

User Guide

M**ULTIPLE C**ON**N**ECTIVITY A**N**ALYSIS (MULAN) **A MATLAB TOOLBOX** **MULAN 1: EVALUATION**



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Reference paper: **A systematic framework for functional connectivity measures**, submitted to Frontiers in NEUROSCIENCE

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1. INTRODUCTION

The MULAN (MULtiple connectivity ANalysis) MATLAB toolbox helps researchers to evaluate connectivity analysis methods in a systematic way. Prior to applying specific methods to a given dataset, MULAN can be used to generate relevant simulated signals, identify valid parameter ranges for the methods, and evaluate their performance and robustness against underlying connection strengths, graph structures and noise levels. Lastly, new methods can easily be added and tested using this toolbox.

This user guide describes the usage of the MULAN interface as well as using a compute cluster to perform the computations.

1.1. MULAN 1 Environment.

MULAN 1 has been tested on three versions of Matlab: MATLAB 7.10.0.499 (R2010a) 64-bit (maci64) for Mac OS X, MATLAB 7.13.0.564 (R2011b) 64-bit (glnxa64) for Linux, MATLAB 7.10.0.499 (R2010a) 64-bit (win64) for Windows.

1.2. MULAN setup.

To begin using MULAN, just place the MULAN1 files in any accessible folder on your computer and make sure to either set the MULAN1 folder as the current path in MATLAB or add the folder containing MULAN1 to the MATLAB path.

2. MULAN INTERFACE

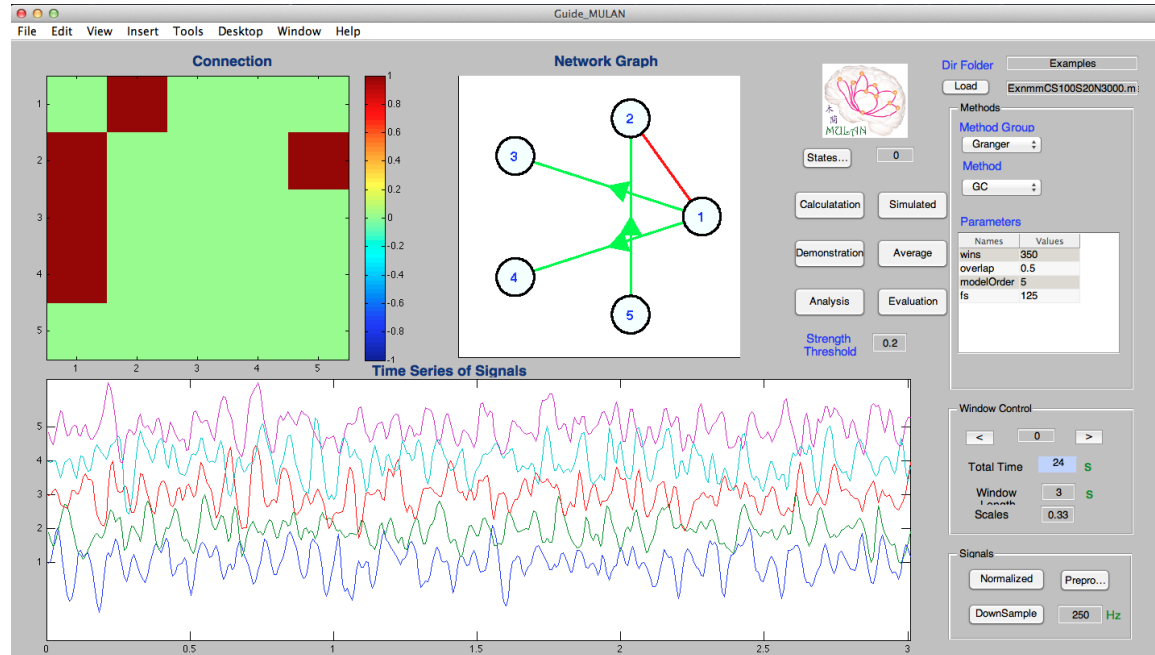


Figure 1 | The interactive graphic user interface (GUI) of MULAN1. In this GUI, the top panels are the connection matrix and network graph, which are the results from given methods and parameters set by the Methods panel. The time series of signals of the given dataset (bottom) can be set by the window control panel.

Start MULAN by two simple options.

Option 1: : Just type "Guide.MULAN" at the Matlab command line and hit enter.

Option 2: : Open file Guide.MULAN.m in MULAN folder, then click the button RUN.

2.1. Simulated data.

If we want to generate the simulated data, please click **Simulated** button.

