Combined Optical and Magnetic Functional Brain Imaging

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1. Introduction

For imaging brain activation, Functional Magnetic Resonance Imaging (fMRI) provides good spatial resolution but poor temporal resolution whereas Diffuse Optical Imaging (DOI) has better temporal resolution but is challenged by the highly scattering superficial head layers that make it difficult for light to reach the brain

This work aims to explore the potential of a dual-modality system that exploits the complementary strengths of MRI and DOI.

2. Dual-modality method

We use MR anatomical scan to separate inactive regions like scalp and skull from the brain in order to reduce the volume where brain activity can be found during a task performance. The procedure is to assign the value zero to voxels corresponding to scalp and skull in the sensitivity matrix of the forward model. We call this the *Brain prior* (see Figure 1), it is a "hard" prior that is embedded directly in the imaging matrix.

The sensitivity matrix is calculated by simulating photon migration in a subject-specific head model. The full segmented 3D head model is calculated from an MR scan where five tissue types are distinguished: scalp, skull, cerebral spinal fluid, grey and white matter. Each tissue type is characterized by its typical absorption and scattering coefficients. Photon migration is simulated by a Monte Carlo method (Boas et al. [1]). In each simulation 10^8 photons are injected, run time was about 12 hours.

The inverse problem consists in reconstructing hemodynamic changes in the brain from the simulated measurements -- it is ill posed due to insufficient data, therefore we use Tikhonov regularization (Bertero et al. [2]). The optimal regularization parameter, α, is calculated using the L-curve method [2] (shown in the y axis label of Figure 1). The reconstruction algorithm terminated after about 20 iterations.

3. Results and Conclusions

The data show that using a spatial prior clearly improves the localization of the activation region in the brain due to the contribution of the MRI data. Similar results were shown in Boas et al. [3] where a cortical prior based on the full segmented head model was used. In contrast, the approach outlined is aimed at use with skull stripped MR images in conjunction with an atlas for approximate tissue segmentation.

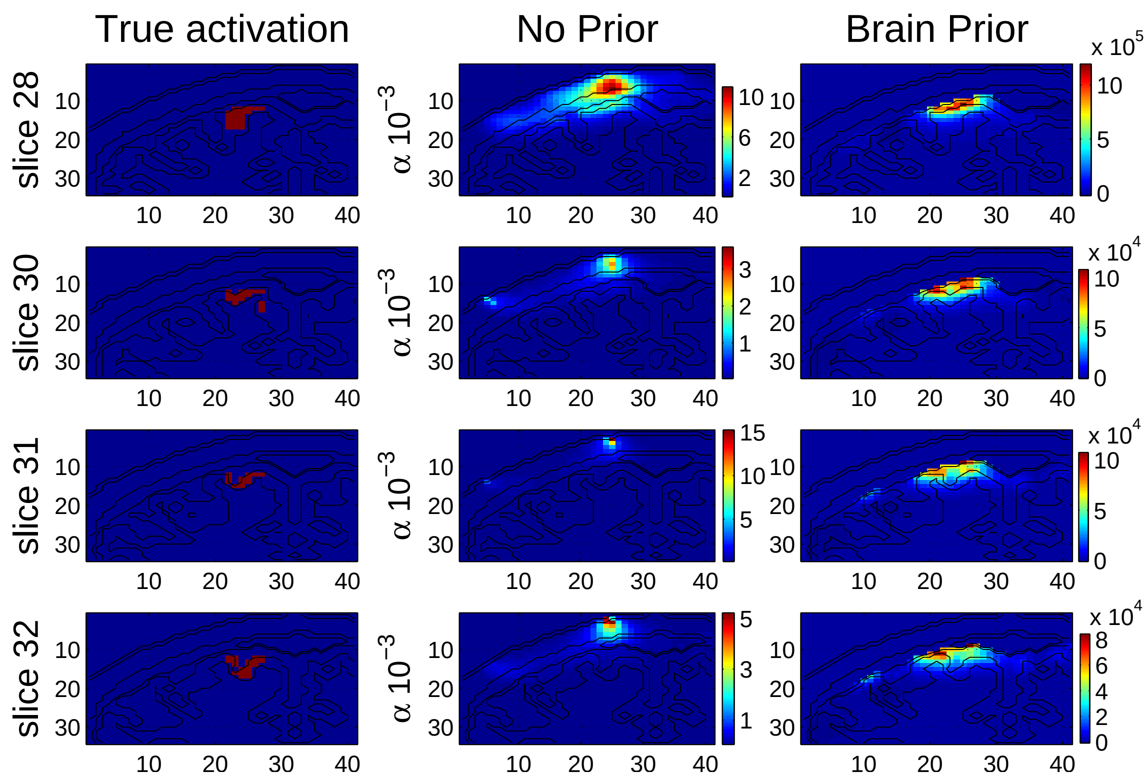

Fig. 1: The figure shows the improvement of the dual-modality method over a simple Tikhonov reconstruction: the first column shows the simulated activation, the second column shows coronal slices of the brain reconstructed using the Tikhonov inverse method and the third column shows the reconstruction calculated adding the hard brain prior to the Tikhonov reconstruction. The contour lines represent the 5 tissue types (scalp, skull, CSF, grey and white matter). The results prove that activation localization in the brain improves dramatically due to the use of a spatial prior. Optical measurements are sensitive to superficial layers and, therefore, localization of brain activity tends to appear closer to the superficial layers but depth sensitivity is shown to improve thanks to the use of the MRI additional anatomical information.

4. Acknowledgments

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5. References

1. D. Boas, J. Culver, J. Stott and A. Dunn, "Three dimensional Monte Carlo code for photon migration through complex heterogeneous media including the adult human head", Optics Express **10**, 159-170 (2002).

2. M. Bertero and P. Boccacci, *Introduction to Inverse Problems in Imaging* (IOP Publishing, Bristol, 1998).

3. D. Boas and A. Dale, "Simulation study of magnetic resonance imaging-guided cortically constrained diffuse optical tomography of human brain function", Appl Opt **44**, 1957-68 (2005).