

ACTIVE BRAIN CENTRES SELECTION FOR FUNCTION CONNECTION ANALYSIS

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Abstract

Human brain is the least explored body organ. Mapping of its particular centres activity yields not only to understanding its function but also can lead to new procedures in treatment of various diseases. EEG (electroencephalography) is one of the main imaging techniques evaluating the electric activity of brain neurons. The most common procedure is measuring the surface (scalp) EEG, the main advantage is non-invasive gathering of such investigations. In recent years, the possibility of tomographic processing of EEG has been becoming more common, so the surface electrode records are projected into the 3D space. This allows a localization of more deeply located sources, whose activity on the scalp is very low. For subsequent processing of the tomographic EEG, like an analysis of relations among the active centres, there is a need of convenient algorithm of region of interest (ROI) selection. Several methods of ROI selection are proposed in this paper. We have developed a new viewer in Matlab environment of output files of sLoreta system. It allows manual color legend settings common to all tomographic images. The viewer is useful for direct connection to the algorithms of selection of active centres presented in the paper and implemented in Matlab. The compact tool for tomographic EEG processing and viewing was created, allowing finding the active centres and facilitating the subsequent examination of centres relation in human brain.

1 Introduction

Processing of surface EEG is one of the oldest methods of human brain function analysis. It is non-invasive measurement, there is no problem with patients suffering claustrophobia like with fMRI (functional magnetic resonance imaging). However, the main advantage is the high time resolution of measured data and direct relationship with electric activity of brain neurons. Surface data recorded with a small number of electrodes gives only very inaccurate space location of sources of such activity. Electric voltage potentials measured on one electrode are the result of summation of electric activity of large amount of neurons. In recent years, the possibility of tomographic (3D) processing of such surface data has occurred, making possible reconstruction of sources of electrical activity in brain space, which considerably increases possibilities of EEG usage for mapping of brain function. Although such calculated data does not reach the accuracy of spatial resolution of fMRI, increasing amount of electrodes covering in detail larger surface of human head scalp leads to continual improvement of tomographic EEG spatial resolution.

In our recent work, a complete toolkit supporting a cooperation of existing software tools was developed, handling complete chain of EEG signal processing from signal acquisition up to tomographic analysis [5]. In this paper, the following processing of tomographic data is discussed for later application of function connection analysis of active brain centres in different tasks.

2 Inverse solution

Calculation of projection of scalp electrodes data into the 3D space is called an inverse solution, an opposite of direct solution, which solves a projection of sources in brain space into the electrodes on the surface of the head. One of such tools for tomographic computation is software sLoreta [1, 2, 3, 4], distributed as a freeware for science use. It calculates an transformation matrix from 3D positions of electrodes, and then it maps the surface electrodes records into the brain space (covering the gray matter, hippocampus and amygdala) which is divided into the 6239 cubes with dimension of $5 \times 5 \times 5$ mm, so-called voxels. The disadvantage is that it operates with mean anatomic image of

brain calculated from large amount of people, the result is not accurately matched with the particular measured person. The advantage of inverse solution via sLoreta is the linearity of the transformation. The data are not distorted in the term of non-linearity, which is important for subsequent analyses.

3 Viewer of sLoreta output files in Matlab

The sLoreta software contains a viewer of computed sLoreta slices but there was a need of developing a viewer of the files in Matlab. The main advantage is direct connection to calculations performed in Matlab environment, a possibility to automatic displaying of slices in desired points, for instance local maximum and minimum, maximal mean activity through all time frames, or focusing on activity in a region of interest (ROI). Another feature is easy adjustment of color legend. Although sLoreta enables settings of color legend like the common scale for all the slices in the record, the settings can be adjusted in accordance with actual analysis requirement in the Matlab viewer. As an example, a principal component analysis (PCA) output, discussed later in this paper, contains both positive and negative values. The yellow signalizes positive values, the blue ones are negative. More close to zero, more dark color, yielding the black color for zero activity (Fig. 1). We can easily display the desired slices of brain and continue with following computations in Matlab without the need of use of any external programs.

