재구성된 광간섭단층 영상의 구조적 유사성을 이용한 수치 목표 평가

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Numerical Objective Assessment Using Structural Similarity for Diffuse Optical Reconstructed Images

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요 약

본 연구의 목표는 확산 광학 단층 촬영에 대한 기준 영상을 사용하여 동질성과 이질성을 분리하기 위한 재구성된 영상들간의 수치적 평가를 위해 구조적 유사성 지수에 기초한 알고리즘을 개발한다. 글로벌 지오메트리 및 관심 영역 평가는 유사성을 산출하기 위해 측정되었으며, 그 결과 구조적 유사성 지수의 평균이 모델 내부에 가시적 포함 여부를 판단할 수 있는 잠재적 성능을 나타낸다는 것을 알 수 있으며, 구조적 유사성 지수는 유방 구조 정보를 평가하기 위한 이미지 평가를 지원 가능한 것으로 확인 되었다.

ABSTRACT

The work within this study develops an algorithm based on the structural similarity index to assess numerically between reconstructed images with a reference image to separate the homogeneity and heterogeneity for diffuse optical tomography. Global geometry and region of interest assessment have been measured to yield the similarity. The results indicate that the mean of structural similarity index shows potential performance to distinguish between visible and invisible inclusion inside the model. Therefore, the structural similarity index may promise to assist the image assessment for evaluating breast structural information.

키워드
Diffuse optical tomography, reconstructed image, structural similarity index, optical property

Ⅰ. Introduction

To process the DOI computationally, a forward problem and inverse solution are employed. A forward problem using the finite element method (FEM), whilst an inverse solution offers the reconstructed optical properties according to light distribution [1-3]. Once these two procedures have been accomplished, the reconstructed images of absorption and reduced scattering can be obtained. Concerning image assessment, the individual or subjective evaluation is used widely since to assess an image, the human ability of eye perceptual is essential. Particularly, in the medical field, medical imaging only can be assessed by expertise who has the medical insight or background. Thus, in this paper, a mean of structural similarity (SSIM) index [4] was utilized to evaluate the reconstructed images of DOI. The purpose of this research is to develop a numerical objective assessment based on SSIM to estimate the similarity between reconstructed images and a reference image. In this case, the reference image was reconstructed homogenous cylinder to mimic breast tissue.

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II. Materials and method

As the goal of DOI is to reconstruct the optical property maps of the tissue, the estimation of this distribution may calculate by minimalizing the misfit differences of the data model. However, solving this inverse problem usually runs into the difficulty of an ill-conditioned problem. As a result, Tikhonov Regularization (TR) is introduced to remedy that issue [5].

After solving the image reconstruction steps, the next procedure is evaluating the reconstructed images. To achieve this objective, an SSIM was applied to obtain the similarity score between two images with considering the calculation in luminance l, contrast c, and structure s [4]. Then generating the SSIM index $SSIM(x,y)= [l(x,y)]^{\alpha} \bullet [c(x,y)]^{\beta} \bullet [s(x,y)]^{\gamma}$ with α, β, and γ are set 1. In additon, local window was utilized with an assigned Gaussian weighting function to acquire the mean of SSIM (MSSIM). Global geometry and region of interest (ROI) assessment have been measured to yield the similarity. Figure 1 depicts the exact reduced scattering coefficient to show the global geometry and ROI location indicated by a red circle. The combination of two MSSIM scores may calculate similarity to determine the existence of inclusion by employing $MSSIM_{tot}=sqrt(MSSIM_{geo} \cdot MSSIM_{ROI})$ where the $MSSIM_{tot}$, $MSSIM_{geo}$, and $MSSIM_{ROI}$ are total, geometry and ROI mean of SSIM.

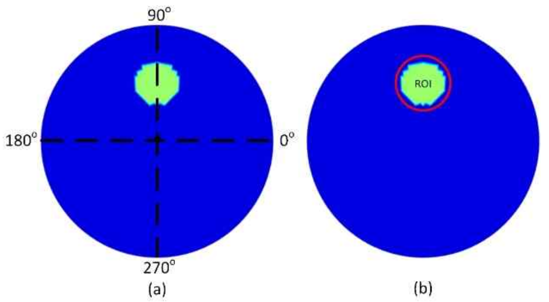

Figure 1. Exact reduced scattering image to show the (a) whole geometry and (b) ROI symbolized with a red circle.

III. Results and Future Work

Two cases were used to obtain the reconstructed images. Figure 2 shows the reconstructed images for homogeneous geometry, in this research as the reference image, visible, and invisible inclusions. The image reconstruction algorithm based on DOI successfully reconstructed the and , thus the next procedure implemented the MSSIM method to numerically assess the image. Table 1 shows the similarity score.

The visible inclusion was represented by low MSSIM since the similarity comparison with the reference image was small, while the invisible inclusion was presented by high MSSIM as the reconstructed image was almost similar to the homogeneous image. These results showed that the SSIM method is promising to assess the reconstructed image of DOI in the case to determine the presence of inclusion (in the breast imaging, it is a tumor).

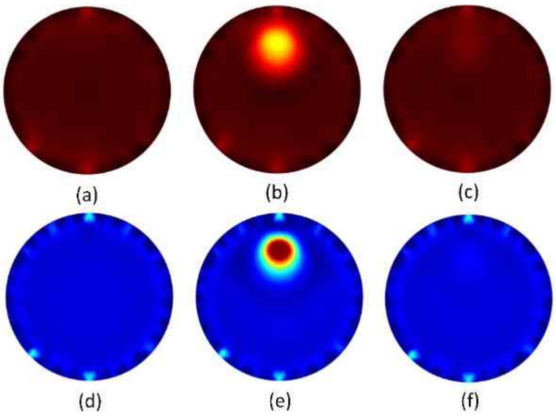

Figure 2. Reconstructed images of (a) and (d) homogeneity, (b) and (e) case A, and (c) and (f) case B.

Table 1. Similarity score.

Case	Optical property	$MSSIM_{geo}$	$MSSIM_{ROI}$	$MSSIM_{tot}$
A	μ_a	0.7524	0.0922	0.2634
B		0.8965	0.5933	0.7293
A	μ'_s	0.7335	0.0033	0.0492
B		0.8887	0.5905	0.7244

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References

[1] Y. Bérubé-Lauzière, M. Crotti, S. Boucher, S.

Ettehadi, J. Pichette, and I. Rech, “Prospects on Time-Domain Diffuse Optical Tomography Based on Time-Correlated Single Photon Counting for Small Animal Imaging,” *J. Spectrosc.*, vol. 2016, pp. 1-23, 2016.

[2] A. Pifferi, D. Contini, A. D. Mora, A. Farina, L. Spinelli, and A. Torricelli, “New frontiers in time-domain diffuse optics, a review,” *J. Biomed. Opt.*, vol. 21, no. 9, pp. 091310, Jun. 2016.

[3] G. Di Sciacca et al., “Enhanced diffuse optical tomographic reconstruction using concurrent ultrasound information,” *Philos. Trans. R. Soc. Math. Phys. Eng. Sci.*, vol. 379, no. 2204, pp. 20200195, Aug. 2021.

[4] Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, “Image Quality Assessment: From Error Visibility to Structural Similarity,” *IEEE Trans. Image Process.*, vol. 13, no. 4, pp. 600-612, Apr. 2004.

[5] L.-Y. Chen, M.-C. Pan, and M.-C. Pan, “Implementation of edge-preserving regularization for frequency-domain diffuse optical tomography,” *Appl. Opt.*, vol. 51, no. 1, p. 43, Jan. 2012.