The Forward Problem of EEG Source Localization using Current Density Imaging

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Introduction

The inverse problem of EEG is to use electric potentials measured on the skin to determine the position, orientation, and strength of the sources within the brain. A practical and accurate solution to this problem would provide the spatial position of EEG sources, which would lead to fundamental advances in neurophysiology and neuropsychology.

To solve the EEG inverse problem, one must be able to solve the related forward problem. The solution to this problem critically depends on the shape and electrical conductivity of the fluids and tissues of the head. All present methods use an assumed head model to solve the forward problem. These assumptions lead to errors in source localization.

We propose to use an MRI method called Current Density Imaging(CDI)[1] to replace the assumed head model with measurements. By using CDI,we measure the lead fields of the skin electrodes. Our hypothesis is that the knowledge of the lead fields allow the skin potential to be easily computed without any assumptions about the head model. To prove our hypothesis, we designed three experiments to show that current density imaged lead fields can solve the forward problem.

Methods

A. The Phantom

A dipole, constructed from a semi-rigid coaxial cable(UT-34C,Micro-Coax),was placed at the centre of a cylindrical phantom. The phantom was filled with gelatin-agar gel containing 40% animal hide gel and 60% agar [2]. Two EEG electrodes were placed symmetrically on a diameter of the flat surface of the phantom, 126mm apart.

B. Computation of Surface Potential from the Lead Fields

The surface potential, V, was computed from the measured lead fields using the following formula[3]:

$$V = \frac{\vec{J}}{\sigma I} \cdot (\vec{iD})$$

Where (iD)is the dipole, current I is the current applied during CDI and Sigma is the conductivity at the dipole.

C. Lead Field Measurement

The current density J was measured using 4D Low Frequency CDI [1].The current I had a bipolar rectangular shape. Slices were orthogonal to the diameter, 5mm thick with a separation of 0mm. The pixel size was 0.9375mm.

D. Conductivity Measurement

An auto balancing bridge (HP4284A) was used to measure the conductivity of the gel for the frequency range of 100Hz-10kHz. The measurement was repeated for six different electrode positions.

E. Current Density at the Dipole Position

The position of the dipole was determined from a signal void it created in the MR images. It was assumed that dipole lay in the last consecutive slice in which this void appeared(Figure1). The current density was estimated by averaging the current density of the 10x10 pixels centred on the dipole in 3 adjacent slices.

F. Forward Solution Accuracy

The potential difference between the EEG electrodes, Vm, was measured using a differential amplifier. The accuracy of the forward problem was then tested by comparing V, computed in step B, with Vm.

Results and Discussion

A. Conductivity Measurement

The results from four-electrode apparatus showed that conductivity of the gel is frequency independent. The standard deviation of the measured conductivities for the specified frequency range was +/- 0.009 (A/m^2).

B. Forward solution Accuracy

The results of the three experiments along with our estimated measurement accuracy in each case are shown in Table 1.
Since the estimated errors are much larger than the actual difference between V and Vm, it can be concluded that these errors are overestimated.

Since knowledge of lead fields allowed the surface potential to be easily computed without any assumptions, our LFCDI method can be used to solve the forward problem of EEG source localization.

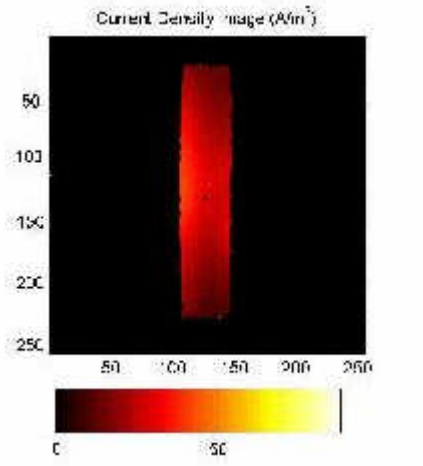

Figure1. A coronal Slice through the Phantom

References

[1]G. C. Scott, and M. L. G. Joy, "Measurement of Nonuniform Current Density by Magnetic Resonance." IEEE Transactions Medical Imaging, Sept. 1991, Vol. 10, No. 3, pp. 362-374.

[2]J. Blechinger,"Tissue-mimicking gelatin-agar gels for use in MRI phantoms" Med. Phys.1988, Vol.15, No.4, pp.629-636.

[3]S. Rush, and D. A. Driscoll, "EEG electrode sensitivity – an application of reciprocity." IEEE Trans. Biomed. Eng. Jan. 1969, vol. BME-16, No.1, pp.15-22.

Table1: The Forward Solution accuracy for all three experiments

	Note	V(v)	Vm(v)
Exp1	iD‖surface	0.260x(10-4) (+/-)7.3%	0.2599x(10-4) (+/-)5%
Exp2	iD‖surface	0.2174x(10-4) (+/-)7.1%	0.2173x(10-4) (+/-)5%
Exp3	iD@45deg	0.1198x(10-4) (+/-)5.6%	0.1197x(10-4) (+/-)5%