EEG Dipole Source Localization

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Introduction

Sources of electromagnetic field, which is a result of neurons activity in a human brain, can be approximate by current dipoles. For the investigation of a human brain as well as for diagnostic of some illness it is necessary to know the location and value of moment of these dipoles. This study is concerned with the analysis of an electroencephalogram (EEG) in order to find the parameters of the dipole sources. Robust and quick algorithm is proposed.

Theory

The solution of localization problem consists of two steps.

At first it is necessary to choose a model of the head, number of current dipoles and to find relation between dipoles and a potential on the surface of the model. The simplest model — homogeneous sphere, has been chosen in this work to satisfy requirement of quickness of localization algorithm. The expression for relation between parameters of sources and the potential should have no singularity for sources lying in the sphere. This condition is fulfilled by expression by [1]:

$$V = \frac{\vec{j}}{4\pi\sigma}\left[\frac{\vec{x_0}-\vec{d_0}}{xd(1-\vec{x_0}\vec{d_0})}-\frac{2\vec{d}}{d^2}\right], \tag{1}$$

where $\vec{j}$ is moment of current dipole, σ conductivity, $\vec{x}$ vector from center of the sphere to the point on the surfaced at which V is calculated and $\vec{d}$ is vector from the point on the surface at which V is calculated to the dipole.

The second step is to find the best fit between the calculated field and the measured field. It could be done by the minimization of the sum:

$$S(p_1, p_2, \ldots, p_n) = \sum_{i=1}^{N}\left[V_i - V_i(\theta_i, \varphi_i, p_1, p_2, \ldots, p_n)\right]^2, \tag{2}$$

where V_i are measured potentials, $V_i(\ldots)$ are potentials obtained from the chosen model and θ_i, φ_i, p_i are parameters of the model.

This problem is non-linear and it have to be solved by non-linear minimization algorithm. Three algorithms were tested (Levenberg-Marquardt, simplex and genetic algorithm) and combined to create quick and robust algorithm. Flow diagram of suggested algorithm is on the figure 1: after data preparation, the space, where the dipole will be searched, is defined. This space is divided to small cubes forming a net. From nodes of the net the simplex algorithm estimating possibility of minimum of S (see eq.2) is started. N minimal value of S are selected and the Marquardt algorithm is started from these points. This algorithm finds minimum of S in specified space.

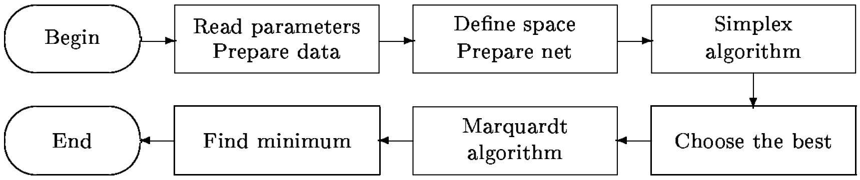

Fig.1: Flow diagram of suggested algorithm.

Results

Designed algorithm was tested on one and two dipoles spherical model. The ability to approximate measured data and robustness to find local minimum was verified on artificial and real data. Approximations (—) of real data (···) by one and two dipoles model are shown on figure 2 and 3 pictures.

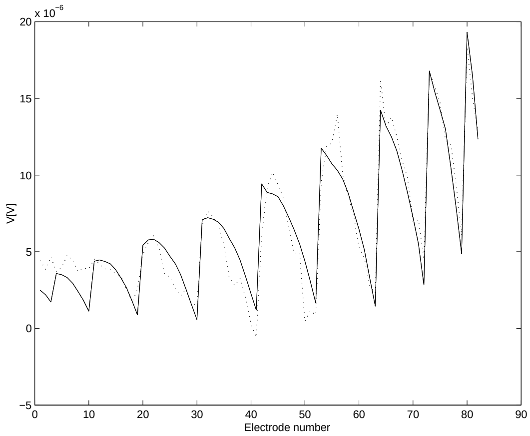

Fig.2: One dipole approximation.

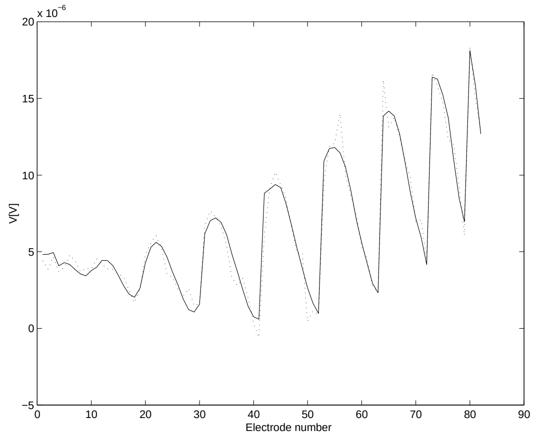

Fig.3: Two dipoles approximation.

The visual comparison of measured and computed potentials is not sufficient. There is another criterion to evaluate precision of localization — goodness of fit (GOF). GOF is commensurate with the power of a localization error and the highest value is 1. GOF about 0.996 was reached with mentioned model. This GOF implies statistical localization error for used methods about 2cm [1]. This localization error consists of three main errors: error caused by inaccurate measuring of electrodes coordinates, error caused by interferences from others sources and error caused by using inaccurate model of the head.

This work should be extend to find the possibility of using more sophisticated model of the head. Another improvement could be reached by using maximum likelihood estimation instead of least square minimization to reduce influence of non-correlated noise caused by interferences.

References

[1] Fender, D. H.: *Source Localization of Brain Electrical Activity*, Method of Analysis of Brain Electrical and Magnetic Signals, EEG Handbook (Gevins, A.S., Rémond, A. eds.), Elsevier, 1987

[2] Ingerle, J.: *Rekonstrukce zdroje EEG aktivity na sférickém modelu hlavy*, Ing. thesis, CTU FEE, 2000