# 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,: 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.



**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.

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 $\lambda_{opt}$ 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

covarinace_residual - compute the covariance matrix for the residuals of estimation

Create_Input_Output - create the matrix of inputs and outupts 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)

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
- 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 toolboox - 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

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