ANALYSIS OF BIG DATA IN NEUROSCIENCE

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Abstract

A new method for the analysis and localization of brain activity has been developed, based on multichannel magnetic field recordings, over minutes, superimposed on the MRI of the individual. Here, a high-resolution Fourier Transform is obtained over the entire recording period, leading to a detailed multi-frequency spectrum. Further analysis implements a total decomposition of the frequency components into functionally invariant entities, each having an invariant field pattern localizable in recording space. The method, addressed as functional tomography, makes it possible to find the distribution of magnetic field sources in space. Here, the method is applied to recordings of spontaneous brain activity in ten healthy adults. The method successfully provides an overall view of brain electrical activity, a detailed spectral description and the localization of sources in anatomical brain space.

Keywords: magnetic encephalography, functional tomography, inverse problem solution, alpha rhythm

Big Data Analysis

Modern scientific studies are performed by means of new powerful equipment, generating large amounts of detailed data. Magnetic encephalography (MEG) provides an example of a foremost biological technology, comparable with the most sophisticated physical devices. Magnetic encephalographs register magnetic field in hundreds of channels with sampling frequency up to several thousand Hertz. Typical 5 minutes’ experiment on the 275 channel device with sampling rate 1200 Hz, provides 100 million field values, so the problem of big data analysis appears a pressing challenge in the MEG technique (see Fig.1).

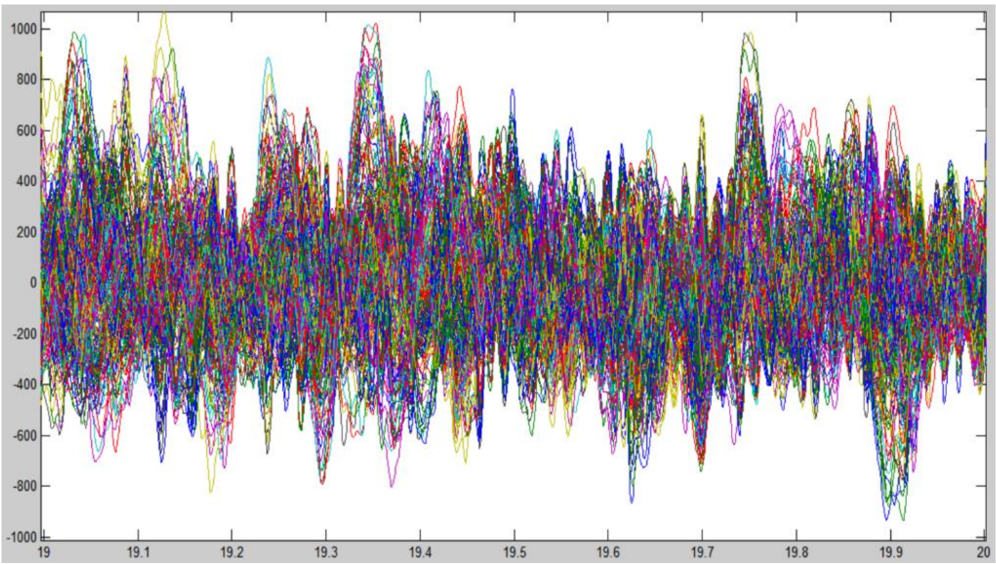

Figure 1. One second of the raw MEG in 275 channels.

Many approaches are used to solve various scientific and diagnostic problems of encephalography. Fourier analysis in many implementations can be called the oldest and the most popular of methods used for the brain data analysis. Through the whole history of this method it was connected with difficulties of calculations, so the development of the Fast Fourier Transform (FFT) dramatically advanced the application of the Fourier analysis in many fields, including brain research. Usually in applications of the Fourier analysis to brain studies the spectra are calculated in short (<10 second) time windows, based on the well-known property of instability of the brain processes. Typically brain studies register activity in many channels simultaneously for protracted time periods (up to tens of minutes in hundreds of channels). Those registered data are usually processed with two important methodological weaknesses: First weakness is that in time dependence analysis the methods are applied, which were developed for the solitary time series, multichannel recordings are implemented mainly to attempt inverse problem solutions. The second weakness lies in the usage of short time windows (less than ten seconds), decreasing the resolution of the Fourier transform. Recently the method of precise frequency-pattern analysis to decompose complex systems into functionally invariant entities was proposed [1-3]. The method is based on the complete utilization of the long-time series, while the multichannel nature of the data is also completely taken into account, making it possible to implement detailed reconstruction of neuronal circuit activity.

The multichannel Fourier transform calculates a set of spectra for registered functions (see Fig.2). All spectra are calculated for the whole registration time *T*, which is sufficient to reveal the detailed frequency structure of the system. The step in frequency is equal to 1/*T*, thus frequency resolution is determined by the recording time.

