

Package ‘vectorwavelet’

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Type Package

Title Vector Wavelet Coherence for Multiple Time Series

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Description New wavelet methodology (vector wavelet coherence) (Oygur, T., Unal, G, 2020 <doi:10.1007/s40435-020-00706-y>) to handle dynamic co-movements of multivariate time series via extending multiple and quadruple wavelet coherence methodologies.
This package can be used to perform multiple wavelet coherence, quadruple wavelet coherence, and n-dimensional vector wavelet coherence analyses.

License GPL (>= 2)

URL <https://github.com/toygur/vectorwavelet>

BugReports <https://github.com/toygur/vectorwavelet/issues>

Depends biwavelet (>= 0.20.19)

Imports iterators, spam, maps, fields, foreach, Rcpp

Suggests knitr, rmarkdown, devtools

Encoding UTF-8

LazyData TRUE

RoxygenNote 7.1.1

NeedsCompilation no

Repository CRAN

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vectorwavelet-package *Vector wavelet coherence for multiple time series*

Description

Description: This package can be used to perform multiple wavelet coherence (mwc), quadruple wavelet coherence (qmwc), and n-dimensional vector wavelet coherence (vwc) analyses.

Author(s)

Tunc Oygur, Gazanfer Unal

Maintainer: Tunc Oygur <info@tuncoygur.com.tr>

Code based on biwavelet package written by Tarik C. Gouhier, Aslak Grinsted, Viliam Simko.

References

T. Oygur, G. Unal.. Vector wavelet coherence for multiple time series. *Int. J. Dynam. Control* (2020).

T. Oygur, G. Unal.. The large fluctuations of the stock return and financial crises evidence from Turkey: using wavelet coherency and VARMA modeling to forecast stock return. *Fluctuation and Noise Letters*, 2017

T.C. Gouhier, A. Grinstead and V. Simko. 2016. *biwavelet: Conduct univariate and bivariate wavelet analyses (Version 0.20.15)*. Available from <http://github.com/tgouhier/biwavelet>

Ng, Eric KW and Chan, Johnny CL. 2012. Geophysical applications of partial wavelet coherence and multiple wavelet coherence. *Journal of Atmospheric and Oceanic Technology* 29-12:1845–1853.

Grinsted, A., J. C. Moore, and S. Jevrejeva. 2004. Application of the cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear Processes in Geophysics* 11:561-566.

Torrence, C., and G. P. Compo. 1998. A Practical Guide to Wavelet Analysis. *Bulletin of the American Meteorological Society* 79:61-78.

`ar1nv`*AR1NV - Estimate the parameters for an AR(1) model*

Description

AR1NV - Estimate the parameters for an AR(1) model

Usage`ar1nv(x)`**Arguments**

`x` One dimensional time series vector

Value

Return a list containing:

`g` estimate of the lag-one autocorrelation.

`a` estimate of the noise variance.

Author(s)

Tunc Oygur (info@tuncogur.com.tr)

Code based on a cross wavelet and wavelet coherence toolbox MATLAB package written by Eric Breitenberger

References

SGrinsted, A., J. C. Moore, and S. Jevrejeva. 2004. Application of the cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear Processes in Geophysics* 11:561-566.

`mwc`*Compute multiple wavelet coherence*

Description

Compute multiple wavelet coherence

Usage

```

mwc(
  y,
  x1,
  x2,
  pad = TRUE,
  dj = 1/12,
  s0 = 2 * dt,
  J1 = NULL,
  max.scale = NULL,
  mother = "morlet",
  param = -1,
  lag1 = NULL,
  sig.level = 0.95,
  sig.test = 0,
  nrands = 300,
  quiet = FALSE
)

