueller polarimetric laparoscope, for the exploration of the internal organs of the human body, has been also developed at LPICM.

Brain tumors destroy the highly anisotropic structure characteristic of healthy white matter, made up of very dense, well-organized axon fibers. Accurate detection of the healthy white matter can help surgeons to better identify, by contrast, the pathological areas. A study conducted by the LPICM, in collaboration with the Department of Neurosurgery at Berne University Hospital, on samples of fresh and fixed brain tissue has shown that full-field Mueller polarimetric imaging can provide detailed mapping of the axonal fiber orientations in healthy white matter over a macroscopic field of view in just a few seconds (https://horao.eu/). In addition, this technique can effectively distinguish between healthy and cancerous areas of the brain.

The main objective of the postdoctoral fellow's work is to develop a full-field Mueller polarimetric imaging system to improve the detection of surgical margins of neurological cancers in vivo. To this end, the post-doctoral fellow will focus on two major complementary parts. First, he will design and manufacture a first prototype of a miniaturized Mueller polarimetric imager using polarized cameras. This part will involve a significant effort to characterize polarized cameras, design a new system for modulating and analyzing the polarization of the light, as well as developing electronics adapted to manage the image acquisition. An important work to optimize the lighting

and detection systems will be also necessary. Finally, a mechanical system will be developed to allow the use of the new imaging system in vivo in the operating room.
In a second phase, once the instrumental part is completed, the post-doctoral fellow will be responsible for transferring the prototype to the University Hospital of Bern and assisting the surgeon in collecting data in vivo, as well as for processing the acquired polarimetric images and compare them with histological analyses considered as the gold standard.

Desired profile or skills: optics, optical instrumentation, optical measurements and signal processing, elements of computational algebra. A very strong motivation in continuous interaction with the medical world and to work in a multidisciplinary context is required.

Linguistic skills: good knowledge of English.

Informatics skills: good knowledge of Matlab.

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