TOOL FOR SIMULATION OF CONNECTIVITY IN FMRI DATA

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Abstract: Software tool *connectivity_simulator*, designed for simulation of connectivity in fMRI data is introduced in this paper. In this tool two methods are implemented, dynamic causal modeling and Granger causal modeling. Both methods are used to estimate effective connectivity in fMRI data. The tool enables to compare these different methods. Knowledge of relations between results of these methods on simulated data enables to better understand effective connectivity estimated on real fMRI data.

Keywords: Dynamic causal modeling, Granger causal modeling, functional magnetic resonance imaging, connectivity, simulator

1. INTRODUCTION

Neuroscience is interdisciplinary field of science, integrating biology, engineering, physics, mathematics, medicine, etc. Dynamic progress occurred in neuroscience in last years. Great contribution was achieved through functional magnetic resonance imaging (fMRI). Data from this modality gives us the possibility to localize brain functions and to estimate the relations between individual brain regions. Software tool for creating simulated fMRI data and for analysis of connectivity in the data is introduced in this paper.

2. THEORY

Neuronal population is stimulated (visual, acoustic, etc.) during an fMRI experiment. Stimulated neurons are consuming energy, which has to be refilled by enhanced blood flow. Blood is containing diamagnetic deoxyhemoglobin and paramagnetic oxyhemoglobin. Ratio of these substances is acquired from fMRI measurement and represents blood oxygenation level dependence (BOLD) signal. The signal could be then processed in order to estimate connectivity in the brain.

2.1. CONNECTIVITY IN BRAIN

Connectivity in brain reflects connections between distinct brain areas. Brain area could be presented as single neuron, neuronal population or brain region. The term connectivity in brain has several different senses. There is anatomical, functional and effective connectivity [2].

Anatomical connectivity is expressing patterns of anatomical connections, physical connections between brain areas, without knowledge about real flow of information. Anatomical connectivity could be estimated by diffusion tensor imaging [2]. Functional connectivity is based on statistical methods. It is usually estimated as correlation or other statistical relation, without knowledge about real structural connections between brain areas [1, 2]. Effective connectivity shows causal effects of one brain region over another. This method is not fully explorative. To estimate effective connectivity is necessary to define model of interactions. The model of interactions represents information about existence of structural connections of selected brain areas [1, 2]. Connectivity has also its clinical importance. It could be potentially used as biomarker for some neurological diseases. Several studies used connectivity for discrimination between schizophrenic patients and healthy control [3] or for discrimination between patients with Alzheimer's disease and healthy control [4].

2.2. GRANGER CAUSAL MODELING

Granger causal modeling (GCM) could be used for modeling of effective connectivity. It is investigating causality in data using vector autoregressive modeling (VAR). Parameters of VAR model are estimated by solving linear regression problem [5]. GCM estimates G-causality and direction of the causality. G-causality between two time series is confirmed when the first time series significantly improves prediction of the second one in the VAR evaluation [6].

2.3. DYNAMIC CAUSAL MODELING

Dynamic causal modeling (DCM) is also used to estimate effective connectivity. Unlike other methods, DCM is based on relevant neurobiological model of dynamics of neural populations. Effective connectivity is estimated through expectation maximization algorithm solving differential equations of the model. [7]

3. TOOL FOR DATA SIMULATION

The purpose of this paper is to show simulation of fMRI data using DCM and GCM. This could be achieved by a tool – the *connectivity_simulator* – programmed in MATLAB. The tool is made for creating simulated fMRI data for more regions of interests using GCM or DCM. The relations between simulated data could be then expressed by effective connectivity. The input for the simulation is stimulation vector, representing fMRI experiment. The user also defines connectivity matrix, method and other parameters for creating simulated data. The connectivity matrix represents model of interactions (i.e. how region of interest influence another region). Rows are influenced regions, columns are influencing regions.

