Improving Image Quality in Diffuse Optical Tomography

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Abstract

Diffuse Optical Tomography (DOT) imaging technique has low spatial image resolution and low image quality. DOT studies have shown that image quality is more affected by the forward model problem equation numbers. Forward model problem is built with the source and detector couplings, frequency, and phase shift data in frequency domain DOT (FDDOT). To improve the image quality, source-detector match numbers or frequency-phase data are increased. In this study, increased number of frequency-shift data were added to the forward model. Since increasing the number of source-detector numbers and frequency-shift data will raise the computational cost, the optimum number of frequency-shift data was set in this work. 8 sources and 8 detectors were placed based on the back-reflection imaging geometry. Diffuse optic tomography technique has basically 3 different running principal mode which are continuous wave (CW), time resolved (TR), and frequency domain (FD). Geometrically DOT imaging modality has also three basic source-detector placement approaches. These are back-reflected, transmission-through and ring imaging modes. Ring geometric placement is the most appropriate for breast imaging. Back-reflected mode is also suitable for breast imaging, beside it is also convenient for other tissue and organ imaging. In this work, back-reflected geometric source-detector placement was used. 8 sources and 8 detectors were placed based on the back-reflected geometric shape and it generated 64 total number of source-detector couplings. Since frequency domain forward model was built, additional frequency-shift data was also added to the forward model problem. 100 MHz modulation frequency was used for light source. Tissue absorption coefficient μ_a is 0.2 cm^{-1} and tissue scattering coefficient μ_s is 80 cm^{-1} . x, y, z cartesian grid coordinate system has 1 micrometer length in each direction for simulation tissue media. In this work, the effect of frequency-shift was observed to improve the reconstructed image quality. Image quality was assessed based on the adding number of frequency-shift data. The total number of 20 and 500 frequency-shifts were tested against each other case. 2 inclusions were embedded inside the imaging tissue simulation geometry. The case 1 which has 20 frequency-shifts and the case 2 which has 500 frequency-shifts were compared with each other. It was observed that case 2 is superior to the case 1. This is the first study to show the effect of increasing frequency-shift data to the forward model problem in DOT imaging modality.

1. Introduction

Improving image quality in Diffuse Optical Tomography (DOT) biomedical optic imaging field is very important issue, since DOT has low spatial image quality and resolution. Researchers have been working to improve the reconstructed image quality for almost 4 decades, unfortunately no big step has been taken for better image qualities until now. DOT imaging modality is using low-energized gaussian pencil-beam laser source photons, which are scattered immediately after penetrating the imaging tissue everywhere inside the tissue. This situation is explained by the help of Rytov or Born diffusion approximation of radiative transport equation inside the live tissue. Depend on the scatterers and absorbers physiology, photons are scattered and absorbed, then photon migration is modelled which maps photon fluencies inside the live tissue. DOT imaging modality has three different geometric

and three different run mode sub-branches. Based on the geometric definition, back-reflected, transmission-through and ring DOT devices have been developed. DOT modality has also three different run modes, which its instrument runs based on the continuous wave (CW), time resolved (TR), or frequency domain (FD). Frequency domain DOT run principle and diffusion equation approximations were mentioned and studied in the literature^[1–5]. FDDOT technique has forward model and inverse problem. Forward model problem weight matrix coefficients were calculated based on the frequency domain diffusion equation^[6]. Inverse problem may only be solved by using pseudo-inverse problem solution method^[6].

2. Method

Forward model was set by using 8 sources and 8 detectors which are placed on the back-reflection imaging geometry. 8 sources and 8 detectors are creating 64 source-detector matches in the back-reflected geometry. 2 different frequency-shift scenarios were used and tested with each other to show better image quality results. The case 1 has 20 and the case 2 has 500 additional frequency-shift data. Imaging geometry has 25 cartesian coordinate x, y, z grid elements in each direction. 15625 voxel grid elements were used. Imaging geometry forward model has 1280×15625 vector elements for case 1, and 32000×15625 vector elements for case 2. Imaging geometry tissue absorption is $m_a=0.2\text{ cm}^{-1}$, and scattering is $m_s=80\text{ cm}^{-1}$. 3-dimensional cartesian grid has 1 mm size in each direction. 8 sources and 8 detectors were placed on the back-reflected imaging geometry as seen in Fig. 1. Blue colors are sources and yellow colors are detectors. Sources and detectors were placed like chess-board color. Each source was followed by each detector and each row and column has the same order.

3. Result

2 different scenarios were tested and assessed against each other. In the first case, 20 frequency-shift data was added to the forward model problem. 2 different absorbers were placed inside the imaging geometry as shown in Fig. 2.A for z and in Fig. 2.B for xy view. 2 embedded inclusions were reconstructed and illustrated for z view in Fig. 2.C and xy view in Fig. 2.D for the first case.

In the second case, 500 frequency-shift data was added to the forward model problem. 2 different absorbers were placed inside the imaging geometry as shown in Fig. 3.A for z and in Fig. 3.B for xy view. 2 embedded inclusions were reconstructed and illustrated for z view in Fig. 3.C and xy view in Fig. 3.D for the second case.

4. Discussion

In this work, two different forward model problem scenarios were compared with each other to improve the reconstructed image quality for FDDOT technique. DOT technique has low spatial image quality resolution which needs to be improved for better clinic diagnostic applications. Basically, forward model

has been set based on the laser source and detector couplings until now for DOT works. In this work, frequency shift data was added for two different number of frequency shift. It was observed that adding more frequency-shift data improved the reconstructed image quality. Since the equation numbers are increased in forward model problem, image resolution is improved successfully. This work has shown that adding additional frequency-shift data is important step to improve the reconstructed images.

Declarations

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Competing Interest

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Financial competing interests:

- In the past five years the author has not received reimbursements, fees, funding, or salary from any organization that may in any way gain or lose financially from the publication of this manuscript, either now or in the future. The author works as Associate Prof. Dr. & Researcher at university that are not financing this manuscript (including the article-processing charge).

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Figures

Figure 1

Source and detector placements. Sources are blue, and detectors are yellow.

Figure 2

Original and reconstructed inclusion images for case 1.

Figure 3

Original and reconstructed inclusion images for case 2.