Package 'xiacf'

June 2, 2026

Type Package

Title Nonlinear Dependence and Lead-Lag Analysis via Chatterjee's Xi

Version 0.6.2

Date 2026-06-02

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Description Computes Chatterjee's non-parametric correlation coefficient for time series data. It extends the original metric to time series analysis by providing the univariate Xi-Autocorrelation Function (Xi-ACF), directional Xi-Cross-Correlation Function (Xi-CCF), and multivariate network evaluation matrices. The package allows users to test for nonlinear dependence using Iterative Amplitude Adjusted Fourier Transform (IAAFT) and Multivariate IAAFT (MIAAFT) surrogate data with strict Family-Wise Error Rate ('FWER') control via Max-statistic approaches. Methodologies are based on Chatterjee (2021) <doi:10.1080/01621459.2020.1758115>, surrogate data testing methods by Schreiber and Schmitz (1996) <doi:10.1103/PhysRevLett.77.635>, and local structural identification by Watanabe (2026) <doi:10.2139/ssrn.6829431>.

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Encoding UTF-8

Imports dplyr (>= 1.1.4), doFuture, foreach, future, ggplot2 (>= 4.0.1), patchwork, progressr, Rcpp (>= 1.1.0), stats, parallelly

LinkingTo Rcpp, RcppArmadillo

Suggests testthat (>= 3.3.2)

Config/testthat/edition 3

Config/roxygen2/version 8.0.0

RoxygenNote 7.3.3

NeedsCompilation yes

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Repository CRAN

Date/Publication 2026-06-02 07:30:02 UTC

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`autoplot.xi_acf` *Plot method for xi_acf objects*

Description

Plot method for xi_acf objects

Usage

```
## S3 method for class 'xi_acf'
autoplot(object, ...)
```

Arguments

`object`	An object of class `xi_acf`.
`...`	Additional arguments passed to other methods.

autoplot.xi_ccf *Plot method for xi_ccf objects*

Description

Plot method for xi_ccf objects

Usage

```
## S3 method for class 'xi_ccf'
autoplot(object, ...)
```

Arguments

`object`	An object of class `xi_ccf`.
`...`	Additional arguments passed to other methods.

autoplot.xi_matrix *Plot method for xi_matrix objects*

Description

Plot method for xi_matrix objects

Usage

```
## S3 method for class 'xi_matrix'
autoplot(object, ...)
```

Arguments

`object`	An object of class `xi_matrix`.
`...`	Additional arguments passed to other methods.

extract_xi_acf *Extract Univariate Xi-ACF from a Multivariate Xi-Matrix*

Description

Extract Univariate Xi-ACF from a Multivariate Xi-Matrix

Usage

```
extract_xi_acf(obj, var, ...)
```

Arguments

obj	An object of class xi_matrix.
var	A character string specifying the variable name to extract.
...	Additional arguments passed to xi_acf.

Value

An object of class xi_acf.

Note

This function performs a fresh re-calculation of the surrogate data distribution specifically for the targeted variables. As a result, two differences from the original matrix output should be expected: 1. **FWER Recalibration:** The global threshold will be recalibrated for the bivariate (or univariate) case, typically making it less conservative and restoring statistical power for the specific pathway. 2. **Monte Carlo Variation:** Due to the randomized nature of surrogate data generation, slight numerical variations in the thresholds and confidence intervals may occur unless a random seed is explicitly set (e.g., 'set.seed()') immediately prior to calling this extraction function.

extract_xi_ccf *Extract Bivariate Xi-CCF from a Multivariate Xi-Matrix*

Description

Extract Bivariate Xi-CCF from a Multivariate Xi-Matrix

Usage

```
extract_xi_ccf(obj, var_x, var_y, ...)
```

Arguments

obj	An object of class xi_matrix.
var_x	A character string specifying the lead variable.
var_y	A character string specifying the lag variable.
...	Additional arguments passed to xi_ccf.

Value

An object of class xi_ccf.

Note

This function performs a fresh re-calculation of the surrogate data distribution specifically for the targeted variables. As a result, two differences from the original matrix output should be expected: 1. **FWER Recalibration:** The global threshold will be recalibrated for the bivariate (or univariate) case, typically making it less conservative and restoring statistical power for the specific pathway. 2. **Monte Carlo Variation:** Due to the randomized nature of surrogate data generation, slight numerical variations in the thresholds and confidence intervals may occur unless a random seed is explicitly set (e.g., 'set.seed()') immediately prior to calling this extraction function.

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print.xi_ccf *Print method for xi_ccf*

Description

Print method for xi_ccf

Usage

```
## S3 method for class 'xi_ccf'
print(x, ...)
```

Arguments

x	An object of class xi_ccf.
...	Additional arguments passed to print.

Value

The original object x invisibly.

print.xi_matrix *Print method for xi_matrix*

Description

Print method for xi_matrix

Usage

```
## S3 method for class 'xi_matrix'
print(x, ...)
```

Arguments

x	An object of class xi_matrix.
...	Additional arguments passed to print.

