PhD Thesis Title: Biological tissues characterization by light scattering: cancer diagnosis applications

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ABSTRACT:

Diffuse Optical Tomography (DOT) is a non-invasive imaging modality which employs a visible or Near infrared (NIR) Laser source for probing biological tissues and measures light intensities at the boundary surface. In recent years, potential applications of DOT have been developed such as breast cancer detection and brain functional imaging. This technique seeks to recover the spatial distributions of optical properties (intrinsic contrast agents, e.g. absorption µa and scattering µs coefficients) inside the medium through an image reconstruction algorithm. However, this is an ill-posed and under-determined inverse problem. It is clear that the quality reconstruction strongly depends on the accuracy of the light propagation forward model. The work of this thesis deals with the resolution of this isuue using the Radiative Transfer Equation as a rigorous model of light propagation in biological tissues. The sensitivity analysis showed that the anisotropy factor g of the Henyey-Greenstein phase function is the most sensitive parameter of the forward model followed by the scattering coefficient µs and then the absorption coefficient µa. In a first step, a Gauss-Newton algorithm was implemented using the sensitivity functions. However, this algorithm allows to estimate a very limited number of the optical parameters (assumed to be constant in space). In a second step, a Quasi-Newton algorithm was developed to reconstruct the spatial distributions of the optical properties. The gradient of the objective function was efficiently computed by the adjoint method through the Lagrangian formalism with a Multi-frequency approach. The reconstructed images were obtained from simulated boundary data. The g factor was reconstructed as a new optical contrast agent in DOT and the crosstalk problem between this factor and µs has been studied in the present thesis. The results showed that the algorithm is efficient and robust to reconstruct, in 2D and 3D geometries, one or several tumor inclusions having different shapes (spherical, cylindrical). The quality of the reconstructed images was examined according to several parameters: the number of modulation frequencies, the crosstalk, the contrast level (Inclusion / Background), the noise level and finally the tumor inclusions positions.

Keywords: Diffuse optical tomography; radiative transfer; inverse problem; adjoint method; image reconstruction algorithm; optical properties.

References to author publications that relate specifically to the dissertation:

1. **A. Addoum**, O. Farges and F. Asllanaj: “Optical properties reconstruction using the adjoint method based on the radiative transfer equation,” *Journal of Quantitative Spectroscopy and Radiative Transfer*, Volume 204 :179–189, 2018. https://doi.org/10.1016/j.jqsrt.2017.09.015

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