Spatial Deconvolution of 3-D Diffuse Optical Tomographic Time Series: Influence of Background Medium Heterogeneity

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INTRODUCTION

We have previously reported that limited spatial resolution of optical information is the principal cause of the relatively low spatial resolution and quantitative accuracy of DOT images reconstructed by linear perturbation techniques [1]. A deconvolution algorithm was developed that was shown to significantly improve qualitative and quantitative image accuracy, with a computational effort that is negligible compared to recourse iterative reconstruction techniques [2-5]. A potential limitation of the earlier work is that it examined only cases where the target medium consisted of a number of convex inclusions embedded in a homogeneous background. Left open is the possibility that the positive results obtained are sensitive to the spatial extent of the inhomogeneity that was considered to minimize the effects of spatial inhomogeneity on the performance of a deconvolution operator, or filter, and those of the medium to which the filter is subsequently applied. Similarly, the effectiveness of deconvolution might be sensitive to three complex parameter spatial distributions, or to increasingly irregular anatomical geometries. Hence we present results of our examinations of these issues.

METHODS

The starting point for the geometrical model used here was a 3D T1-weighted structural MRI of the human head. The section shown in Figure 1, which lies at the level of the temporal horn of the lateral ventricle, was used as the basis of a homogeneous target medium for simulations. Seven principal tissue types—air, muscle, skull, subcutaneous fluid, CSF, gray matter, and white matter—were identified within the selected area, the interfaces between them, as well as the external boundary, were traced. A 2D finite element model was created, taking the selected region’s bony and neuroanatomical interfaces as the boundaries of surface sub-regions. Next, a model with 10 geometry parameters was constructed: the 2D model is orthogonal, producing the cylinder depicted in Figure 2(a). Finally, an additional small sub-volume was created within the “gray matter” region of the 3D model, having the size and shape that would result from the model’s internal surfaces, as shown in Figure 2(b). Optical coefficient values can be assigned to each sub-region independently; thus, as shown in Figure 2(a), the number is the temporal mean) assigned to the CSF (Table 1).

3D T1-weighted structural MRI of the human head, First was the existing point for the heterogeneous target medium in use in this report’s simulation studies. The section shown intersects the pre-motor and primary motor cortex.

RESULTS

Spatially convolved images are shown in Figure 4(a-d), as the 4(a) 4(c) results. Case1/Filter2 is computed using a weight function that under-estimates the CSF optical coefficients, while the Case2/Filter3 image is obtained when weight functions are used that over-estimate the CSF optical coefficients. The center-of-gravity coordinates (W1 and W2) are they are qualitatively very similar: there is a substantial depth location error, with the recovered would be accurately located within the skull); the size of the inclusion is over-estimated in all cases, the magnitude of the optical coefficients are under-estimated in all cases.

Figure 2. (a) Exterior view of the 3D model geometry generated from the MRI section shown in Fig. 1; surface detector positions are also indicated. (b) interior view of the 3D model from Fig. 2(a), revealing the inclusion embedded in the gray-matter zone.

Figure 3. Plots of αx vs. time, in the inclusion and gray-matter compartments of the 2D tissue model of Fig. 2(b)(c).

Figure 4. Volume residing of the 3D (b) target medium. (a) Case1/Filter3 reference medium (see Table 1), before deconvolution. (b) Case1/Filter2 reference medium, after deconvolution [2]. (c) Case2/Filter2 reference medium, before deconvolution. (d) Case2/Filter2 reference medium, after deconvolution. Table 1. Optical coefficient values for the different tissue compartments of the head model (see Fig. 1), with the following αx = 0.040 and μs = 0.005...