Sensor Weighted Multiple Sphere Head Model for MEG
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Introduction: The head model most widely in use in MEG is a single equivalent sphere. Although the fields for this model are easy to compute, the single sphere has been criticized as inadequate in representing the true variations in the shape of the head. The Boundary Element Method (BEM) can be used to introduce more realistic head geometries. Application of these methods, however, is limited by their lengthy computation time and the huge computer memory requirements for matrix inversion. Furthermore, substantial errors in the forward field can arise if the surfaces are not tessellated with sufficient density. In this study, we present the theoretical foundations of a Sensor Weighted Multiple Sphere (SWMS) head model, for which the preliminary work was presented last year¹. We also demonstrate here the connection between our novel Regularized Percentage Error (RPE)¹ and the actual localization error in the inverse problem.

Method: The external magnetic field measured by MEG can be divided into two terms, namely the infinite homogeneous term and fictitious or “secondary” current term. The infinite homogeneous term is independent of head geometry. The fictitious current term, however, is treated differently for each head model. The SWMS model finds the equivalent sphere that minimizes the difference between the true fictitious current term and that associated with the spherical model. The procedure uses anatomical boundaries and surface normals extracted from 3D MR images as the basis for modeling the true fictitious currents (Fig. 1). The SWMS approach differs from other locally fitted spheres methods² since a single sphere is fit to the entire source volume for each sensor as illustrated in Fig. 2. In contrast, other locally fitted sphere models may fit spheres at different locations in the head volume, but with the same sphere used to model the signal at all sensors. This latter technique has the disadvantage that the user must select how to partition the source volume into the different spherical regions. Once the equivalent spheres are determined for each sensor, the cost of computing the SWMS forward model is identical to that for a single sphere model.

Result: Numerical comparisons of RPE to a “gold standard” three-layer BEM in the forward computation using a single sphere, SWMS and a single-layer BEM reveal that SWMS has similar accuracy to BEMs, and substantially better than the single sphere model, for a realistically shaped brain volume¹. The single sphere model shows the largest RPE in the frontal region, while the performance of our SWMS model is similar to the BEM. We have compared the localization performance in this frontal region using a single sphere model and SWMS for a small number of simulated dipoles. The simulated forward fields were computed using a BEM with three layers (brain, skull, scalp) extracted from an MRI. The mean localization errors are about 6 mm for the single sphere model and about 3 mm for our SWMS, indicating that the SWMS model can more accurately model this frontal region. We will present at the meeting our localization comparisons for dipole locations through the entire head volume.


Fig. 1: (Left) Anatomical boundary and surface normals extracted from MR.

Fig. 2: (Right) A schematic plot of SWMS, each MEG sensor is assigned with its own best fitting sphere.