```

Arguments

y	time series 1 in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
x1	time series 2 in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
x2	time series 3 in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
pad	pad the values will with zeros to increase the speed of the transform. Default is TRUE.
dj	spacing between successive scales. Default is 1/12.
s0	smallest scale of the wavelet. Default is 2*dt.
J1	number of scales - 1.
max.scale	maximum scale. Computed automatically if left unspecified.
mother	type of mother wavelet function to use. Can be set to morlet, dog, or paul. Default is morlet. Significance testing is only available for morlet wavelet.
param	nondimensional parameter specific to the wavelet function.
lag1	vector containing the AR(1) coefficient of each time series.
sig.level	significance level. Default is 0.95.
sig.test	type of significance test. If set to 0, use a regular χ^2 test. If set to 1, then perform a time-average test. If set to 2, then do a scale-average test.
nrands	number of Monte Carlo randomizations. Default is 300.
quiet	Do not display progress bar. Default is FALSE

Value

Return a vectorwavelet object containing:

coi	matrix containg cone of influence
rsq	matrix of wavelet coherence
phase	matrix of phases
period	vector of periods
scale	vector of scales
dt	length of a time step
t	vector of times
xaxis	vector of values used to plot xaxis
s0	smallest scale of the wavelet
dj	spacing between successive scales
mother	mother wavelet used
type	type of vectorwavelet object created (mwc)
signif	matrix containg sig. level percentiles of wavelet coherence based on the Monte Carlo AR(1) time series

Author(s)

Tunc Oygur (info@tuncoygur.com.tr)

Code based on MWC MATLAB package written by Eric K. W. Ng and Johnny C. L. Chan.

References

T. Oygur, G. Unal.. Vector wavelet coherence for multiple time series. *Int. J. Dynam. Control* (2020).

T. Oygur, G. Unal. 2017. The large fluctuations of the stock return and financial crises evidence from Turkey: using wavelet coherency and VARMA modeling to forecast stock return. *Fluctuation and Noise Letters*

Ng, Eric KW and Chan, Johnny CL. 2012. Geophysical applications of partial wavelet coherence and multiple wavelet coherence. *Journal of Atmospheric and Oceanic Technology* 29-12:1845–1853.

Examples

```
old.par <- par(no.readonly=TRUE)

t <- (-100:100)

y <- sin(t*2*pi)+sin(t*2*pi/4)+sin(t*2*pi/8)+sin(t*2*pi/16)+sin(t*2*pi/32)+sin(t*2*pi/64)
x1 <- sin(t*2*pi/8)
x2 <- sin(t*2*pi/32)

y <- cbind(t,y)
```

```

x1 <- cbind(t,x1)
x2 <- cbind(t,x2)

## Multiple wavelet coherence
result <- mwc(y, x1, x2, nrand = 10)

result <- mwc(y, x1, x2)

## Plot wavelet coherence and make room to the right for the color bar
## Note: plot function can be used instead of plot.vectorwavelet
par(oma = c(0, 0, 0, 1), mar = c(5, 4, 4, 5) + 0.1, pin = c(3,3))
plot.vectorwavelet(result, plot.cb = TRUE, main = "Plot multiple wavelet coherence")

par(old.par)

```

n.check.data

Check the format of multivariate time series

Description

Check the format of multivariate time series

Usage

```
n.check.data(y, x = NULL)
```

Arguments

y	time series y in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
x	multivariate time series x in matrix format (m rows x (1 + (n-1)) columns). The first column should contain the time steps and the other columns should contain the values.

Value

Returns a named list containing:

t	time steps
dt	size of a time step
n.obs	number of observations

Author(s)

Tunc Oygur (info@tuncoygur.com.tr)

Code based on biwavelet package written by Tarik C. Gouhier.

Examples

```
#Example 1:
t1 <- cbind(1:100, rnorm(100))
n.check.data(y = t1)

#Example 2:
t1 <- cbind(1:100, rnorm(100))
t2 <- cbind(1:100, rnorm(100), rnorm(100), rnorm(100))
n.check.data(y = t1, x = t2)
```

n.check.datum	<i>Helper function</i>
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Description

Helper function

Usage

```
n.check.datum(x)
```

Arguments

x matrix

Value

list(t, dt, n.obs)

Note

This function is not exported

plot.vectorwavelet	<i>Plot vectorwavelet objects</i>
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Description

Plot vectorwavelet objects which are multiple wavelet coherence, quadruple wavelet coherence and n-dimensional vector wavelet coherence.

