BIOENGINEERING AND MEDICAL-SURGICAL SCIENCES

DET - ImPACT: quantitative photoacoustic imaging and ethical artificial intelligence solutions

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Context of the research activity	The overall topic of this PhD research program is the development of an imaging framework focusing on hardware and software developments for inclusive quantitative photoacoustic imaging, starting at an in-silico simulation level and going up to both phantom in-vitro acquisitions and finally in-vivo tests.
Objectives	Photoacoustics (PA) is a rapidly emerging imaging modality thanks to its inherent functional and metabolic capacity, sensitivity, depth penetration, non-invasiveness and radiation-free measurement of optical tissue properties. Hemoglobin is an active absorber of light and hence an ideal chromophore that enables quantitative PA-based analysis of vasculature in terms of morphology, network complexity and functional metabolism, i.e., blood oxygenation. Current limitations to PA imaging include artefact-ridden images when using traditional linear ultrasound probes (LUPs) for detection, or the need of ad-hoc detectors. Another challenge for PA imaging is that variations in skin tone, hence melanin content, can alter measurements between subjects in ways that the imaging device was not designed to anticipate. If ignored, this produces inaccurate functional information such as blood oxygenation levels based simply on the different skin tone. The PhD project has the following main objectives which the candidate will be required to do: - Develop a simulation framework for photoacoustic imaging using a linear probe and various physiological digital phantoms. - Design and test the system setup on an in-vitro level on customized phantoms in compliance with the criteria defined by the International Photoacoustic Standardisation Consortium (IPASC). - Test the system on an in-vivo level and support development of inclusive ethical artificial intelligence methods. The candidate will focus on developing a simulation framework to aid in the

	development of deep learning techniques for enhancing images acquired with optical imaging methods, such as photoacoustic tomography within the PRIN 2022 PNRR project ImPACT-AI (CUP: E53D23016300001). Moreover, focus will be put on designing and testing the imaging system setup, initially focusing on phantoms and then extending to in-vivo acquisitions. Furthermore, the candidate will be involved in the development of inclusive deep learning methods, particularly focusing on the impact and compensation of skin tone variations in quantitative photoacoustic imaging for the estimation of blood oxygenation. It is expected that, at the end of the PhD activity, the candidate will be able to propose a complete framework for photoacoustic imaging, ranging from in-silico to in-vitro to in-vivo acquisitions and tests.

Skills and competencies for the development of the activity	The candidate must have a Master Degree, preferably in Biomedical Engineering, and with previous experience in medical image and data analysis, particularly in the context of biomedical optical imaging. The successful candidate has a strong and documented expertise in these topics: • Optical image methods, such as photoacoustic imaging and optical coherence tomography/optical coherence tomography angiography • Use of simulation tools for photoacoustic imaging, for both the optical and acoustic pathway • Development of in-silico and in-vitro phantoms that mimic physiological systems and properties for optical imaging methods and should demonstrate the knowledge of traditional image processing methods (filters, morphological operations, segmentation techniques) and should have the basic notion of deep learning methods for both segmentation and classification (i.e. convolutional neural networks, semantic segmentation, AlexNet/GoogLeNet/ResNet, GANs, etc). Programming skills and experiences in the implementation of deep learning models in Python are appreciated but not required. Hands-on experience with optical imaging systems is appreciated but not required.