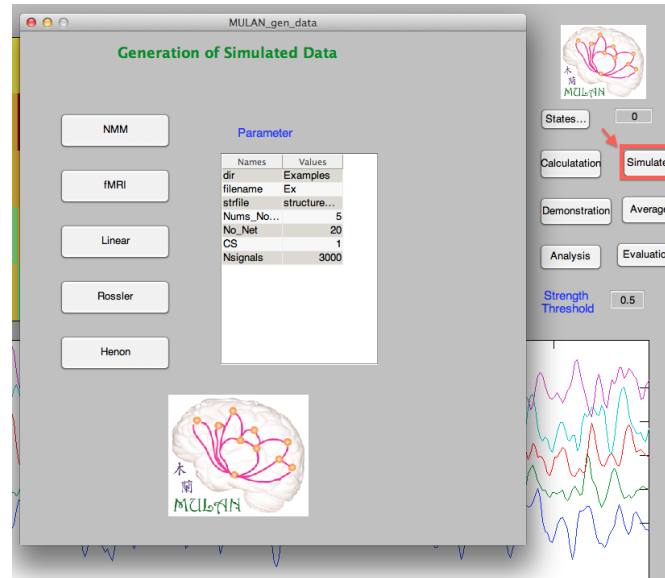


Figure 2 | Generation of Simulated Data.

The parameters which we can choose are:

- dir : the folder which are used to store the results.
- filename : the base name you choose; the software will add more details on the filenames of each dataset. For example, 'nmm' for model type, CS for connection strength.
- strfile : the structure file which stores the information about underlying structures.
- Nums_Node : The numbers of nodes for the datasets
- CS : The connection strengths
- Nsignals : The lengths of signals which you would like to generate.

Then choose the types of models listed on the left, for example, click **NMM** button to generate NMM datasets. There is the message dialog to inform you if it has finish successfully or not.

2.2. Setting Panels.

First we need to specify the following terms, ref to Fig. 3.

Dir Folder : We put the folder name that has the data file we are about to analyze.

File name : We put the file name in which data stores. Put the name of data file and then click **Load** button.

Method Group : We need choose the method family which we want to use.

Method : We can specify a method from a specified family. We use Granger family as an example in Fig. 3. A methods list on the right provides the abbreviation and corresponding notations about the methods.

Parameters : Once we've chosen the method family, the parameters which need to be specified will be listed in a table.

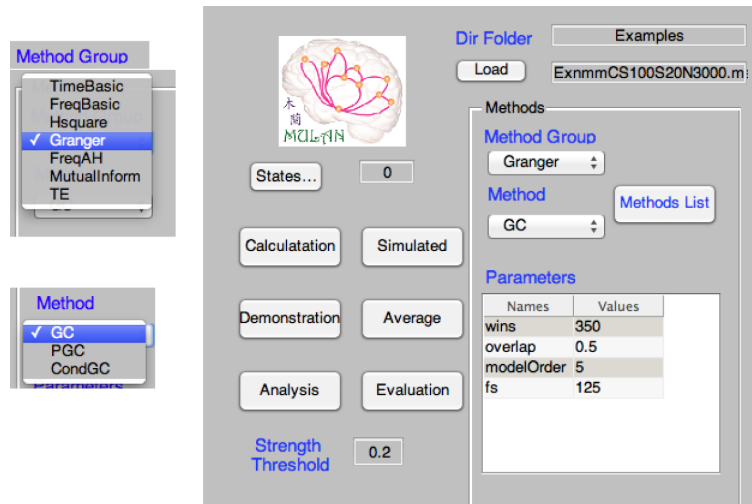


Figure 3 | setting Panels

2.3. Methods list.

Table 1 | Abbreviation and notations of the connectivity analysis methods. Please refer to the submitted paper for the mathematical definitions.

