Assessment of Diffuse Optical Tomography Image Reconstruction Methods Using a Photon Transport Model

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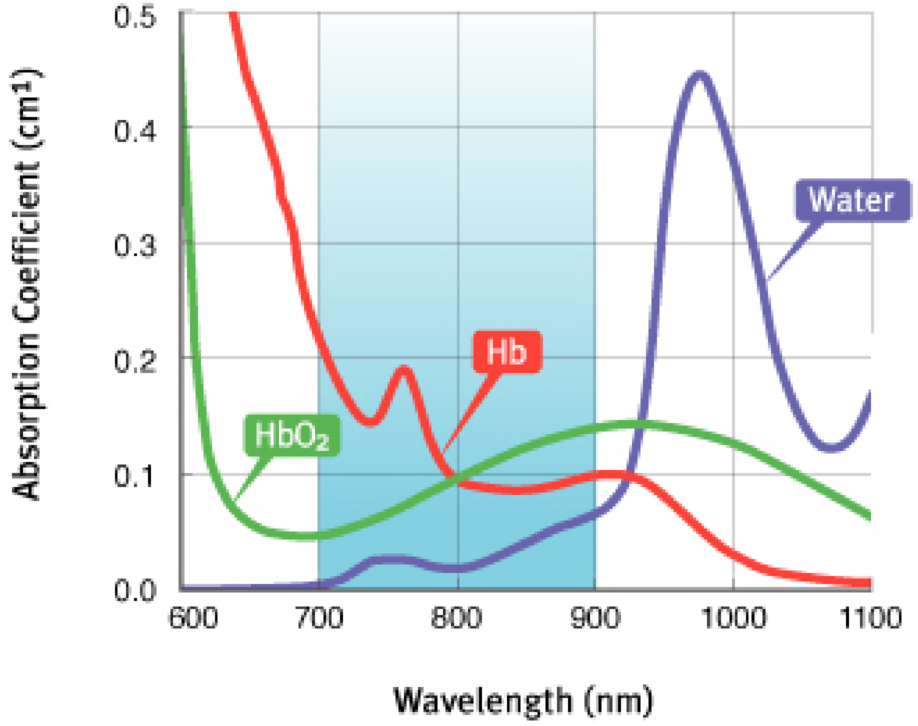
Contents

Introduction & Background

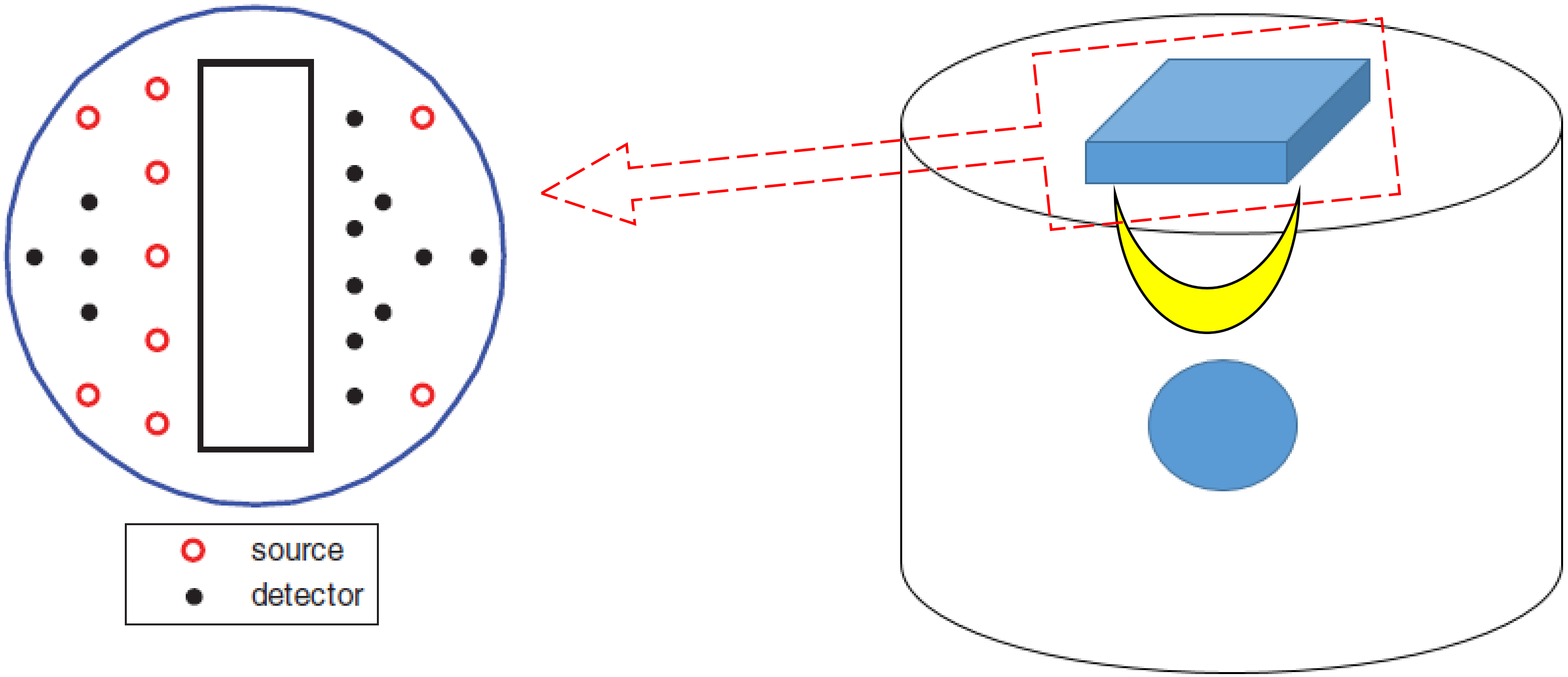
- Diffuse optical tomography (DOT) uses near-infrared light to map hemoglobin concentrations within tissue for breast cancer detection and diagnosis.