Usage

```
## S3 method for class 'vectorwavelet'
plot(
  x,
  ncol = 1024,
  fill.cols = NULL,
  xlab = "Time",
  ylab = "Period",
  tol = 1,
  plot.cb = FALSE,
  plot.coi = TRUE,
  lwd.coi = 1,
  col.coi = "white",
  lty.coi = 1,
  alpha.coi = 0.5,
  plot.sig = TRUE,
  lwd.sig = 4,
  col.sig = "black",
  lty.sig = 1,
  bw = FALSE,
  legend.loc = NULL,
  legend.horiz = FALSE,
  arrow.len = min(par()$pin[2]/30, par()$pin[1]/40),
  arrow.lwd = arrow.len * 0.3,
  arrow.cutoff = 0.7,
  arrow.col = "black",
  xlim = NULL,
  ylim = NULL,
  zlim = c(0, 1),
  xaxt = "s",
  yaxt = "s",
  form = "%Y",
  ...
)
```

Arguments

<code>x</code>	vectorwavelet object generated by <code>mwc</code> , <code>qmec</code> , or <code>vwc</code> .
<code>ncol</code>	number of colors to use. Default is 1024.
<code>fill.cols</code>	Vector of fill colors to be used. Users can specify color vectors using <code>colorRampPalette</code> or <code>brewer.pal</code> from package <code>RColorBrewer</code> . Default is <code>NULL</code> and will generate MATLAB's jet color palette.
<code>xlab</code>	xlabel of the figure. Default is "Time"
<code>ylab</code>	ylabel of the figure. Default is "Period"
<code>tol</code>	tolerance level for significance contours. Significance contours will be drawn around all regions of the spectrum where <code>spectrum/percentile >= tol</code> . De-

	fault is 1. If strict i^{th} percentile regions are desired, then <code>tol</code> must be set to 1.
<code>plot.cb</code>	plot color bar if TRUE. Default is FALSE.
<code>plot.coi</code>	plot cone of influence (COI) as a semi-transparent polygon if TRUE. Default is TRUE. Areas that fall within the polygon can be affected by edge effects.
<code>lwd.coi</code>	Line width of COI. Default is 1.
<code>col.coi</code>	Color of COI. Default is white.
<code>lty.coi</code>	Line type of COI. Default is 1 for solide lines.
<code>alpha.coi</code>	Transparency of COI. Range is 0 (full transparency) to 1 (no transparency). Default is 0.5.
<code>plot.sig</code>	plot contours for significance if TRUE. Default is TRUE.
<code>lwd.sig</code>	Line width of significance contours. Default is 4.
<code>col.sig</code>	Color of significance contours. Default is black.
<code>lty.sig</code>	Line type of significance contours. Default is 1.
<code>bw</code>	plot in black and white if TRUE. Default is FALSE.
<code>legend.loc</code>	legend location coordinates as defined by <code>image.plot</code> . Default is NULL.
<code>legend.horiz</code>	plot a horizontal legend if TRUE. Default is FALSE.
<code>arrow.len</code>	size of the arrows. Default is based on plotting region ($\min(\text{par}()\$pin[2]/30, \text{par}()\$pin[1]/40)$).
<code>arrow.lwd</code>	width/thickness of arrows. Default is $\text{arrow.len} * 0.3$.
<code>arrow.cutoff</code>	cutoff value for plotting phase arrows. Phase arrows will be plotted in regions where the significance of the <code>z</code> values exceeds <code>arrow.cutoff</code> . If the object being plotted does not have a significance field, regions whose <code>z</code> values exceed the <code>arrow.cutoff</code> quantile will be plotted. Default is 0.7.
<code>arrow.col</code>	Color of arrows. Default is black.
<code>xlim</code>	the x limits. The default is NULL.
<code>ylim</code>	the y limits. The default is NULL.
<code>zlim</code>	the z limits. The default is NULL.
<code>xaxt</code>	Add x-axis? The default is <code>s</code> ; use <code>n</code> for none.
<code>yaxt</code>	Add y-axis? The default is <code>s</code> ; use <code>n</code> for none.
<code>form</code>	format to use to display dates on the x-axis. Default is <code>'%Y'</code> for 4-digit year. See <code>?Date</code> for other valid formats.
<code>...</code>	other parameters.

