PDC: A Matlab package for the partial directed coherence connectivity analysis with estimation of multivariate autoregressive models

Purpose

PDC is a collection of Matlab modules for

- estimating parameters of multivariate autoregressive (AR) models,
- diagnostic checking of fitted AR models,
- estimating partial directed coherence and statistics, and
- plotting routines

The partial directed coherence algorithms implemented in PDC are described in the following papers, which should be referenced if you use PDC in publications:

- Baccalá, L. A. & Sameshima, K. (2001a) Partial directed coherence: A new concept in neural structure determination, *Biological Cybernetics*, 84(6), pp. 463–474.
- Baccalá, L. A. & Sameshima, K. (2001b) Overcoming the limitations of correlation analysis for many simultaneously processed neural structures, *Progress in Brain Research*, 130, pp. 33–47.
- Takahashi DY, Baccalá LA, Sameshima K. Connectivity inference via partial directed coherence. *Journal of Applied Statistics*, 34(10):1255-1269, 2007. *In press.*

PDC has been successfully tested under Matlab 7.1 and later versions, up to Matlab 7.4.

Warning:

Under Matlab 6.5 **pdc_analysis_template6.m** must be used bellow instead, due to differences in plotting syntax

First and last PDC revision: 30 November 2007

Installation

The basic PDC package consists of 15 Matlab routines, 16 analysis examples taken from the literature, and one template routine (**pdc_analysis_template.m**) showing how to use PDC package for generalized partial directed coherence of a single epoch signal.

Although not mandatory, ARfit package for MVAR estimation is also included in this distribution. Addiotionally there is set of supporting routines and data file necessary or used by the basic routines and examples.

To install PDC, copy the package (available as zip-archive) into a target directory and from under Matlab run path_install (see getting_started.txt)

To run the PDC package, the following Matlab Toolboxes: Control, Statistical, and Signal Processing Toolboxes are necessary. To check if you have these toolboxes in you Matlab installation, execute the command

>>ver

Then you should see in your listing at least the following three toolboxes:

Control System Toolbox	Version 6.2.1	(R14SP3)
Signal Processing Toolbox	Version 6.4	(R14SP3)
Statistics Toolbox	Version 5.1	(R14SP3)

To check if everything is correctly set up, go to the target directory and execute:

>>pdc_analysis_template

(or >>pdc_analysis_template6 for Matlab 6.5)

If command-line window is finished with the following message.

```
==========PDC_ANALYSIS_TEMPLATE SUCCESSFULLY FINISHED ==============
```

then, most probably the installation was performed correctly

Routine descriptions

anapdcn
: Template function for express single segment PDCn computation with

arfitcaps
: Arfit capsule

cmlsm
: MVAR least squares estimator

crosstest
: Cross-correlation computation between data signal column vectors

granmaty
: Test Granger causality structure

mcarns
MVAR Nuttall-Strand algorithm

mcarvm
MVAR estimation using Vieira Morf algorithm

mvar
Estimate MVAR

mvarresidue
Residues test for whiteness

pdcn
Compute Partial^Directed^Coherence from MAR estimate

pdcxplot
PDC plot in matrix layout with power spectra in the main diagonal.

prpardd
Compute Partial^Directed^Coherence from series j to i.

vech
Vech or vec is matrix column stacking operator function

xdelay
Xdelay criterion for AR order estimation

zmatrm
Computation of Z - data structure (no estimation of the mean)%

Getting started template routine

pdc_analysis_template - PDC analysis getting started template file

getting_started.txt - installation description file

Examples descriptions

(Only for Matlab 7 to run under Matlab 6.5 - edit and replace pdcxplot.m by pdcxplot6.m in the following files)

andrews_herzberg - Sunspot and melanoma series causality analysis.

chavez16 - Example nonlinear bivariate independent model Eq. (16) p.118.

chavez18 - Equation (18): Linear Bivariate model (p.118)

chavez19 - Example Eq-(19): Nonlinear Bivariate model p.119.

chavez20 - Equation 20 (p.119): "Simple Model Bivariate Conditional Heteroskedasticity"

gourevitch02 - Example Model 2: Linear bivariate model with bidirectional influence

gourevitch05 - Gourévitch, Bouquin-Jeannes, Faucon

gourevitch06 - Biol Cybern 2006

gourevitch07 - Biol Cybern 2006

schelter01 - Schelter, Winterhalder, Eichler, Peifer,Hellwig, Guschlbauer, Lücking,

schelter02 - Schelter, Winterhalder, Hellwig, Guschlbauer, Lücking, Timmer

takahashi01 - Takahashi, Baccalá, Sameshima

winterhalder02 - Winterhalder et al.Comparison of linear signal processing techniques to

winterhalder_variant - Winterhalder et al.Comparison of linear signal

Refs for examples:

- **andrews_herzberg.m**
  Data File skin.dat from Andrews and Herzbe
- **chavez16.m, chavez18.m, chavez19.m, chavez20.m**
  Chávez, Martinerie, Van Quyen. Statistical assessment of nonlinear causality: Application to epileptic EEG signals. J Neurosci Methods. 124:113-128, 2003.
- **gourevitch02.m, gourevitch05.m, gourevitch06.m, gourevitch07.m**
  Gourévitch, Bouquin-Jeannes, Faucon. Linear and nonlinear casuality between signals: methods, examples and neurophysiological applications. Biol Cybern 95:349-369, 2006.
- **schelter01.m**
  Schelter, Winterhalder, Eichler, Peifer,Hellwig, Guschlbauer, Lücking, Dahlhaus, Timmer. Testing for directed influences among neural signals using partial directed coherence. Journal of Neuroscience Methods 152:210-218, 2005.
- **schelter02.m**
  Schelter, Winterhalder, Hellwig, Guschlbauer, Lücking, Timmer. Direct or

indirect? Graphical models for neural oscillators. J Physiology - Paris 99:37-46, 2006.

- **winterhalder02.m**
  Winterhalder et al.Comparison of linear signal processing techniques to infer directed interactions in multivariate neural systems. Signal Processing 85:2137–2160, 2006.
  Note: **winterhalder_variant.m** – the number of independent variable was increased to seven

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