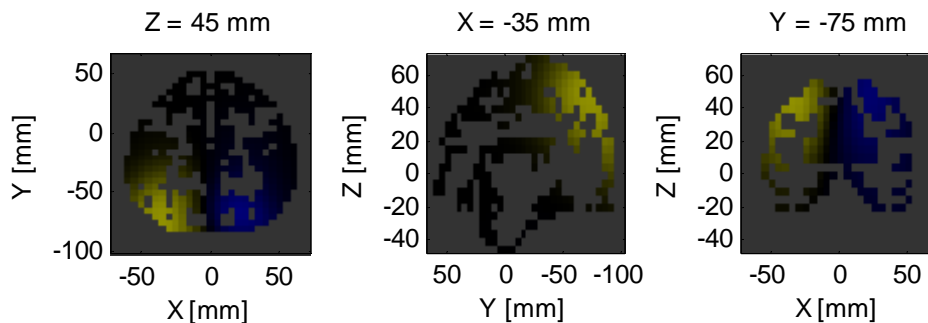


Figure 1: Viewer of sLoreta output files in Matlab: transversal, sagittal and coronary slice, Talairach coordinates are displayed. sLoreta voxels do not cover the brain continuously.

4 Region of interest selection

For subsequent processing of the tomographic EEG (loreta slices), like an analysis of relations among the active centres, there is a need of convenient algorithm of region of interests (ROI) selection. The question is how to choose the certain areas from original 6239 voxels, which will be then processed in next steps.

4.1 Local maxima of mean activity selection

Each value of every voxel in a time moment represents a power of current density in the volume. The idea of this method is selection of mid-points of active centres as local maxima of mean activity of all time samples in the measurement. The data matrix contains a set of time frames of activity of all 6239 voxels. By calculation of mean values of each voxel, a basic representation of activity distribution is obtained (Fig 2.). The important fact is the voxel indexes are sorted in layers, therefore close voxels can have a large difference in index. Coordinates of each voxel are stored in a text file, a Matlab function for converting the index into the coordinates was created and Euclidean distances are computed.

The minimal desired distance among the mid-points of centres is chosen, because although sLoreta divides the brain into the 6239 voxels, thanks to the small number of electrodes the resolution cannot be so detailed and it is obvious, that two highly active adjacent voxels are the part of one centre of activity. The estimated minimum distinguishable diameter of ROI is approximately 2 cm, it is reasonable to choose this value as the minimal distance. Next parameter is the total number of centres. The algorithm finds the voxel with global maximum of mean activity value in the first step. Then it sets the zero value to all voxels in the neighbourhood of chosen minimal distance, which yields to exclusion of all voxels falling into the same centre in following steps. After that, a new voxel with global maximum of mean activity is found and the process repeats until the total number of centres is

selected. This algorithm assures the minimal distance of local maxima voxels. The final ROIs are constructed as group of all voxels in the selected distance from the centre voxel (Fig. 3).

The advantage of this procedure is spreading the network of ROI all over the brain based on the activity, on the other hand the algorithm is manipulating with data without any understanding of relations of signals among the voxels. That is why it is suitable as an interlink between sLoreta and a following statistic method for future data processing.

