Proceedings of the Fifth International Brain-Computer Interface Meeting 2013 DOI:10.3217/978-3-85125-260-6-89

Comparisons of the Spatial Resolution between Disc and Tripolar Concentric Ring Electrodes

X. Liu[1], W. Besio[1]
[1]*University of Rhode Island, Kingston, RI, USA*

Correspondence: W. Besio, Department of Electrical, Computer, and Biomedical engieering, USA. E-mail: besio@ele.uri.edu

Abstract. We compared the half sensitivity volume and the common spatial subspace decomposition of visual evoked potentials as measures of spatial resoulion between conventional disc electrodes and tripolar concentric ring electrodes with a computer simulation. The results suggest that tripolar concentric ring electrodes can achieve much higher spatial resolution than conventional disc electrodes.

Keywords: EEG, CSSD, Spatial Resolution, tripolar concentric ring electrode, TCRE

1. Introduction

Brain Computer Interfaces (BCIs) can provide persons who cannot use their muscles but are cognitively intact with an alternative form of communication and control. Electroencephalography (EEG) measures potentials on the scalp caused by the neural activity of the brain. EEG has high temporal resolution, but suffers from poor spatial resolution due to the blurring effects of the volume conductor [Nunez et al., 1994]. To improve the spatial resolution the surface Laplacian, second spatial derivative, has been applied to EEG.

For conventional electrodes, the global surface Laplacian operation is performed on the spline potential interpolation over the surface. However, a cross validation procedure is required to compute the inverse of an ill-posed matrix in the construction of the spline interpolation equations, which cannot be performed in real-time EEG based applications such as BCI. [Besio et al., 2006] have reported on a local surface Laplacian from tripolar concentric ring electrodes (TCREs), which helps to avoid complex computations in surface Laplacian approximation while achieving improved spatial resolution [Liu et al., 2011]. Two computer simulations were performed for this work to compare the spatial resolution for disc electrodes and TCREs.

2. Methods and Results

Both of the simulations were based on a 4-layer concentric spherical human head model developed by [Cuffin and Cohen, 1979].

The half sensitivity volume (HSV) is defined as the volume where the potential is at least half of the maximum value measured [Malmivuo and Suihko, 1997]. According to the definition, HSV is inversely proportional to the spatial resolution of corresponding electrodes. Fig. 1 shows that the HSV of the TCRE is about 1/10 of the conventional disc electrodes HSV.

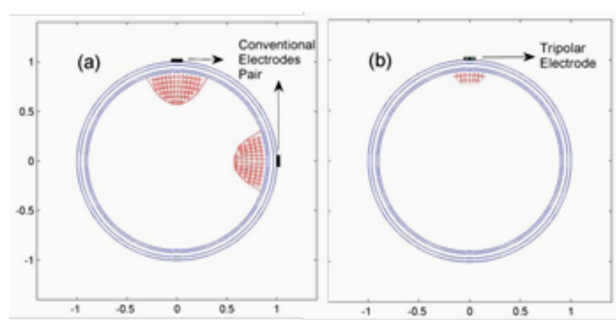

Figure 1. *HSV of disc and TCREs.*

Common spatial subspace decomposition (CSSD) was developed to separate specific brain activities from the background [Wang et al., 1999]. In our simulation an 8 by 8 electrode array, with the electrodes diameter of 1 cm, was placed on the scalp above the visual cortex area with a 1.0 cm center-to-center distance between electrodes. A signal dipole with eccentricity of 0.9 was placed under the electrode array. Two noise dipoles with eccentricity of 0.75 were concurrently activated under the array as background brain activity. Ten samples of visual evoked potentials (VEPs) were generated from the dipoles. In the simulation, we first recorded the background by setting the magnitude of the signal dipole to zero. Then, we recorded the VEP combined with background. Finally, the CSSD was applied to the recorded data to extract the VEP. The TCRE EEG (tEEG), which automatically estimates the Laplacian [Besio et al., 2006], was calculated for comparison.

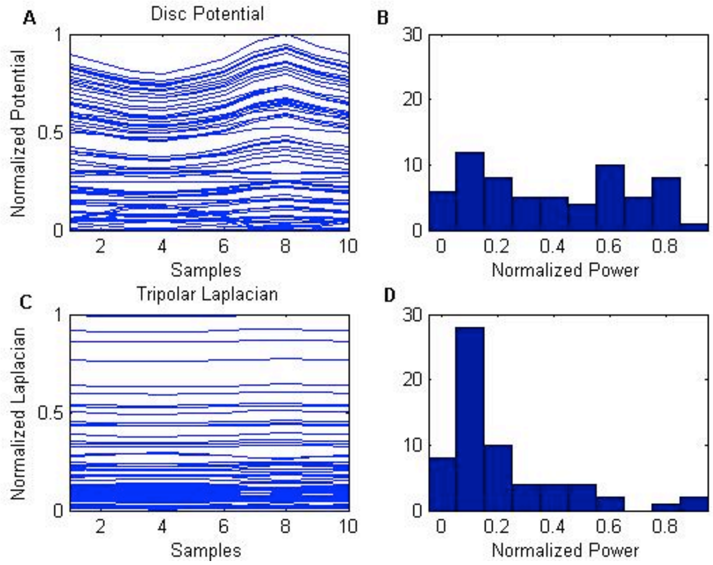

Figure 2. *The normalized signals of the VEP (A), tEEG VEP (B) and the histograms of their corresponding power.*

Fig. 2A shows the normalized VEP from the 64 conventional disc electrodes. Fig. 2B is a histogram of the normalized power of the VEPs. Fig. 2C and 2D shows the normalized tEEG VEP and histogram of the normalized tEEG VEP power from the array of TCRE at the same locations, respectively. From Fig. 2D we can see that most of the TCREs had low power in the tEEG VEP, 0.5 or less, while Fig. 2B shows the disc VEP was distributed over a wider area of the electrodes array. These results show how tEEG is more specific than EEG.

3. Conclusion

The results of the HSV and the VEP indicate that the TCRE is more focused than the conventional disc electrodes. The cross correlation of the tEEG VEP for the TCREs that had high CSSD were 1.0 or nearly 1.0 meaning that the background interference was attenuated. Due to these properties we should be able to achieve higher spatial resolution with TCREs.

References

Nunez PL, Silberstein RB, Cadiush PJ, Wijesinghe J, Westdorp AF, Srinivasan R. A theoretical and experimental study of high resolution EEG based on surface Laplacians and cortical imaging. *Electroencephal Clin Neurophysiol*, 90:40-57, 1994.

Besio W, Koka K, Aakula R, Dai W. Tri-Polar Concentric Ring Electrode Development for Laplacian Electroencephalography. *IEEE Trans Biomed Eng*, 53(5):926-933, 2006.

Liu X, Makeyev O, Besio WG. A comparison of tripolar concentric ring electrode and spline Laplacians on a four-layer concentric spherical model. *33rd Annual International IEEE EMBS Conference*, 2949-2952, 2011.

Cuffin BN, Cohen D. Comparison of the magnetoencephalogram and electroencephalogram. *Electroencephal Clin Neurophysiol*, 47:132-146, 1979.

Malmivuo JA, Suihko VE. Sensitivity Distributions of EEG and MEG Measurements. *IEEE Trans Biomed Eng*, 44(3):196-208, 1997.

Wang Y, Berg P, Scherg M. Common spatial subspace decomposition applied to analysis of brain responses under multiple task conditions: a simulation study. *Clin Neurophysiol*, 110:604-614, 1999.