Fitting a thalamo-cortical model to EEG power spectrum using evolutionary algorithms

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Mathematical modeling is a powerful tool that enables researchers to understand the mechanisms underling biological systems. A successful model formulation that allows us to unravel the dynamic properties of a complex system should be able to reproduce the observed specific features in experimental data. In general a model output depends on the model parameters, and reproducing experimental measurements requires selecting a good set of unknown parameters. Nevertheless finding a set of model parameters that fits the recording data is a complex and exteremly difficult task. In the recent years, several optimization algorithms have been applied successfully in a wide range of scientific fields. It has been extensively demonstrated that minimizing the error between model output and the measured data as a nonlinear optimization task has solved the most of the parameter estimation problems [1]. However the problem of parameter estimation in the context of neural population modeling, which is well suited to reproduce the measured electroencephalogram (EEG) data, remains to be investigated. Instead of using different types of optimization methods, we have focused on evolutionary algorithms (EAs) that have been used successfully to assign the parameter values of various types of complex systems [2]. Moreover EAs require neither gradient information nor prior knowledge about the initial guesses for model parameters.

In this work we extend a recently developed cortical model [3,4] and study a neural population model of a single thalamo-cortical module consisting of three different populations of neurons, namely cortical excitatory neurons, thalamocortical relay neurons and inhibitory thalamic reticular neurons. We use EAs such as particle swarm optimization (PSO) and differential evolution (DE) algorithm to fit the thalamo-cortical model to power spectrum of measured EEG data over frontal and occipital head regions. It is shown that EAs can accurately estimate all of the independent model parameters and the model fits well the observed spectral features within the delta- and alpha-frequency bands. Although PSO and DE show comparable performance, PSO is more efficient to construct the confidence regions of the estimated parameters. Our findings demonstrate that choosing an appropriate fitness function plays an important role in the performance of the fitting techniques. In addition, the low dimensionality of the proposed thalamo-cortical model allows us to obtain some inequality conditions for the stability of the system. The results from of our study show that these analytical constrains improve the performance of the parameter estimation methods.

References

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