Inverse skull conductivity estimation problems from EEG data

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A fundamental problem in theoretical neurosciences is the inverse problem of source localization, which aims at locating the sources of the electric activity of the functioning human brain using measurements usually acquired by non-invasive imaging techniques. Such a technique is the electroencephalography (EEG) which measures the effect of the electric activity of active brain regions through values of the electric potential furnished by a set of electrodes placed at the surface of the scalp [2]. The inverse source localization problem in EEG is influenced by the electric conductivities of the several head tissues and mostly by the conductivity of the skull. The human skull is a bony tissue consisting of compact and spongy bone compartments, whose shape and size vary over the age and the individual's anatomy making difficult to accurately model the skull conductivity.

Our goal here is to establish uniqueness and a constructive scheme for the inverse skull conductivity estimation problem using partial boundary EEG data, in the preliminary case of an homogeneous skull conductivity. This is a version of the many inverse conductivity issues still under study nowadays [1]. The problem is thus examined in a three layer spherical head model made of three concentric nested spheres, each of them modelling the scalp, skull and brain tissues (from the outer most to the inner most layer, respectively). The head is assumed to be piecewise homogeneous, and each of the three layers is supposed to have a constant conductivity. We also assume that the conductivities of the brain and the scalp are known, while the conductivity to be recovered is the one of the intermediate spherical layer (skull).

We solve the above conductivity estimation problem from the available EEG partial boundary data, expanded on the spherical harmonics basis, and transmitted over the spherical interfaces by transfer functions, while we consider that the source term is already estimated. Linear algebra computations then allow us to establish uniqueness properties and a reconstruction algorithm for the skull conductivity. Other aspects under consideration are the stability of the inverse problem and the robustness of the reconstruction algorithm.

Further, situations with unknown (or partly known) source term will be investigated as well, maybe with additional EEG datasets or other modalities like magnetoencephalography (MEG) and electrical impedance tomography (EIT). Finally, for a non-homogeneous skull model, with compact and spongy bone parts of different conductivity values, we keep the aim of recovering these two distinct values from boundary data.

This is joint work between: INRIA Sophia Antipolis, France, Teams APICS, ATHENA, and BESA GmbH, Germany

References

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