Dynamic Optical Tomography: Resolution and Contrast Enhancement by Frequency-Filtering

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Abstract— In this report we demonstrate the capacity to significantly enhance the resolution and contrast of internal structures imaged by dynamic optical tomography. We recognize that the presence of time-harmonic behavior (*e.g.*, vasomotion), permits use of simple feature-extraction protocols capable of producing a high-contrast image. Results obtained from numerical simulation of a medium experiencing localized spatial harmonic behavior showed that target contrast could be improved by a factor of 40, accompanied by a marked improvement in resolution.

Keywords: Dynamic optical tomography, imaging, physiology, frequency analysis

Introduction: Naturally occurring contrast mechanisms at NIR wavelengths include the local variations in tissue absorption and scattering properties. A key component significantly contributing to absorption in tissue is heme-containing proteins (*e.g.*, hemoglobin and myoglobin). In the absence of adequate contrast, object detectability can be difficult or impossible. We recognize, however, that in the case of dynamic measurements, the existence of time-harmonic behavior (such as exhibited by the vasculature), can serve as addition contrast mechanism. Below we describe a numerical experiment that we performed to explore this potential. To simulate the harmonic beating of two blood vessels, we computed a series of 50 images that alternately switched between two states that differ in the diameter of included vessels (simulating diastole and systole), as shown in Figure 1. Medium properties were: dia.=9cm, background μ_a=0.04 cm^{-1}, μ_s=10 cm^{-1}; object: μ_a= 0.08 cm^{-1}, μ_s=20 cm^{-1}, dia.= 0.4, or 0.6 cm. Tomographic data consisted of 18 equally spaced detectors for each of 6 equally spaced source positions. Gaussian noise at a level of 20 dB was added to each data set. Figure 2 shows representative images of μ_a for each state, obtained from a 1st Born solution, without regularization, of a linear perturbation equation assuming knowledge of the background optical properties. Figure 3 shows the resulting composite images obtained by time-series image analysis. Figure 3a shows the amplitude of the temporal Fourier transform at the beat frequency for each pixel. Object contrast relative to background is improved by a factor of 40 compared to the original image. A roughly similar improvement in contrast was obtained by computing the inter-pixel cross-correlation value for a pixel positioned in the area of high contrast shown in Figure 3a.

Figure 1a Figure 1b

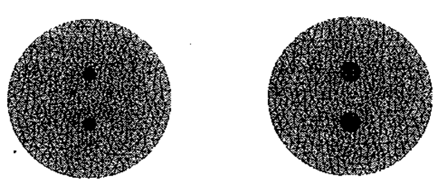


Figure 2

Diastole Systole

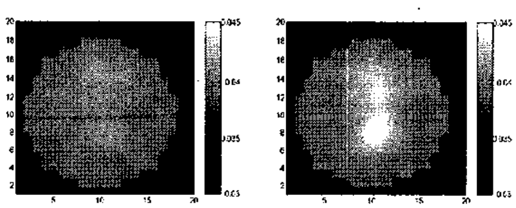
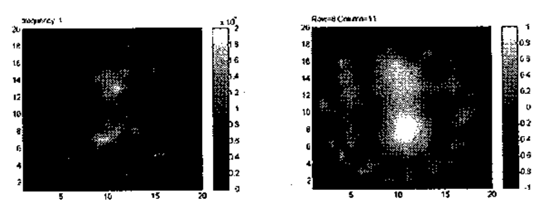


Fig 3a
Fourier Transform Image

Fig 3b.
Cross-correlation Image



Conclusion and Summary:

The existence of a natural beat frequency in vascular activity represents an added contrast and resolution enhancement mechanism available to the optical tomography method, provided dynamic imaging studies are performed.

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