- Near-infrared light (ranges from 700 to 900 nm)



Introduction & Background

- Tissue is illuminated by NIR and the reflected light is measured at the surface of the tissue. These measurements are then used to estimate (recover) the optical proprieties of the interior tissue.



Purpose

In this study, we used COMSOL to generate 3D forward data. These data were used to reconstruct DOT images using two image reconstruction methods. The performance of each method was illustrated via different test results.

Computational Method

The Forward Model

Two main ways to Model Photon transport in Biological Tissues

Monte Carlo method: tracking a sufficient number of photons.

- able to model complex geometries.
- And complex heterogeneous media.
- Require longer computation times.

Analytical models :

- Radiative transport equation (RTE)
- Diffusion Equation

- computationally fast.
- limited to simple geometries.

Computational Method
The Forward Model

- Radiative transport equation (RTE) is difficult to compute .
- One approximation is that photon transport is dominated by scattering rather than absorption, ($\mu a << \mu s'$).
- That way, RTE can be approximated by Diffusion Equation

$$\frac{\partial \mathrm{U}(\vec{\mathrm{r}},\mathrm{t})}{\partial \mathrm{t}} + \mathrm{c}\mu_{\mathrm{a}}\mathrm{U}(\vec{\mathrm{r}},\mathrm{t}) - \mathrm{c}\nabla \cdot [\mathrm{D}\ \nabla \mathrm{U}(\vec{\mathrm{r}},\mathrm{t})] = \mathrm{q}(\vec{\mathrm{r}},\mathrm{t})$$

  - "U" is the photon density
  - "q" is photon density source strength.
  - $D = \frac{1}{3(\mu_a+\mu_s')}$ is the diffusion coefficient of medium
  - "***c***" is the speed of light inside the medium.

Computational Method
Use of COMSOL Multiphysics

- Diffusion Equation can be reformulated to ***Helmholtz wave equation (COMSOL Eq. Form)*** as:

$$\nabla.(-\mathrm{c}\nabla \mathrm{u}) + a\, u = \mathrm{f}$$

Where “u” is the photon density,

“c” is the diffusion coefficient (isotropic),

“a” is the absorption coefficient,

“f” is the source term.

Computational Method

Use of COMSOL Multiphysics

- A cylinder with 10 cm diameter and 8 cm height was employed in COMSOL to simulate the semi-infinite breast model (Fig. 1.a). A sphere with an adjustable diameter and depth distance was embedded inside the cylinder to model the breast tumor for deferent sizes and depths.