Abbr.	Notations	Abbr.	Notations
Correlation			
BCorrU	Bivariate correlation undirected	PCorrU	Partial correlation undirected
BCorrD	Bivariate correlation directed	PCorrD	Partial correlation directed
h^2			
Bh ² U	Bivariate h^2 undirected	Ph ² U	Partial h^2 undirected
Bh ² D	Bivariate h^2 directed	Ph ² D	Partial h^2 directed
Mutual Information			
BMITU	Bivariate mutual information undirected	PMITU	Partial mutual information undirected
BMITD1	Bivariate mutual information directed 1	PMITD1	Partial mutual information directed 1
BMITD2	Bivariate mutual information directed 2	PMITD2	Partial mutual information directed 2
Coherence			
BCohF	Bivariate Fourier transforms	PCohF	Partial Fourier transforms
BCohW	Bivariate wavelet transforms	PCohW	Partial wavelet transforms
Granger family			
GC	Granger causality	PGC	Partial Granger causality
CondGC	Conditional Granger causality		
Transfer Entropy			
BTEU	Bivariate transfer entropy undirected	PTEU	Partial transfer entropy undirected
BTED	Bivariate transfer entropy directed	PTED	Partial transfer entropy directed
\mathcal{AH}			
Af	\bar{A} in the frequency domain	hmvar	\mathcal{H} in the frequency domain
PDC	Partial directed coherence	DTF	Directed transfer function
PDCF	Partial directed coherence factor	DC	Directed coherence
GPDC	Generalized partial directed coherence	ffDTF	Full frequency directed transfer function
GGC	Gewekes Granger Causality	dDTF	Direct directed transfer function
PCOH1	Partial ordinary coherence 1	COH1	Ordinary coherence 1
PCOH2	Partial ordinary coherence 2	COH2	Ordinary coherence 2
MAVR	\bar{A} in the time domain	Smvar	Power Spectrum
AS	\bar{A} square		

2.4. Calculation of connection matrices. (Fig. 4).

- (1) After specifying the data file, method and calculation parameters, click the button **Calculation**.
- (2) Once the calculation finishes, the message dialog will pop up to inform you that the calculation completed.
- (3) Then you will find your results in the same folder of the data with a subfolder **Results**, which will allow you to access your results afterward so that you can save calculation time when the method parameters are the same.

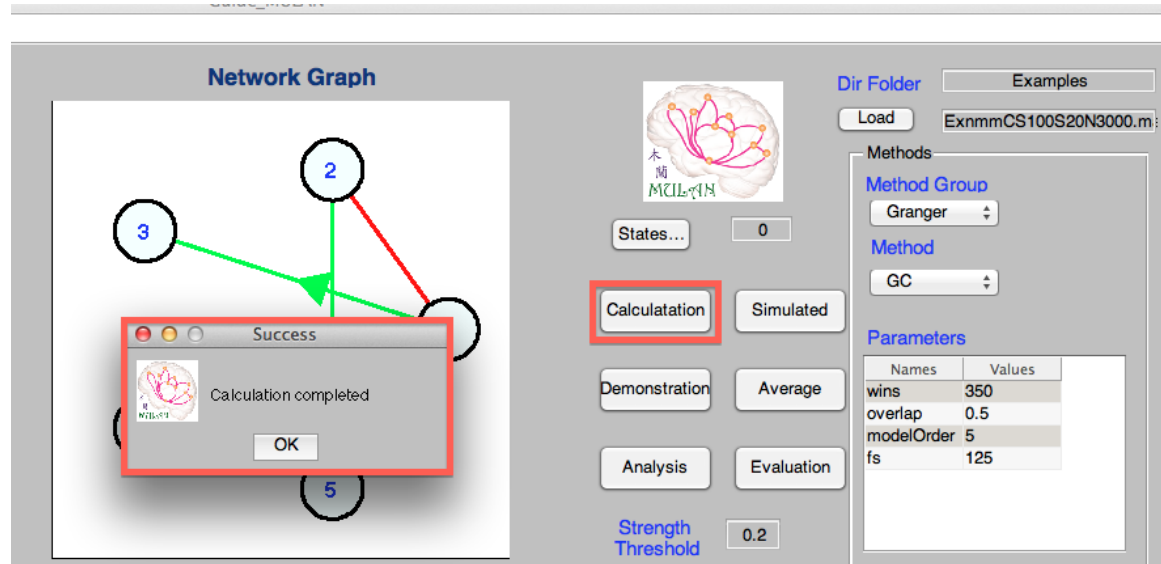


Figure 4 | Calculation of the computed connection matrices by choosing Methods and Parameters

2.5. Demonstration of the results.

After calculation of the computed connection matrices, the results can be visualized (Fig.5):

- Step 1 Choose the **threshold** of connection strength in $[0, 1]$.
- Step 2 Click the button **Demonstration** will show the connection matrix and graph corresponding to the data segment during the current windows.
- Step 3 Choose current data segment by directly inputting the current start time point, or by clicking **backward/forward** buttons.
- Step 4 The three windows, Connection, Network Graph and time-series of signals, will change accordingly.