Value

No return value, shows the objects plot.

Author(s)

Tunc Oygur (info@tuncoygur.com.tr)

Code based on `biwavelet` package written by Tarik C. Gouhier.

qmwc

*Compute quadruple wavelet coherence***Description**

Compute quadruple wavelet coherence

Usage

```
qmwc(
  y,
  x1,
  x2,
  x3,
  pad = TRUE,
  dj = 1/12,
  s0 = 2 * dt,
  J1 = NULL,
  max.scale = NULL,
  mother = "morlet",
  param = -1,
  lag1 = NULL,
  sig.level = 0.95,
  sig.test = 0,
  nrands = 300,
  quiet = FALSE
)
```

Arguments

y	time series 1 in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
x1	time series 2 in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
x2	time series 3 in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
x3	time series 4 in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
pad	pad the values will with zeros to increase the speed of the transform. Default is TRUE.
dj	spacing between successive scales. Default is 1/12.
s0	smallest scale of the wavelet. Default is 2*dt.
J1	number of scales - 1.
max.scale	maximum scale. Computed automatically if left unspecified.

mother	type of mother wavelet function to use. Can be set to morlet, dog, or paul. Default is morlet. Significance testing is only available for morlet wavelet.
param	nondimensional parameter specific to the wavelet function.
lag1	vector containing the AR(1) coefficient of each time series.
sig.level	significance level. Default is 0.95.
sig.test	type of significance test. If set to 0, use a regular χ^2 test. If set to 1, then perform a time-average test. If set to 2, then do a scale-average test.
nrand	number of Monte Carlo randomizations. Default is 300.
quiet	Do not display progress bar. Default is FALSE

Value

Return a vectorwavelet object containing:

coi	matrix containing cone of influence
rsq	matrix of wavelet coherence
phase	matrix of phases
period	vector of periods
scale	vector of scales
dt	length of a time step
t	vector of times
xaxis	vector of values used to plot xaxis
s0	smallest scale of the wavelet
dj	spacing between successive scales
mother	mother wavelet used
type	type of vectorwavelet object created (qmwc)
signif	matrix containing sig.level percentiles of wavelet coherence based on the Monte Carlo AR(1) time series

Author(s)

Tunc Oygur (info@tuncoygur.com.tr)

References

- T. Oygur, G. Unal.. Vector wavelet coherence for multiple time series. *Int. J. Dynam. Control* (2020).
- T. Oygur, G. Unal. 2017. The large fluctuations of the stock return and financial crises evidence from Turkey: using wavelet coherency and VARMA modeling to forecast stock return. *Fluctuation and Noise Letters*

Examples

```

old.par <- par(no.readonly=TRUE)

t <- (-100:100)

y <- sin(t*2*pi)+sin(t*2*pi/4)+sin(t*2*pi/8)+sin(t*2*pi/16)+sin(t*2*pi/32)+sin(t*2*pi/64)
x1 <- sin(t*2*pi/16)
x2 <- sin(t*2*pi/32)
x3 <- sin(t*2*pi/64)

y <- cbind(t,y)
x1 <- cbind(t,x1)
x2 <- cbind(t,x2)
x3 <- cbind(t,x3)

## Quadruple wavelet coherence
result <- qmwc(y, x1, x2, x3, nrand = 10)

result <- qmwc(y, x1, x2, x3)

## Plot wavelet coherence and make room to the right for the color bar
## Note: plot function can be used instead of plot.vectorwavelet
par(oma = c(0, 0, 0, 1), mar = c(5, 4, 4, 5) + 0.1, pin = c(3,3))
plot.vectorwavelet(result, plot.cb = TRUE, main = "Plot quadruple wavelet coherence")

par(old.par)