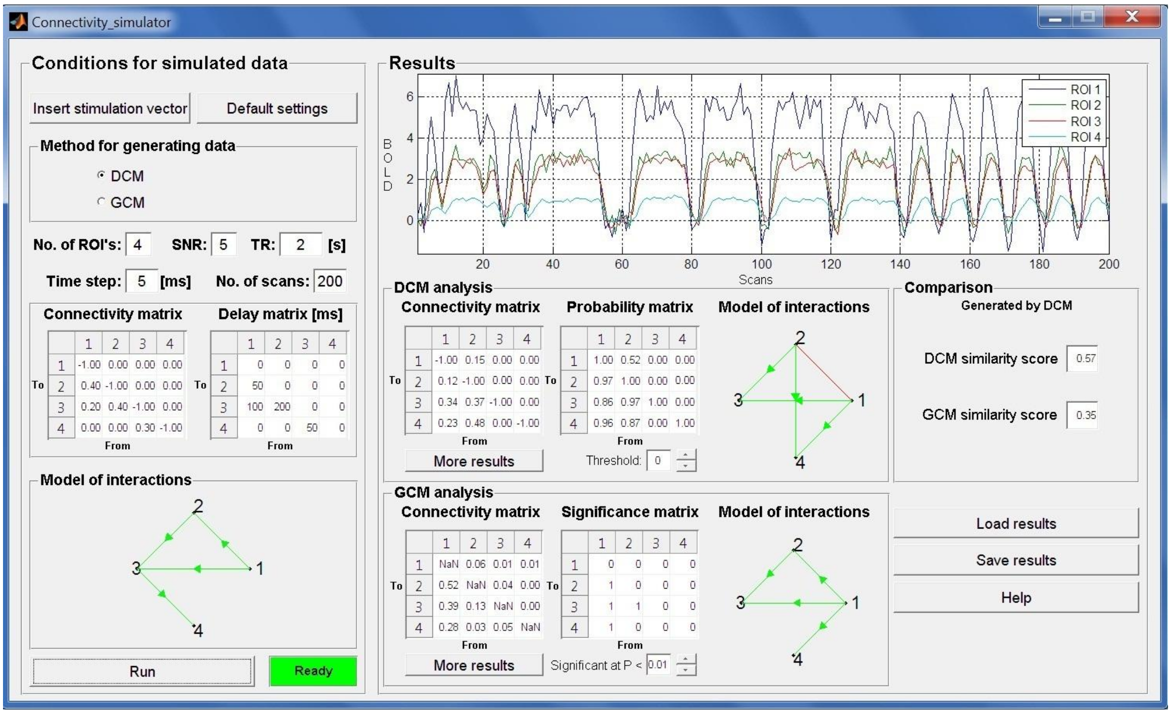

Figure 1: Graphical user interface of *connectivity_simulator*. The conditions for fMRI data simulation, defined by user, are displayed on the left. The results and other support buttons are situated on the right side of the interface.

Connectivity between two regions describes, how strongly is information transmitted from one region to another. The connection could be unidirectional or bidirectional. Unidirectional connection is plotted as green line with arrow in appropriate direction. Bidirectional connection is plotted as red line between the regions. MATLAB functions, involved in toolbox *Anil Seth Code* [6] are used for GCM simulations and estimations. For DCM simulations and estimations modified MATLAB functions from toolbox *SPM8* are used [8]. The graphical user interface is shown in figure 1. Products of *connectivity_simulator* are simulated fMRI data, evaluation of the data by DCM and GCM, data visualization and comparison. The visualization methods in this tool are designed to show different methods (DCM and GCM) as comparable as possible. To show differences between simulated signals the simulated data are plotted in one graph. Horizontal axis of this graph represents scans in seconds. Vertical axis is magnitude of BOLD signal. Differences between signals are not only shape and magnitude. The signals are also delayed in tens or hundreds milliseconds. This simulates delay of the information transmission between neuronal populations in the brain [2].

4. CONCLUSION

In this paper, the *connectivity_simulator* was introduced as a tool for analysis of connectivity in simulated fMRI data. The tool could be easily and user friendly used in MATLAB environment. It enables simulation and evaluation of fMRI data using two different models for estimating effective connectivity. *Connectivity_simulator* enables to reveal relations between GCM and DCM on simulated data. This is useful for better understanding the effective connectivity evaluated from real data. The basics of brain connectivity were described in the theory of this paper. Also basic description of GCM and DCM was mentioned. Connectivity can be used as biomarker for several neurological diseases. This is good motivation to improve methods for estimation of connectivity and to better understand the nature of neuronal system.

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