ECE 594C: Lab 3 (EEG modeling)

Assigned: November 1
Report Due: November 10 (electronic submission)
Preparation: Get EEG data from Fei, learn how to visualize the brain regions corresponding to a spatial response (already done)

As we have seen, the data can be classified into 4 categories, with images corresponding to *animal* or *no animal,* and a response for each image that are *correct* or *incorrect.* The brain dynamics, and hence spatiotemporal EEG response, for each scenario is expected to be somewhat different, hence we analyze them separately using independent component analysis.

(a) Concatenate the readings for several images for each category into a single $N \times T$ data matrix $\mathbf{Y}$, where $N = 31$ is the number of electrodes and $T = MK$ is the number of samples, with K denoting the number of images (a parameter to be played with) and M the number of time samples per image. Run PCA on this data, plot the eigenvalue profile, and select the number L of important components (also a parameter to be played with).

(b) As in Lab 1, project down into the space spanned by the dominant eigenvectors and apply ICA to the $L \times T$ projected data matrix $\mathbf{Z}$. You will get L time courses for the "independent" sources that are extracted, each normalized to zero mean and unit variance. Align the time courses for different images into a single segment of length M samples and plot them superposed on each other. Also plot the mean time course, averaged over images. Do you see any patterns?

(c) Estimate the $N \times L$ original mixing matrix corresponding to these sources (there are multiple ways of doing this: correlation of the extracted sources with the original data $\mathbf{Y}$, or using the unmixing matrix $\mathbf{W}$ produced by ICA and the dominant eigenvalues/eigenvectors from PCA). Plot the superposed and mean time courses (see (b) above) for the "strongest" sources, corresponding to columns with largest norm. Also show the corresponding "active" brain regions.

(d) Discuss any patterns in the time course relative to the timing of stimulus and response. From the spatial response, speculate on which brain regions might be involved for each component.

(e) Discuss the cognitive significance (if you find any) of the spatiotemporal patterns extracted using ICA. Do these patterns conform to what one would expect from cognitive models for the task? How do the patterns depend on the category (animal or not, correct or not)? Do you find any temporal dependencies within or across components? Are any of the components clearly identifiable as artifacts such as eye blinks?

(f) Can ICA really hope to separate correlated activity in different brain regions? To get insight into this question, go back to the artificial model of Lab 1 and introduce a third source which is *identical* to the second source, but simply delayed by 3 samples. Now, generate a 10×3 mixing matrix with random entries (thus, the second and third sources are multiplied by different columns) and apply PCA/ICA as before. Can you separate out the sources? The point of this exercise is to understand whether neuronal firing in one brain region leading to (i.e., with some delay) firing in another region (i.e., different spatial response) can be potentially separated out by ICA, even if there is a deterministic relation between the activities in these two regions for a given task.

(g) Using the coarse guidelines in Figures 4 and 5 in [Scherg90] (posted to the course web page), or any other references on head modeling and source localization, can you say something about whether the spatial response for each of the strong independent components are well-explained by a single dipole (if so, what would the orientation be), or whether multiple dipoles might be needed?

(h) (Optional) Report on any other ideas you have tried out.

Please feel free to discuss questions or difficulties across groups and with the instructor.

[Scherg90] M. Scherg, "Fundamental of dipole source potential analysis," *Advances in Audiology Reprint,* Auditory Evoked Magnetic Fields and Electric Potentials, vol. 6, pp. 40-69, 1990.