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Design and Evaluation of a Multimodal Imaging System for Medical Tissue Analysis

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Multimodal imaging, the combination of various optical imaging techniques, is widely used for biomedical applications because of the complementary nature of the information content. In this context, a promising technology is Raman spectroscopy. Raman spectroscopy is a label-free, highly molecular specific technique, which enables the detection of biomolecules such as lipids and proteins.
This study presents the design of a novel multimodal imaging system that combines Raman spectroscopy with visible (VIS) and near-infrared (NIR) spectroscopy as well as light microscopy (bright-field, dark-field, and polarisation microscopy) in the incident light mode. In addition, the imaging system is equipped with a light path for transmitted light microscopy.
In clinical and pathological diagnostics, bright-field microscopy of stained tissue sections in the transmitted light mode is a well-established imaging technique. Combined with images of an unstained tissue section obtained from other imaging modalities, the stained tissue section serves as a reference for tissue classification models.
The first application of the imaging system is realised to distinguish between grey matter (GM) and white matter (WM) of mouse brain tissue. All applied modalities are able to differentiate between the two main brain areas. The best results for the unstained tissue section are achieved for Raman spectroscopy in the high-wavenumber region and polarisation microscopy. In addition to the distinction between GM and WM, both modalities emphasise differences in the density of myelinated axons. Further tissue experiments investigate the design‘s capability to detect haemorrhage with VIS and Raman spectroscopy and to detect water with NIR spectroscopy.
Moreover, experiments for the specification of several setup parameters like the lateral resolutions of the spectroscopic modalities, the spectral characteristics of the light sources, the microscope stage’s accuracy, and the various signal stabilities are carried out. Additionally, a workflow to perform imaging of biological samples is elaborated.
In the end, potential setup modifications to increase the measurement efficiency are proposed. Anyhow, the designed multimodal imaging technique is an all-in-one solution, which facilitates the measurement of unstained tissue samples with different modalities and the results‘ complementation by images of stained tissue sections.