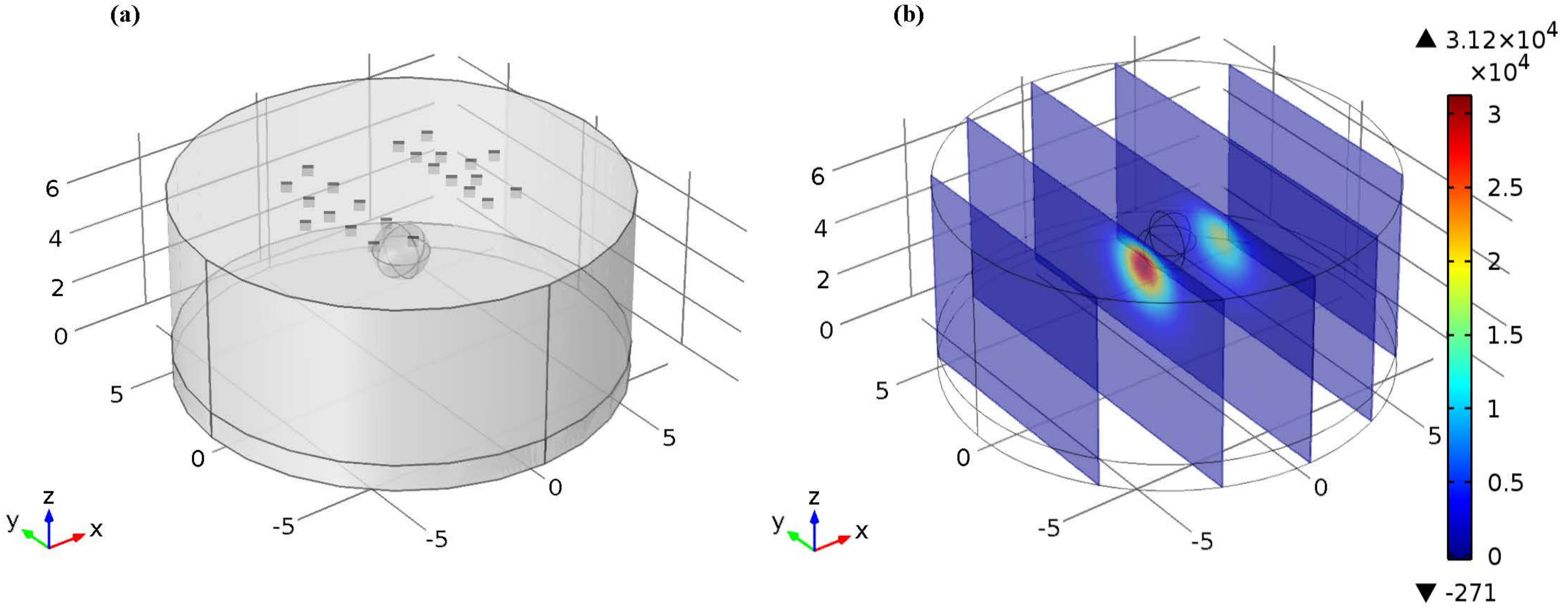


Image Reconstruction Methods

“The goal of the inverse problem is the recovery of optical properties at each voxel in the mesh using measurements of light fluence from the tissue surface…”

1) **Born Approximation**

A course mesh and a finer mesh are used for the background and ROI, respectively. As a results, the image reconstruction is well defined and the reconstruction is less sensitive to noise. Additionally, the convergence of matrix can be achieved within a small number of iterations.

2) **NIRFAST**

NIRFAST is both a modeling and image reconstruction package based of finite element method. In this work, we only had used it for image reconstruction. NIRFAST uses the least-squares (LS)-based approach for solving the inverse problem.