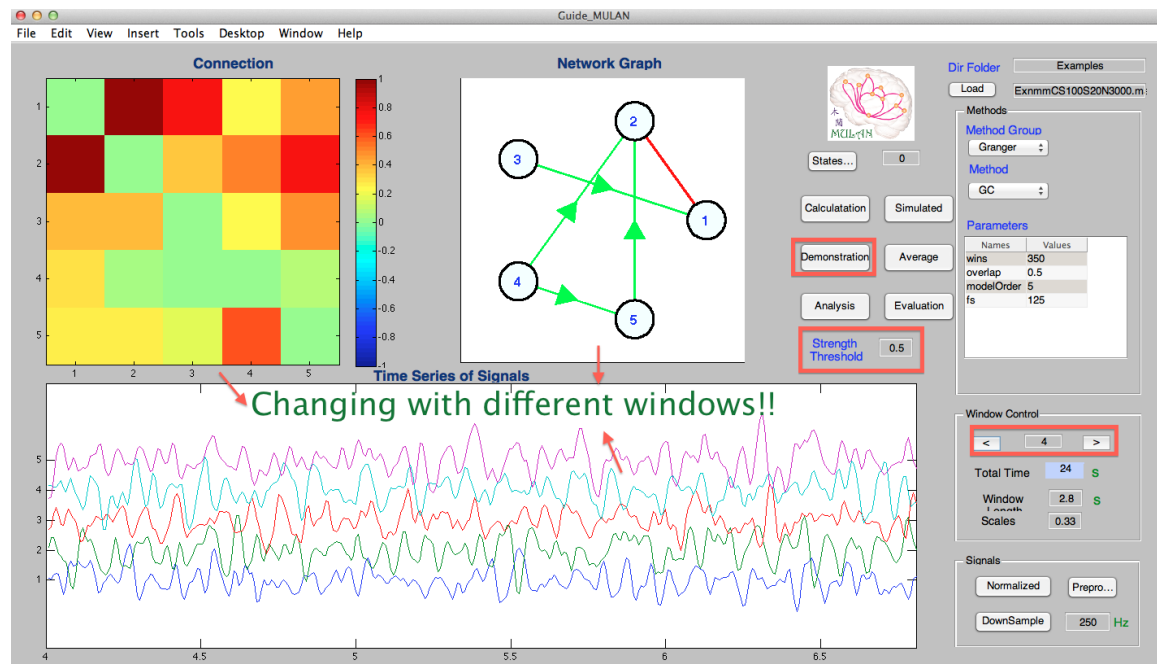


Figure 5 | Demonstration of the results.

2.6. Demonstration of average results.

As we suggested in the paper, the average value is more stable than the results from a single window. In order to view average results over the whole dataset, please click the button **Average** (Fig.6).

