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 $\mu_s=0.04$ cm$^{-1}$, $\mu_t=10$ cm$^{-1}$; object: $\mu_s=0.08$ cm$^{-1}$, $\mu_t=20$ 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 representatives images of $\mu_s$ 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.

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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