Results

Target (Tumor) was simulated

1) for different sizes (1.5 ,2 , 2.5 , 3 cm)

2) different depths (1, 1.5, 2, 2.5, 3 and 3.5 cm)

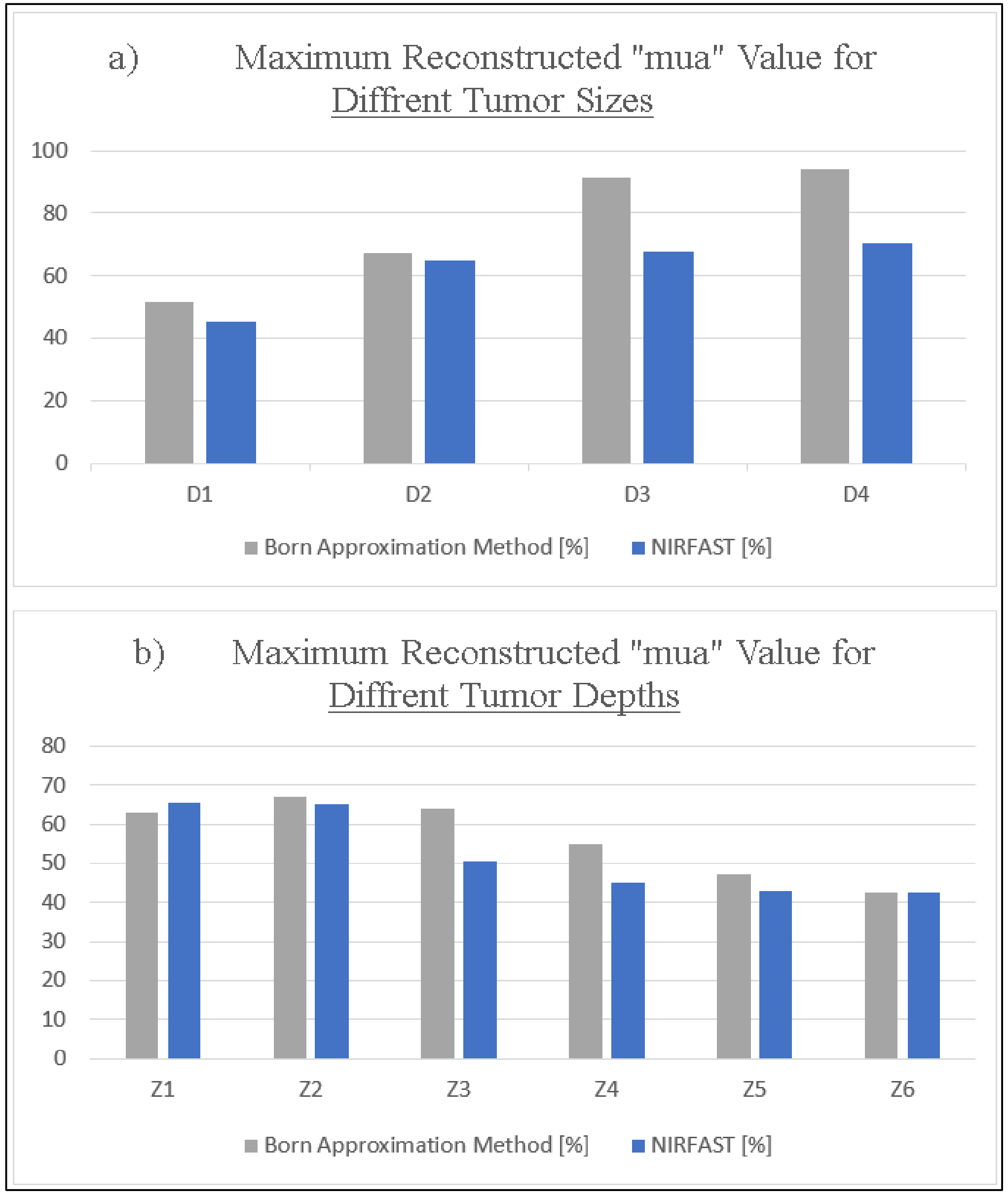
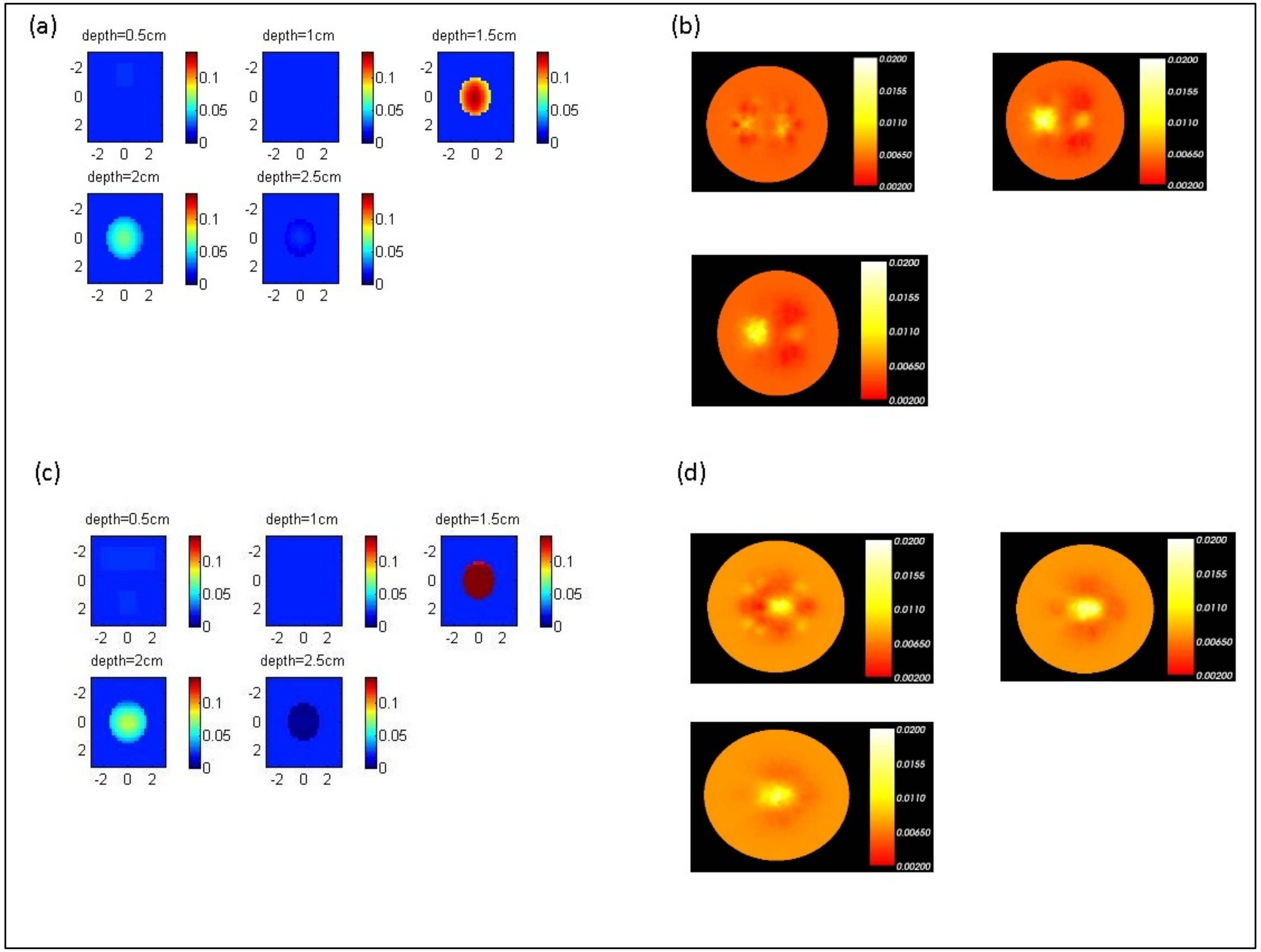