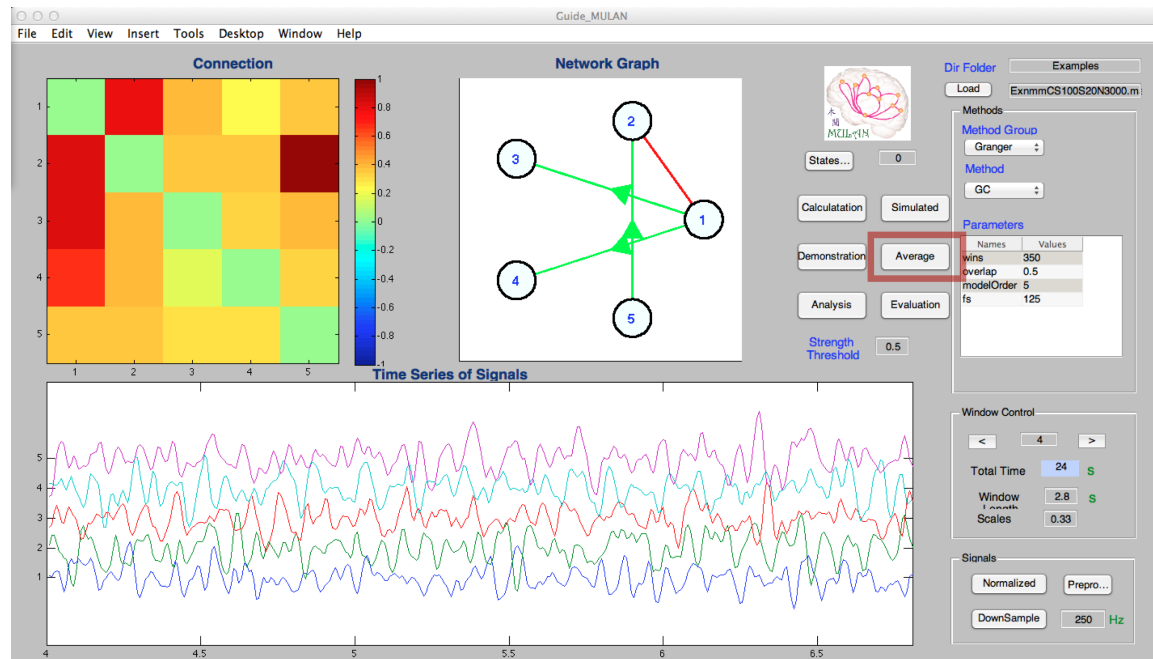


Figure 6 | Demonstration of the results.

2.7. Detailed analyses.

MULAN can provide detailed results by clicking button **Analysis**. A pop-up figure describes the connectivity strengths between the pairs of channels as function of windows shown in blue and average value over all windows shown in purple, as shown in Fig. 7.

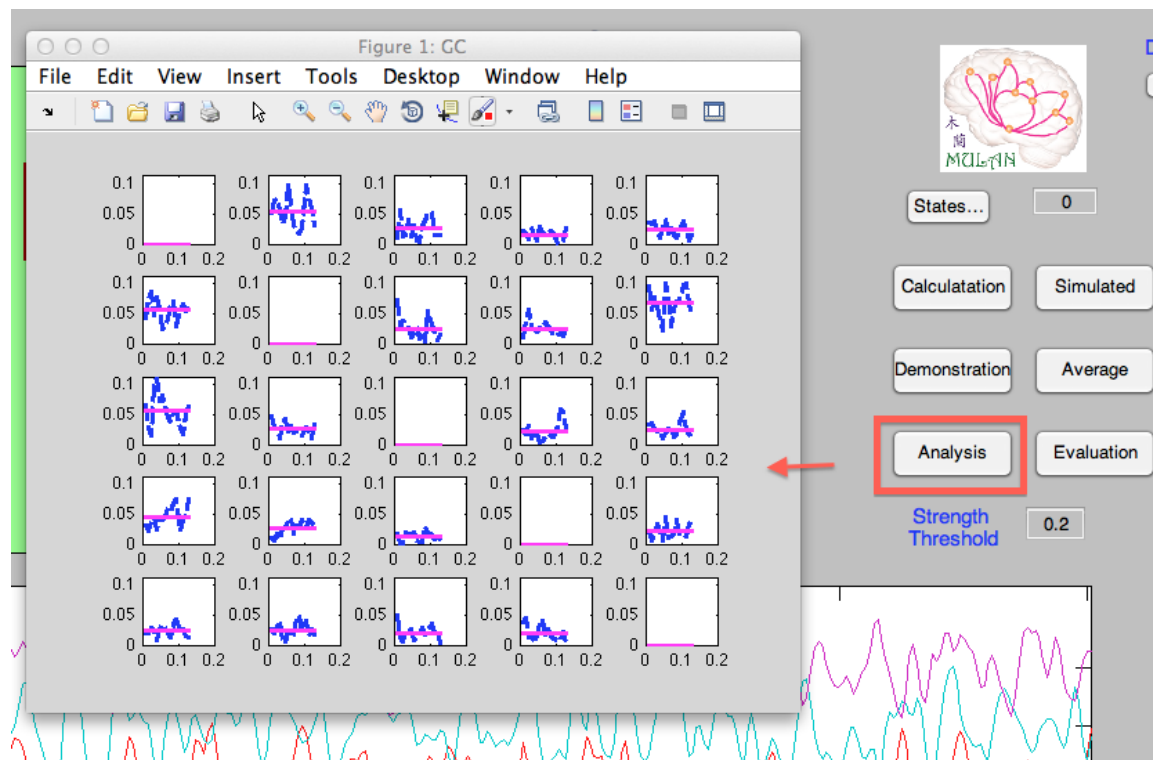


Figure 7 | Detail results on all windows.

2.8. Evaluation of methods.

Click the button **Evaluation** to bring up a figure displaying evaluation results of methods. Note that the **Evaluation** button only works in the cases of known ground truth structures. Please refer to Fig. 8.

