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Diffuse optical imaging based on the adjoint radiative transfer equation

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ABSTRACT

The spatial reconstruction of optical properties in Diffuse Optical Tomography (DOT) can be considered as a large-scale optimization procedure. The forward model is based on the Radiative Transfer Equation (RTE) in the frequency domain. In this work, a Gradient-based algorithm which employs the gradient of the objective function has been used. Moreover, the gradient of this function was calculated efficiently through an easy and fast way based on the adjoint method. The results prove that the algorithm is robust to reconstruct the spatial distribution of the optical properties in 2D and 3D geometries.

OBJECTIVES

- Simultaneous spatial reconstruction of the absorption and scattering coefficients in a high-absorbing medium.
- Spatial reconstruction of the anisotropy factor of the Henyey-Greenstein phase function as a new optical contrast agent.
- Reconstruction of the spatial distribution of the fluorophore concentration.

INVERSE PROBLEM

➤ The RTE adjoint equation is obtained throughout the lagrangian formalism of the adjoint method such as:

$$\left[-\Omega \cdot \nabla + \left(\frac{-i\omega}{v} + \mu_t(r) \right) \right] \lambda_s(r, \Omega, \omega) - \mu_s(r) \int p(\Omega', \Omega) \lambda_s(r, \Omega', \omega) d\Omega' = - \frac{\partial J(\beta)}{\partial \psi_s}$$

➤ Source term due to the residues between measured and predicted data

➤ The gradient expression of the objective function with respect to the optical properties is given by the inner product:

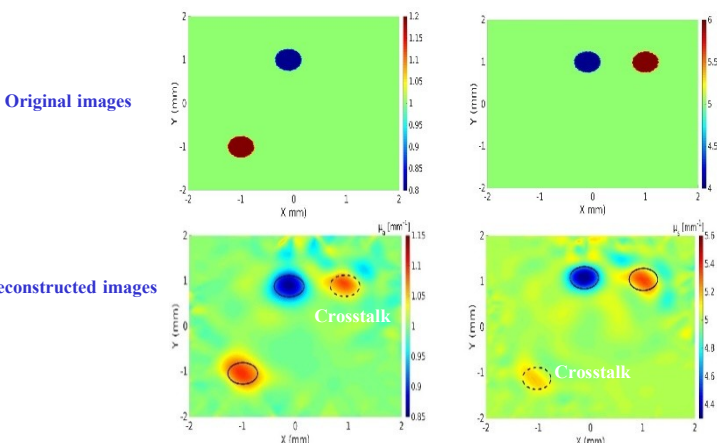
$$(\nabla J(\beta)) \cdot \delta\beta = \left(\lambda_c \cdot \frac{\partial Rc}{\partial \beta} \right) + \left(\lambda_s \cdot \frac{\partial Rs}{\partial \beta} \right)$$

➤ After computing efficiently the gradient, the *Lm-BFGS* Quasi-Newton is employed in order to update the spatial distribution of the optical properties

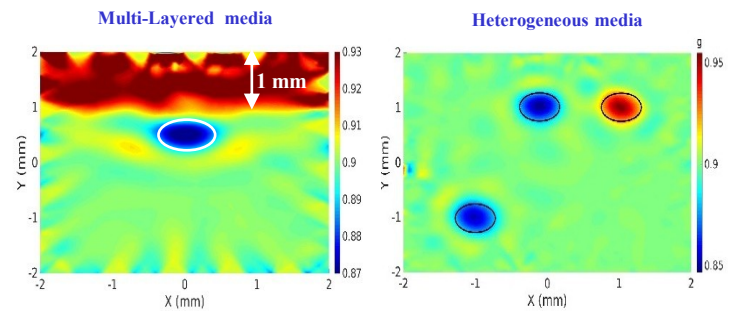
RESULTS

1 Simultaneous reconstruction of μ_a and μ_s

(High-Absorbing medium where the diffusion approximation is not valid)



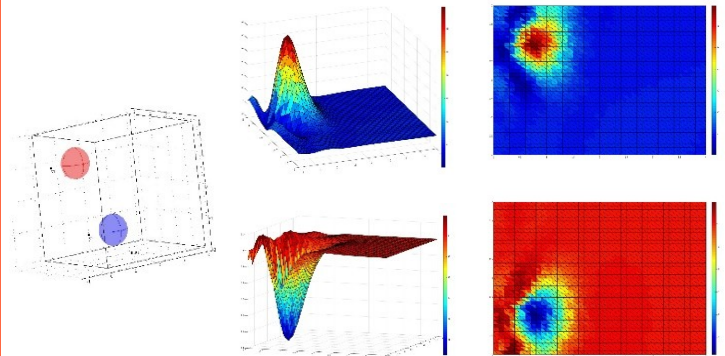
2 Spatial reconstruction of the Anisotropy factor g



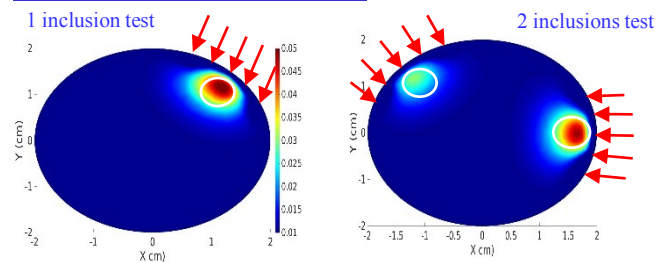
- The inclusions are accurately located and reconstructed.
- The thickness of the top layer is well recovered.
- The estimated local values of g are achieved with a good quality.

3 3D reconstruction of the μ_s coefficient

The medium contains two inclusions. The two slices passing through the center of the inclusions are represented below.



4 Fluorescence reconstruction



CONCLUSIONS & PERSPECTIVES

- The spatial reconstruction of μ_a and μ_s is achieved with a reasonable accuracy even with a situation in which the DA fails to predict light propagation.
- The g factor is reconstructed as a new optical contrast agent in DOT.
- This algorithm can be used to accurately recover the fluorophore distribution.
- In the next step, we intend to test our algorithm for 3D reconstruction based on Monte-Carlo data.