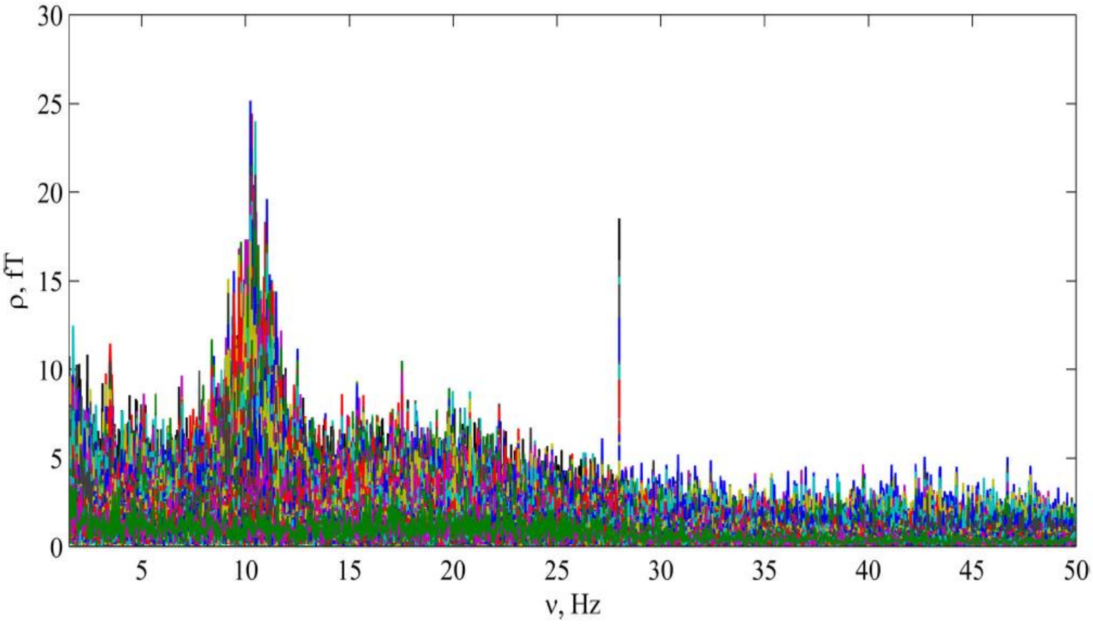

Figure 2. The multichannel spectrum contains 15000 frequencies for five-minutes experiment.

The next step of the analysis is to reconstruct time series at each frequency, to extract coherent oscillations and to calculate the magnetic field pattern for those oscillations. Then the inverse problem is solved for each pattern and the solutions are distributed in space, thus providing a functional tomogram of the brain.

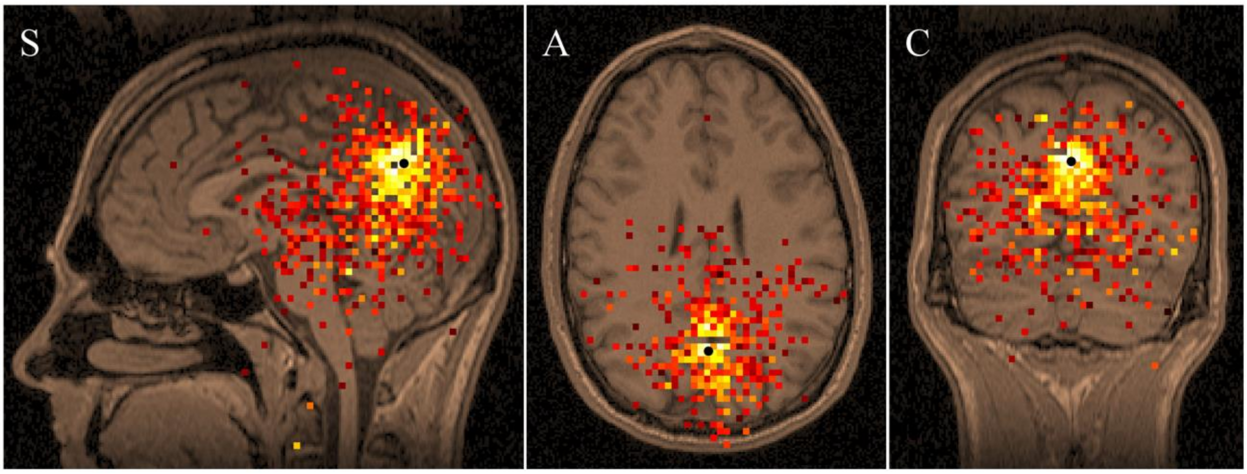

Figure 3. Functional tomogram of the average alpha-rhythm activity of ten subjects, shown over the MRI.

Functional tomograms were obtained for alpha rhythm from multichannel MEG data. These functional tomograms demonstrate individual variances of the power spatial distribution, generally corresponding to our present knowledge concerning the alpha rhythm localization in the occipital and posterior parietal lobes (see Fig.3). It can be concluded, therefore, that the functional tomography method, based on magnetic-encephalograms analysis, can determine spontaneous brain activity sources.

A fundamental advantage of this framework lies in the fact, that all recorded data is fully utilized.

Method of functional tomography can be applied to the diagnostics of activity in the whole brain and in broad frequency band, revealing areas of abnormally high or abnormally low activity.

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References

1. Llinás R.R., Ustinin M.N. *Precise Frequency-Pattern Analysis to Decompose Complex Systems into Functionally Invariant Entities*: U.S. Patent. US Patent App. Publ. 20160012011 A1. 01/14/2016.

2. Llinás R.R., Ustinin M.N., Rykunov S.D., Boyko A.I., Sychev V.V., Walton K.D., Rabello G.M., Garcia J. Reconstruction of human brain spontaneous activity based on frequency-pattern analysis of magnetoencephalography data // *Front. Neurosci.,* Vol. 9, oct 2015.

3. Llinás R.R., Ustinin M.N. Frequency-pattern functional tomography of magnetoencephalography data allows new approach to the study of human brain organization. *Front. Neural Circuits*. *2014. V. 8. P. 43.*