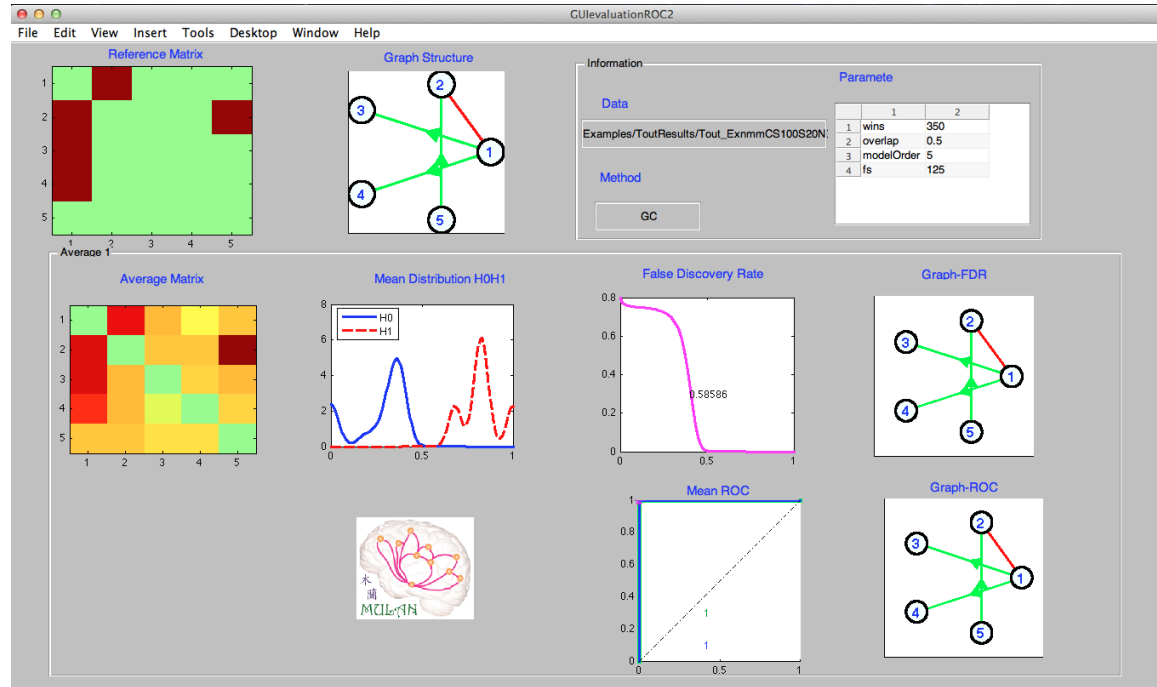


Figure 8 | Evaluation of results from Granger causality.

Fig. 8 contains the results about *average matrix*, H_0/H_1 distributions, the *false discovery rate (FDR)* and the *receiver operating characteristic (ROC)*. Two graphs, to the right of FDR and ROC, are shown by choosing thresholds from two ways: 1) From FDR where $FDR=0$, 2) From ROC where the optimal threshold corresponds to the point closest to the upper left corner.

3. MULAN CLUSTER COMPUTING

3.1. Calculation.

This section helps users to test their connectivity analysis methods or results systematically, e.g. when applying all methods with different parameters on the different datasets in batch.

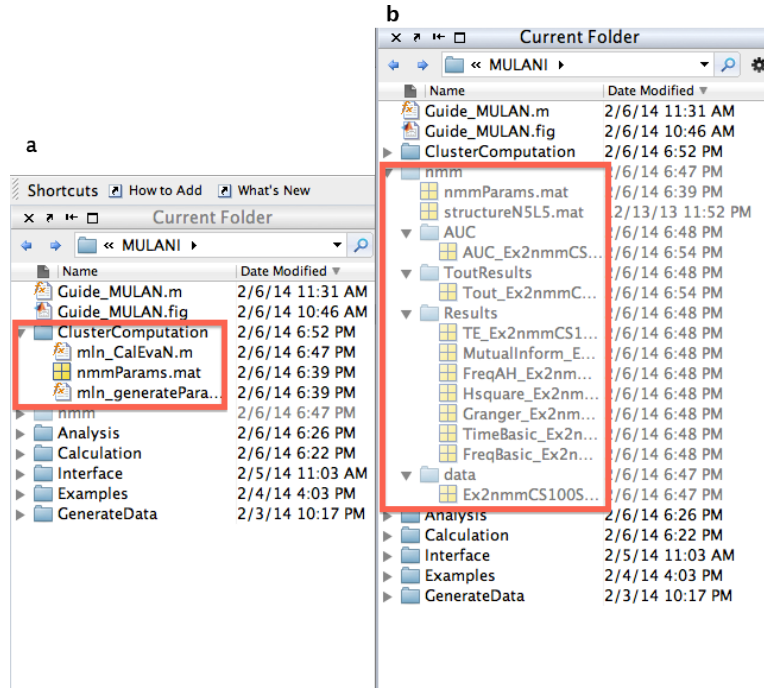


Figure 9 | Evaluation of results from Granger causality.

