Artificial neural network predicts inter-areal functional connectivity

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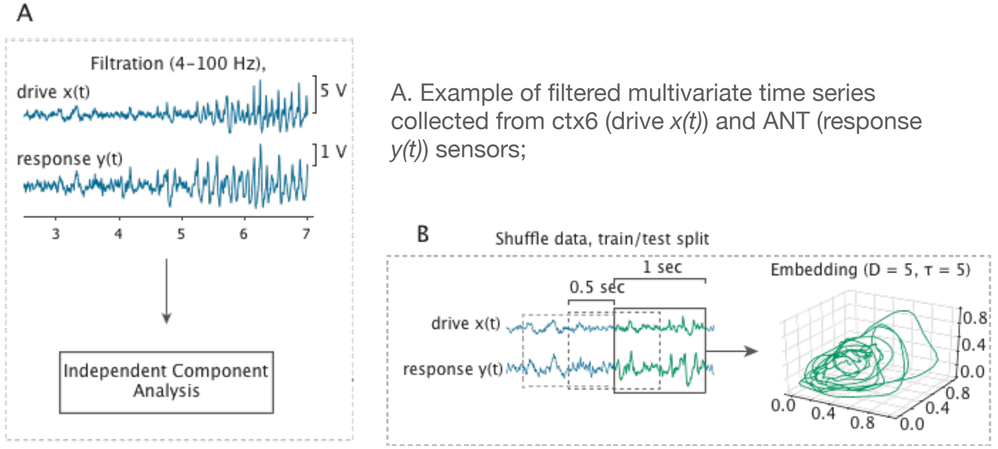
In present paper we introduce an extended machine-learning-based approach to detect inter-areal functional connectivity based on artificial neural network (ANN). We prove the efficiency of the proposed method by applying multilayer perceptron to find functional relations between the cortex and thalamus of the pathological WAG/Rij rats during the epileptic seizure based on the multivariate electrocorticography (ECoG) recordings. We show that the proposed algorithm is able to reconstruct the increased coupling within a thalamo-cortical network during the seizure versus a baseline activity



A. Example of filtered multivariate time series collected from ctx6 (drive *x(t)*) and ANT (response *y(t)*) sensors;

B. The training paradigm. The functional dependence between drive and response states was calculated in 1-sec window with 0.5-sec step. Each data segment was embedded, shuffled and splitted on training and validation sets.

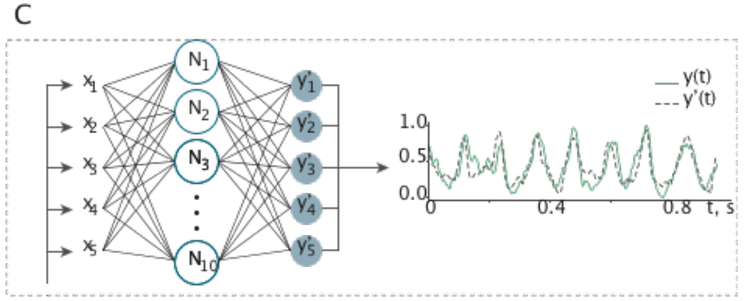
The training process was performed with the Adam optimizer (*learning rate* = 0.001). The MLP algorithm was implemented with the Keras library with Tensorflow backend developed in Python 3.4.

Functional dependence estimation

To evaluate the correlation between the original response data *y* and the prediction obtained via MLP, we used the R^2-score measure:

$$R^2 = 1 - \frac{\sum_{d=1}^{D} 1 \sum_{i=1}^{N} \left(y_d(t_i) - y'_d(t_i) \right)^2}{\sum_{d=1}^{D} 1 \sum_{i=1}^{N} \left(y_d(t_i) - \bar{y}_d \right)^2},$$

with *D* as a number of embedding dimensions, y'(t), y(t), and $\bar{y}(t)$ are *d*-th component of predicted and original time series and the mean value of the latter, respectively



C. Left panel: MLP model for calculation the prediction state *y'(t)*; right panel: an example of predicted state *y'(t)* and original target state *y(t)*.

Proposed method allowed to map the state of the response system based on the state of the drive system, which in our case are the SWD-signals collected from *ctx* and *thl* sensors of the epileptic rats' brain. Fig. C shows an example of the mapping y'(x) versus the original response time series y(x) corresponding to the absence seizure. The R^2-score for this trial was 0.79 confirming the established functional dependence.

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