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Fluorescence Tomography Enhanced by Taking into Account the Medium Heterogeneity

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Fluorescence tomography modality is envisioned to be an economical functional quantitative measure and could benefit to the pharmacological industry for experiments on small animal. It consists in injecting cancer specific fluorescence marker and reconstructing the fluorescence by using the fluorescence tomography technique. The reconstructed fluorescence can be used as a marker of the cancer activity to evaluate the efficiency of treatments.

Currently, the technique is limited by the large heterogeneities of biological tissues which create artefacts on the reconstruction and reduce the quality of the subsequent analysis. Here, we describe how we take these heterogeneities into account and show the efficiency of our method through a phantom experimental validation.

Fluorescence tomography experiments consist in illuminating a highly scattering medium with near infrared light (excitation wavelength) and measuring the transmitted light at the excitation and the fluorescence wavelengths thanks to the use of filters placed in front of the camera. Our light source is a continuous laser (690nm, 26 mW, Powertechnology) beam coupled into a multimode optical fibre and focused by a lens to a single spot underside the studied medium. The fibre and the lens are driven by two motorized translation stages that allow XY scanning of the specimen. At each step of the laser spot, light is collected from the specimen and imaged onto the cooled CCD camera using a 25 mm f/l objective. For this experiment, we position a cylindrical tank (interior dimensions: diameter=6 mm, height=6.5mm) filled with 1micromol/L of Alexa750 fluorophore positioned at 1.5mm from the bottom of a cylindrical-shaped box (diameter=110 mm) filled up with a scattering liquid (mixture of water, black India ink as the absorber and intralipid (Fresenius Kabi) as the scattering medium).

Measures at the excitation wavelength allow the determination of a map of the optical properties of the medium. As opposed to the methods classically employed, we show in this paper, that the use of Green functions G adapted to the inhomogeneous medium allows better reconstruction of the fluorescence map.

The calculation of the transfer functions G for an inhomogeneous medium follows the mathematical derivations classically used in the literature. G are deduced from the difference between the measurements and the measure we would have for a homogeneous medium with known optical parameters (homogeneous absorption and reduced scattering coefficients). It can be obtained by repeating the experiment described before without the fluorescent cylindrical reservoir or by using, as we did, an analytical forward model.

The grid for the attenuation and fluorescence reconstruction is a 14x14x15 mesh. We first reconstruct the attenuation map of the medium along with the G functions corrected from the medium attenuation variations. It shows the presence of a cylindrical region of low attenuation at $2.5\text{mm} < z < 9.5\text{mm}$, explained by the fact that

no ink was added in the fluorescent solution.

We then reconstruct the fluorescence map (20 iterations of ART (algebraic reconstruction technique), relaxation=0.01). It shows that the reconstruction with corrected G functions is closer to the expected values than non corrected reconstruction especially when the z resolution is considered. Vertical profiles of the two distributions in the axis of the fluorophore tank shows the z-localization and z-resolution are better when the reconstruction is performed with corrected transfer functions.

To obtain more accurate fluorescence tomography reconstruction, we recommend the use of G functions corrected from variations of the optical properties of the studied object.

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