```

vwc

Compute n-dimensional vector wavelet coherence

Description

Compute n-dimensional vector wavelet coherence

Usage

```

vwc(
  y,
  x,
  pad = TRUE,
  dj = 1/12,
  s0 = 2 * dt,
  J1 = NULL,
  max.scale = NULL,
  mother = "morlet",
  param = -1,
  lag1 = NULL,

```

```

    sig.level = 0.95,
    sig.test = 0,
    nrands = 300,
    quiet = FALSE
)

```

Arguments

y	time series y in matrix format (m rows x 2 columns). The first column should contain the time steps and the second column should contain the values.
x	multivariate time series x in matrix format (m rows x n columns). The first column should contain the time steps and the other columns should contain the values.
pad	pad the values will with zeros to increase the speed of the transform. Default is TRUE.
dj	spacing between successive scales. Default is 1/12.
s0	smallest scale of the wavelet. Default is 2*dt.
J1	number of scales - 1.
max.scale	maximum scale. Computed automatically if left unspecified.
mother	type of mother wavelet function to use. Can be set to morlet, dog, or paul. Default is morlet. Significance testing is only available for morlet wavelet.
param	nondimensional parameter specific to the wavelet function.
lag1	vector containing the AR(1) coefficient of each time series.
sig.level	significance level. Default is 0.95.
sig.test	type of significance test. If set to 0, use a regular χ^2 test. If set to 1, then perform a time-average test. If set to 2, then do a scale-average test.
nrands	number of Monte Carlo randomizations. Default is 300.
quiet	Do not display progress bar. Default is FALSE

Value

Return a vectorwavelet object containing:

coi	matrix containing cone of influence
rsq	matrix of wavelet coherence
phase	matrix of phases
period	vector of periods
scale	vector of scales
dt	length of a time step
t	vector of times
xaxis	vector of values used to plot xaxis
s0	smallest scale of the wavelet

dj	spacing between successive scales
mother	mother wavelet used
type	type of vectorwavelet object created (vwc)
signif	matrix containing sig. level percentiles of wavelet coherence based on the Monte Carlo AR(1) time series

Author(s)

Tunc Oygur (info@tuncoygur.com.tr)

References

T. Oygur, G. Unal.. Vector wavelet coherence for multiple time series. *Int. J. Dynam. Control* (2020).

Examples

```
old.par <- par(no.readonly=TRUE)

t <- (-100:100)

y <- sin(t*2*pi)+sin(t*2*pi/4)+sin(t*2*pi/8)+sin(t*2*pi/16)+sin(t*2*pi/32)+sin(t*2*pi/64)
x1 <- sin(t*2*pi/8)
x2 <- sin(t*2*pi/16)
x3 <- sin(t*2*pi/32)
x4 <- sin(t*2*pi/64)

y <- cbind(t,y)
x <- cbind(t,x1,x2,x3,x4)

## n-dimensional multiple wavelet coherence
result <- vwc(y, x, nrands = 10)

result <- vwc(y, x)

## Plot wavelet coherence and make room to the right for the color bar
## Note: plot function can be used instead of plot.vectorwavelet
par(oma = c(0, 0, 0, 1), mar = c(5, 4, 4, 5) + 0.1, pin = c(3,3))
plot.vectorwavelet(result, plot.cb = TRUE, main = "Plot n-dimensional vwc (n=5)")

par(old.par)
```

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