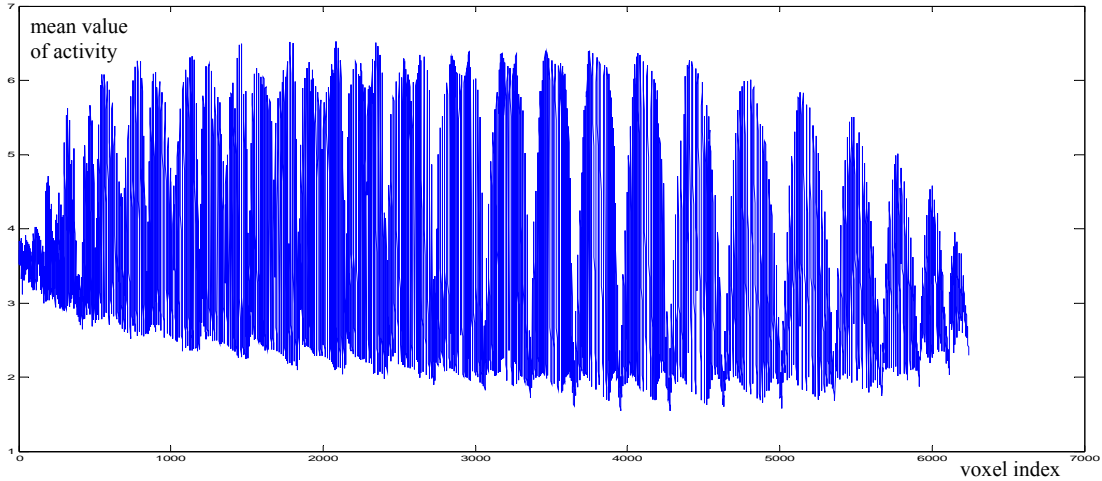


Figure 2: Mean value of activity for each voxel

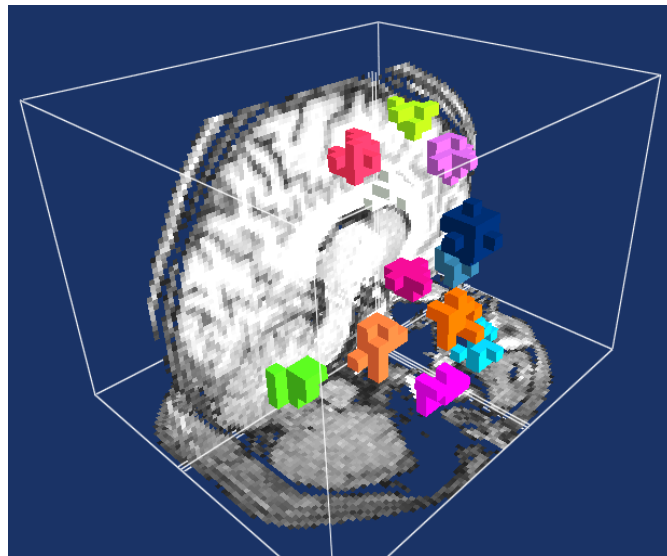


Figure 3: Demonstration of 12 ROIs automatically selected as local maxima of mean activity in BrainGain 3D viewer

4.2 Principal Component Analysis

Principal component analysis (PCA) represented in Statistics Toolbox in Matlab by the function *princomp* [6] performs a decomposition of input data matrix x into the principal component matrix $coeff$ and a representation of these data in the principal component space $score$

$$x = score \cdot coeff^{-1} = score \cdot coeff^T, \quad (1)$$

rows of x correspond to n time samples, columns to p voxels, rows of component matrix $coeff$ corresponds to p voxels and columns to p components, rows of matrix $score$ corresponds to n time samples and columns p to components.

PCA performs the decomposition on the basis of eigen vectors of covariance matrix x . The first component covers as much of the variability in the data as possible, each succeeding component accounts for as much of the remaining variability as possible [7]. All components are orthogonal and uncorrelated. PCA finds for each component a map of voxels which can represent an active centre of brain function. The *princomp* function returns optional parameter *latent* with principal component

variances, determining the amount of information covered. This allows a selection of the most strong components convenient for subsequent function connection analysis. On the figure 1, a demonstration of one of such components is displayed in Matlab viewer.

5 Conclusion

PCA seems to be the suitable method for separating the uncorrelated regions. Automatic selection of local mean activity maxima can also be a useful method for initial distributing of ROI network through the brain space for subsequent statistic analysis. The viewer of sLoreta output files was created in Matlab. Missing parts in the chain of compact environment of EEG signal processing from the EEG data measurement to ROIs selection were created.

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