

ANN-GC toolbox

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The Matlab toolbox allows to train and Artificial Neural Network with one input layer and one output used for the solution of linear regression problems through Stochastic gradient descent l_1 algorithm (SGD- l_1). Then by exploiting the state (SS) models it is possible to compute conditional and unconditional Granger causality (GC) [1]-[2]-[3].

[1]-Antonacci, Y.; Minati, L.; Faes L.; Pernice R.; Nollo G.; J.Toppi, A.Pietrabissa; Astolfi L.; Estimation of Granger causality through Artificial Neural Networks: applications to physiological systems and chaotic electronic oscillators, PeerJ Computer Science 2020, sub.

[2]-Faes, L.; Marinazzo, D.; Stramaglia, S. Multiscale information decomposition: Exact computation for multivariate Gaussian processes. Entropy 2017, 19, 408.

[3]-Barnett, L.; Seth, A.K. Granger causality for state-space models. Phys. Rev. E 2015, 91, 040101.

The code is provided free of charge. It is neither exhaustively tested nor particularly well documented. The authors accept no liability for its use. Use, modification and redistribution of the code is allowed in any way users see fit. Authors ask only that authorship is acknowledged and ref. [1]-[2] is cited upon utilization of the code in integral or partial form. To get started, we recommend that you run and work through the two demonstration scripts.

Demonstration scripts

test_simulation - Performs VAR identification with OLS and ANN and computes conditional GC (pairwise conditional Granger Causality) for a 5-variate process (TimeSeries.mat) with the methodology described in Sim I [1]. Due to the high computational time required, the analysis is restricted to a 5-variate process.

TestSimulationIII - Performs VAR identification with OLS and ANN and computes conditional GC (pairwise conditional Granger Causality) for a 10-variate

process generated as described in [1] (Simulation study III).

test_application - Performs the VAR identification with OLS and ANN and analyze brain-body interactions during stressful task, according to the application of physiological networks (TimeSeriesStress). Note that the analysis was reduced to one single subject due to the high computational time required for the entire procedure.

Test_oscillators - Performs all the analysis for computing the cross-correlation analysis of Figure 11 and the following analysis for the computation of unconditional GC on the entire ring of 32 chaotic oscillators.

Functions

GCV_ANN - estimation of λ_{opt} with Generalized Cross-Validation criterion as described in the Methods section

training_SGD_L1 - training of the neural network through the SGD- l_1 algorithm

cGCsurrogate - performs the evaluation of null distribution for conditional GC values with Iterative Adjusted Fourier Transform (IAAFT). Includes surriaafft and surrshuf for its purpose

covariance_residual - compute the covariance matrix for the residuals of estimation

Create_Input_Output - create the matrix of inputs and outputs for the ANN

Create_train_test_sets - from Input and Output matrices splits by an hold out approach in train and test sets.

Predict_output - From the matrix of the weights and the matrix of outputs predict the output of the ANN

idMVAR - identification of a VAR model with OLS

varma2iss - Compute parameters of an innovations form state space model from the parameters of the equivalent vector ARMA model

iss_PCOV - Calculate partial variances from the innovations form state space parameters

ss2iss - Compute innovations form parameters for a general state space model by solution of a discrete algebraic Riccati equation (DARE)

var_to_tsdata - Generate random Gaussian VAR time series, even multi-trial

plot_pw -plot conditional GC networks containing causal relationships

suptitle -adds text to the top of the figure

knee_pt - find the knee in a curve

NOTE:

- ss2iss function is taken from the State-Space Granger Causality Matlab Toolbox - <http://users.sussex.ac.uk/~lionelb/downloads/ssgc.zip>
- var_to_tsdata function is taken from MVGC Matlab Toolbox - <https://users.sussex.ac.uk/~lionelb/MVGC/>
- idMVAR, iss_PCOV, varma2iss are taken from the Matlab Tool for multiscale Information Decomposition <http://www.lucafaes.net/msID.html>
- plot_pw is taken from multivariate Granger Causality Matlab toolbox - <http://www.sussex.ac.uk/sackler/mvgc/>
- knee_pt was created by Dmitry Kaplan and can be redistributed without modifications (license in attachment)
- the code used for the implementation of SGD- l_1 (training_SGD_L1) is inspired from TensorFlow Neural Networks Playground for MatLab

<https://github.com/StackOverflowMATLABchat/NeuralNetPlayground>

Dataset description

- top_row.mat and top_row.csv include the signals produced by the 32 electronic oscillators measured over time.
- TimeSeriesStress.mat is a three-dimensional matrix including the seven synchronized times series of 300 time points in the three experimental conditions as described in the Application of Physiological Time series section of the main document. The same is reported in the csv files for each experimental condition (REST.csv, MENT.csv and GAME.csv).
- TimeSeries.mat is two-dimensional matrix reporting 1500 time points for 5 different process used for the test_simulation script and the matrix of theoretical AR coefficients with an optimal order equal to 3. The same are reported in two different csv files: Y.csv for the time series and Am.csv for the AR coefficients.

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