EEG/MEG Propagating Dipole Source Estimation

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Background

Electroencephalography (EEG) and magnetoencephalography (MEG) are the only two methods to study the functional organization of the brain with a temporal resolution close to 1 ms. This unique feature seems to be useful to measure with enough precision propagating activity on the cortex. Moreover, both EEG and MEG are complementary rather than competitive, as mathematically argued by Muravchik and Nehorai in [9].

An example of application of brain topography is the treatment of patients suffering from temporal lobe epilepsy (TLE), in which anti-epileptic drug treatment fails. Seizures, with loss of conscience, may occur in such patients several times a month or even many times a day, and thus severely hamper social functioning. These patients can be considered candidates for surgery. When considering surgery, it is important that the location of the epileptic focus is well determined beforehand.

Because EEG /MEG records are taken on or above the surface of the head, these measurements are not a direct representation of the distribution of the activity on the cortex. Indeed, the head layers of different conductivity modify the electric potential and magnetic field distribution. Then localizing the source from EEG/MEG measurements become an *inverse problem* which has a non-unique solution. In addition there are also noisy signals that contaminate the measurements. Thus statistical procedures must be called for to estimate the location and orientation of the brain sources of cerebral activity.

To simplify the problem, models of the head, the source, and the noise are needed [6] to project the characteristics of activity at the cortex out of the measured data.

The head is often modeled as a conducting region of space, in which the conductivity changes with the various types of tissue (i.e., the scalp, the skull, the brain, and the fluids surrounding the brain and other tissues).

Source models are chosen according to the neurological study subject. It can be assumed that one or more dipoles are at a fixed position during a given time-interval and that their strength and orientation varies over time. The orientation can also be fixed. This is the so-called fixed dipole model. Another approach allows the dipoles to change their position as well as their strength and orientation. Basically, this method fits one or more dipoles at each time-instant independently. This is the moving dipole model [5, 7]. It is also possible to estimate current distributions in the brain . Basically, the result of this method is a fixed dipole solution with many fixed dipoles located at discretized points in the region of interest.

We are proposing and developing a dynamic or propagating dipole model. The moving dipole model can estimate the instantaneous parameters of a propagating ECD as a function of time for each sample separately, as if the source was stationary. In our work, it is conjectured that the parameter's evolution is better described by the trajectory of a dynamic model given by a set of known difference equations. The approach presented in [12] is based on a deterministic description of dipole trajectories. In [11] we introduced the use of a linear dynamic stochastic model to describe the trajectories. We used simulated trajectories, motivated in studies of auditory evoked responses [4].

Procedures for Linear State-Space Models

We delineate two procedures for identifying the dynamics of a propagating dipole and for tracking its position on the brain. The common factor among them is the supposition of linear state-space models, i.e., the combination of a linear observation model with a linear propagation model.

In the first procedure we assume polynomial dynamic for the propagation and we estimate the dipole position and other dynamic parameters while tracking using a Kalman smoother.

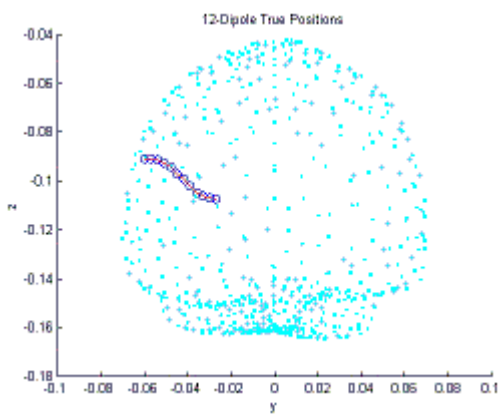
For the second procedure we pre-etimate the system matrix prior to the use of a Kalman smoother for tracking the position of the propagating dipole.

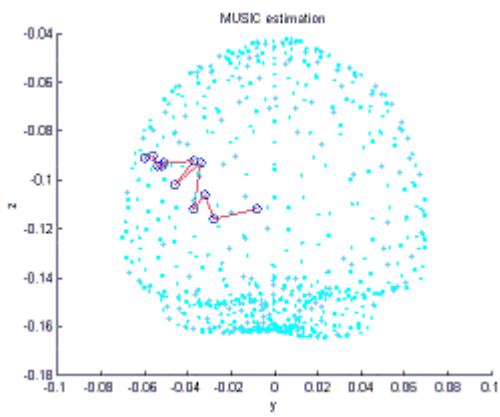
For both prcedures we have any pre-estimations of the propagating dipole positions. We MUSIC is a example of such single snapshot pre-estimation algorithm.

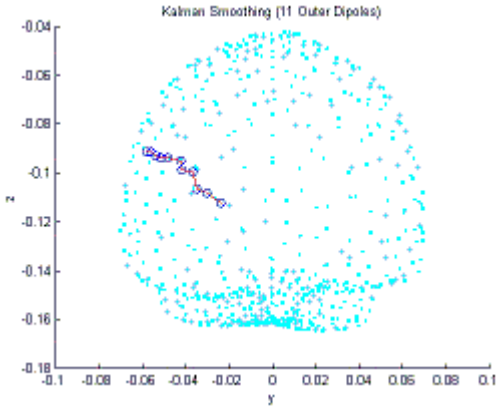
We defer the development of procedures involving nonlinear propagation and observation models for future work.

In the presentation we show results of simulation experiments for a single propagating dipole source with geometrical data from a real head. Also a real source activation model is used.

Some results are the shown in the figures. Figure 1 show the trajectory for the original simulated propagating source. Figure 2 showd the results after estimating the trajectory using MUSIC. Figure 3 shows the results after applying our first procedure.







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