A demo function is called *mln_CalEvaN.m* which you can find it in the folder '*MULAN1/ClusterComputation/*', shown as in Fig.9(a). This function can generate the datasets, calculate the connection strengths by using all given connectivity analysis methods and calculate the AUC (area under curve) value of ROC (Receiver operating characteristic).

The result files from this function will be found in a given folder name which has four subfolders: 1) */data* for datasets 2) */Results* for the different methods, 3) */TOUTResults* for all results in one file and 4) */AUC* for the AUC results, as shown in Fig.9(b).

APPENDIX A. MULAN DATA STRUCTURES

This section describes how to set the data structures of the datasets.

Please refer to the structures of the example dataset as an example:

`'/MULAN1/Examples/data/ExnmmCS100S20N3000.mat'`. Data structures:

- `lfp(Obligation)`: $nchannel \times timeseries$ double. $nchannel$ is the number of signal channels.
- `Params(Obligation)`: structure
 - `fs (Obligation)`: sample frequency
 - `str(Optional)`: $1 \times nchannel$ list of the names of the channels. If this field does not exist or is empty, the names will be numbered.
- `Connectivity(Optional)`: $nchannel \times nchannel$ double $M_{i,j}$. The value $M_{i,j}$ is the connection strength from channel j to channel i .

Note that the structure "Params" can include many fields but "fs" is only mandatory field for MULAN Toolbox. The variable 'Connectivity' is only necessary for simulated datasets.

APPENDIX B. PREPROCESSING MULAN DATA

MULAN Toolbox provides some features to process the data.

B.1. Time frequency analysis.

- (1) Click button **Preprocess** in MULAN main GUI on Fig. 11.
- (2) A parameter setting interface pops up. It allows you to change parameters to spectrum analysis. Then you can choose buttons **Fourier** or button **Wavelet** to transform. (Fig. 11).
- (3) Then a figure including the spectrum subfigures with each channel will pop out.

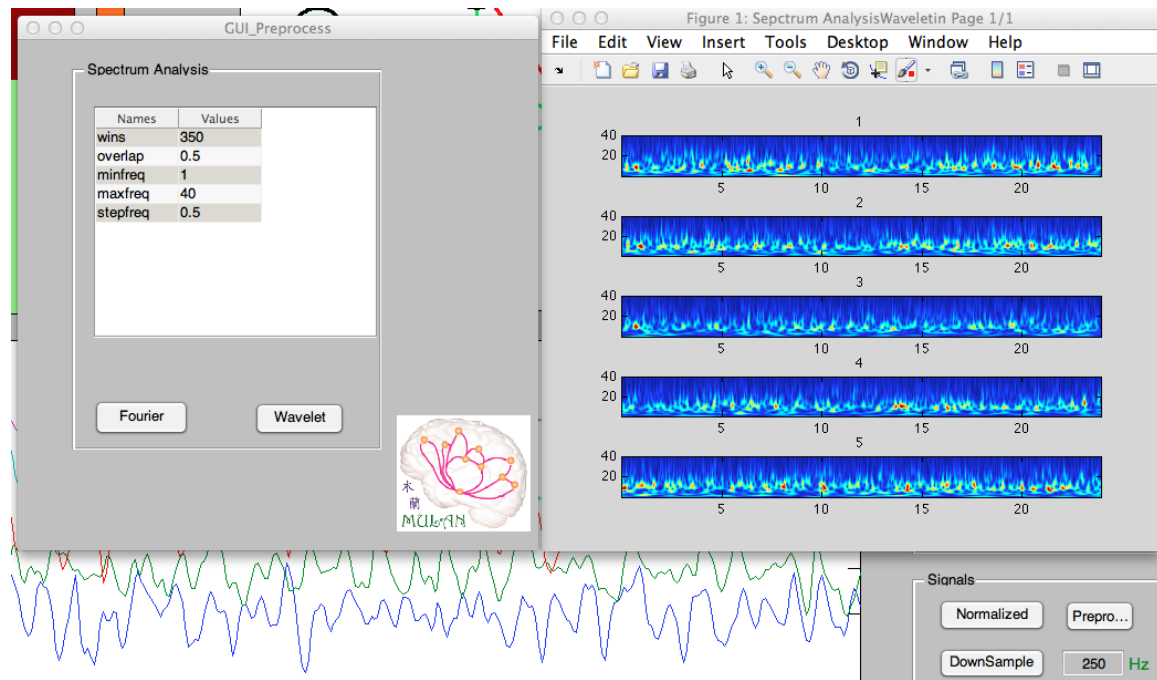


Figure 11 | The time frequency analysis

B.2. Signal processing.

