Cortical Dipole Source Estimation Considering Time Window

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1. Introduction

High resolution visualization techniques of the brain electrical activity are expected to analyze functional brain activity and to localize the foci of epileptic discharges. The electroencephalograms (EEG) can noninvasively measure the brain electrical activity in actual environments. However, the spatial resolution of the potential distribution on the scalp surface is low because of the low conductivity of a skull. To overcome this problem, the dipole source localizations have been investigated[1,2]. In the single time-slice source localization[1], when the amplitude of EEG is small, the estimation error became large under the noisy condition. On the other hand, the multiple time-slice source localization[2] that assumes the position and the orientation of the dipole source are invariant is difficult to accomplish the estimation when the dipole source moves.

In the present study, we proposed the dipole source estimation method by considering the time window and the moving speed of the sources. The dipole source was estimated with various time windows and the estimation accuracy was evaluated in the simulation with a volume-conductor head model.

2. Method

The head volume conductor was approximated by an inhomogeneous three-concentric-sphere model. This model takes the variation in conductivity of different tissues, such as the scalp, the skull, and the brain, into consideration.

The dipole source was searched so that the error between the scalp potential calculated from the dipole source and the observed scalp potential might become minimum. If the initial value of the dipole source is far from the actual value, the data may converge to local minimum. In the present study, we searched the minimum value by using the dipole source information on the last time for an initial value.

Single time-slice source localization uses an instant time data of the scalp EEG to estimate the dipole source. On the other hand, multi time-slice source localization is the estimation method using a certain time interval of the scalp EEG that assumes the position and the orientation of the dipole source are invariant. We investigated the relationship between the length of time window and the moving speed of the dipole. Since the temporal resolution of EEG is high, it is thought that the dipole source does not change remarkably in short time.

The simulation was performed to verify the proposed method. The position of dipole sources moved from an occipital region to a frontal region and the strength changed as 10Hz sin wave that supposed alpha wave. Furthermore, 10% Gaussian white noise was added as background noise. The simulated EEG was acquired at a sampling rate of 1 kHz and the length of analysis section is 0.5s. The dipole sources that moved at various speeds were examined. Finally, estimated dipole source was compared with actual dipole source with position errors, amplitude errors, and orientation errors.

3. Results

Figure 1 shows the results of error between estimated dipole source and actual dipole source with different moving speed of the dipole. The results with the time window of 1 ms means single time window. When the dipole source moves at 0.18[deg/ms] and at 0.30[deg/ms], the errors became minimum with the time window of 4 or 5 ms. On the other hand, when the dipole source moves at 0.06[deg/ms], the errors became minimum with the time window of 20 ms. The multiple time slice approach by setting the time window with appropriate length provided better performance than the single time window.

4. Conclusion

We proposed a new method to estimate dipole sources by considering the length of the time window and the moving speed of dipole source. The dipole sources could be estimated with sufficient accuracy by setting the appropriate time window compared with the single time data. Further, investigation for human experimental data using realistic head model is necessary to validate the proposed method.

Reference

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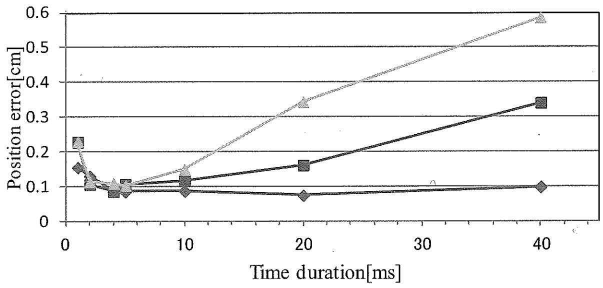
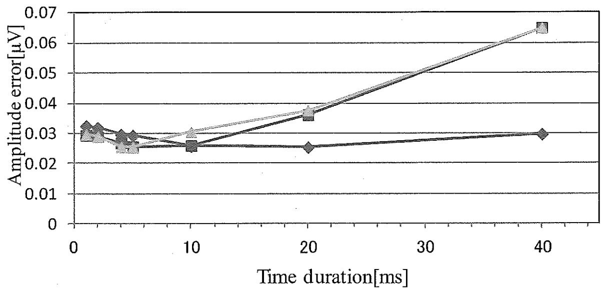
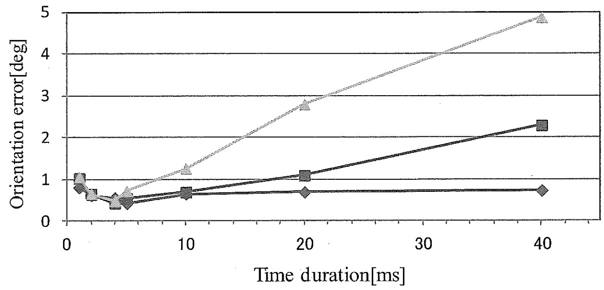


(a)Position error



(b)Amplitude error



(c) Orientation error

Fig.1. Estimation errors of dipole sources when changing the time windows.

◆0.06[deg/ms] ■0.18[deg/ms] ▲0.30[deg/ms]