Table 1: Percentage of the maximum reconstructed “mua” value to the true value, 0.2 cm^{-1}. For (a) different target sizes. (b) different target depths.

Results

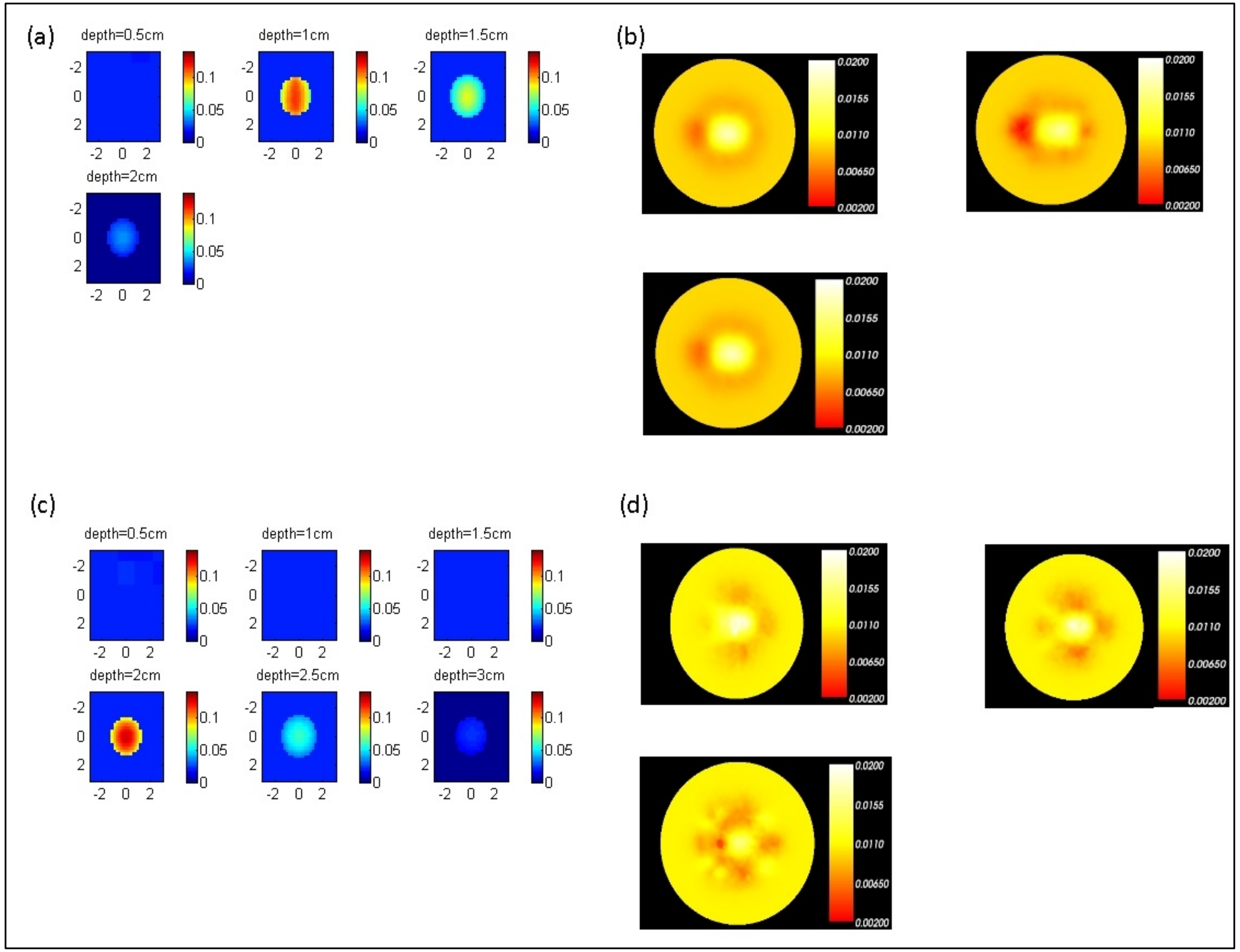
Different Sizes



DOT reconstruction using two methods Born Approximation, (a) and (c), and NIRFAST, (b) and (d). Both are for the same target depth (2cm): the first row corresponds to **a target (tumor) of 1.5 cm diameter**. The second row corresponds to **a target (tumor) of 2.5 cm diameter**

Results

Different Depths



DOT reconstruction using two methods Born Approximation, (a) and (c), and NIRFAST, (b) and (d). Both are for the same target size (diameter=2cm): the first row corresponds to **a target (tumor) of 2 cm depth**. The second row corresponds to **a target (tumor) of 2.5 cm depth**

Conclusion

- This model helps us to simulate light in tissue. And take data for DOT image reconstruction.
- In future:
  - This model will help us to perform all kinds of studies regarding application of DOT breast tissue.
  - We want to study the two different types of breast tumors (malignant & benign) to see if we can differentiate them .

Refrances

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