- (1) Click the button **Normalized** in the "Signals" panel MULAN main GUI on Fig. 11. Then the normalized data will show up. If we want to go back to the original data, please click the button **Load**.
- (2) If you want to down sample the data, please first choose the expected frequency x Hz, then click the button **DownSample**. Note that x must be less than the original sample frequency.
- (3) Then a new file named "...fsx.mat" will be created and saved in the current folder.

B.3. Signal distribution. See Fig. 12.

Click the button **States Plot** in MULAN main GUI on Fig. 11 after setting the value of delay τ next to this button. This will display a figure with subfigures, each of them describing the signal distribution between channel i and channel j with delay τ .

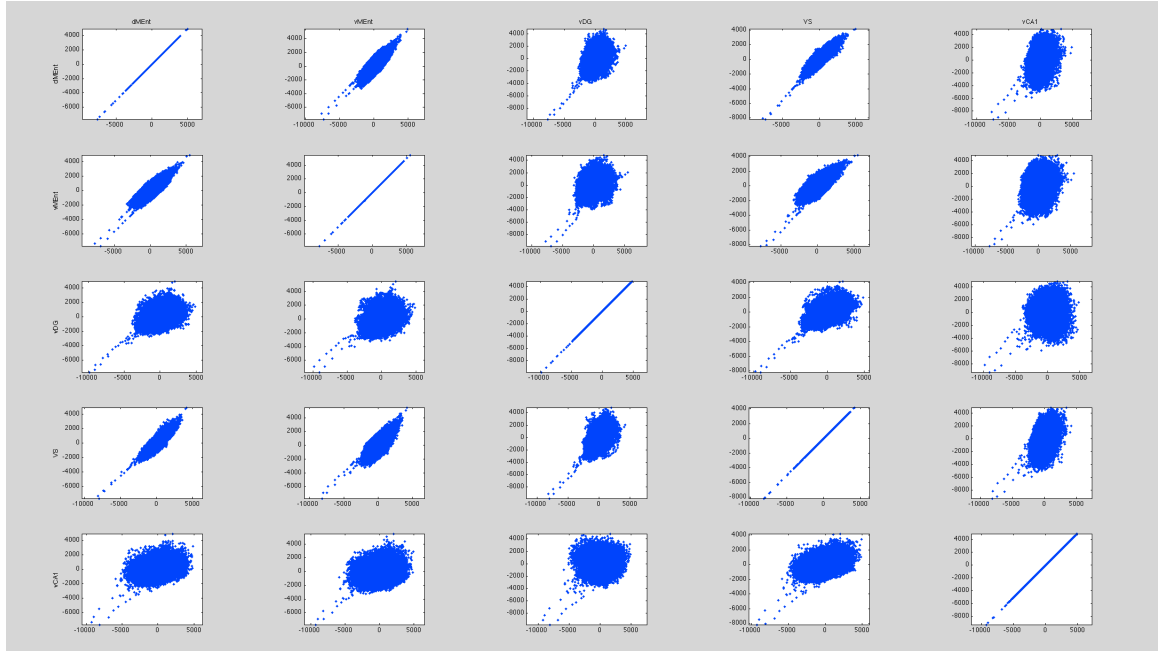


Figure 12 | Signal distribution between channels with a given time delay

ACKNOWLEDGEMENTS

Special thanks to Marmaduke Woodman for software testing and English editing of this user guide.

We are very thankful to the following open source toolboxes from which we were able to derive functions and methods:

- Statistical Parametric Mapping (SPM), from the wellcom Trust Centre for Neuroimaging, available at <http://www.fil.ion.ucl.ac.uk/spm/>
- Granger Causal Connectivity Analysis toolbox, from Anil K.Seth, available at <http://www.anilseth.com/>.
- BIOSIG-toolbox, from Alois Schloegl, available at <http://biosig.sf.net/>.
- BSMART: A Matlab/C Toolbox for Analyzing Brain Circuits, from Jie Cui, Lei Xu, Steven L. Bressler, Mingzhou Ding, Hualou Liang, available at <http://www.brain-smart.org/>.
- Neurophysiological Biomarker Toolbox (NBT), from Simon-Shlomo Poil, <http://www.nbtwiki.net/>.