Value

The original object x invisibly.

run_rolling_xi_acf *Rolling Window Analysis for Xi-ACF*

Description

Rolling Window Analysis for Xi-ACF

Usage

```
run_rolling_xi_acf(
  x,
  time_index = NULL,
  window_size,
  step_size = 1,
  max_lag,
  n_surr = 399,
  sig_level = 0.05,
  max_iter = 100,
  n_cores = NULL,
  save_dir = NULL
)
```

Arguments

x	A numeric vector representing the time series data.
time_index	An optional vector representing timestamps.
window_size	An integer specifying the size of the rolling window.
step_size	An integer specifying the step size. Default is 1.
max_lag	An integer specifying the maximum lag to compute.
n_surr	An integer specifying the number of IAAFT surrogate datasets. Default is 399.
sig_level	A numeric value specifying the significance level (FWER). Default is 0.05.
max_iter	An integer specifying the maximum iterations for the IAAFT algorithm. Default is 100.
n_cores	An integer specifying the number of cores for parallel execution.
save_dir	A character string specifying the directory path to save intermediate results.

Value

A `data.frame` containing the rolling window results.

`run_rolling_xi_ccf` *Rolling Directional Xi-CCF Analysis*

Description

Performs a rolling window analysis using Chatterjee's Xi cross-correlation to assess the time-varying non-linear lead-lag relationship between two time series with FWER control.

Usage

```
run_rolling_xi_ccf(
  x,
  y,
  time_index = NULL,
  window_size,
  step_size = 1,
  max_lag,
  n_surr = 399,
  sig_level = 0.05,
  max_iter = 100,
  n_cores = NULL,
  save_dir = NULL
)
```

Arguments

x	A numeric vector representing the first time series.
y	A numeric vector representing the second time series.
time_index	An optional vector representing timestamps.
window_size	An integer specifying the size of the rolling window.
step_size	An integer specifying the step size. Default is 1.
max_lag	An integer specifying the maximum positive lag to compute.
n_surr	An integer specifying the number of MIAAFT surrogate datasets. Default is 399.
sig_level	A numeric value specifying the significance level (FWER). Default is 0.05.
max_iter	An integer specifying the maximum iterations for the MIAAFT algorithm. Default is 100.
n_cores	An integer specifying the number of cores for parallel execution.
save_dir	A character string specifying the directory path to save intermediate results.

Value

A `data.frame` containing the rolling window results.

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surrogate_iaaft_cpp *Generate Multiple IAAFT Surrogates (Univariate)*

Description

Generate Multiple IAAFT Surrogates (Univariate)

Usage

```
surrogate_iaaft_cpp(x, n_surr, max_iter = 100L)
```

Arguments

x	A numeric vector.
n_surr	Number of surrogates to generate.
max_iter	Maximum iterations for IAAFT.

Value

A matrix of surrogates (N x n_surr).

surrogate_miaaft_cpp *Generate Multiple MIAAFT Surrogates (3D Array / Cube)*

Description

Generate Multiple MIAAFT Surrogates (3D Array / Cube)

Usage

```
surrogate_miaaft_cpp(X, n_surr, max_iter = 100L)
```

Arguments

X	A numeric matrix (N x p).
n_surr	Number of surrogates to generate.
max_iter	Maximum iterations for MIAAFT.

Value

A 3D array (arma::cube) of dimensions N x p x n_surr.

xiacf-deprecated *Deprecated functions in xiacf*

Description

These functions are provided for backward compatibility with older versions of xiacf and will be removed in future releases.

Usage

```
xi_test(x, max_lag = 10, n_surr = 399, sig_level = 0.95, max_iter = 100, ...)

generate_iaaft_surrogate(...)

generate_miaaft_surrogates(...)

generate_miaaft_surrogate_cpp(...)

run_rolling_xi_analysis(...)

compute_xi_acf_iaaft(...)

compute_xi_ccf_miaaft(...)

compute_xi_matrix_miaaft(...)
```

Arguments

x	A numeric vector or matrix depending on the function.
max_lag	An integer specifying the maximum lag.
n_surr	An integer specifying the number of surrogate datasets.
sig_level	A numeric value specifying the significance or confidence level.
max_iter	An integer specifying the maximum iterations.
...	Additional arguments passed to the updated functions.

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xi_acf *Compute empirical Xi-ACF and its significance via IAAFT surrogates*

Description

Compute empirical Xi-ACF and its significance via IAAFT surrogates

Usage

```
xi_acf(x, max_lag = 10, n_surr = 399, sig_level = 0.05, max_iter = 100, ...)

## S3 method for class 'xi_acf'
print(x, ...)
```

Arguments

x	A numeric vector representing the time series data. Must not contain missing values (NA) or be a constant.
max_lag	An integer specifying the maximum lag to compute. Default is 10.
n_surr	An integer specifying the number of surrogate datasets to generate. Default is 399.
sig_level	A numeric value between 0 and 1 specifying the significance level. Default is 0.05.
max_iter	An integer specifying the maximum iterations for the IAAFT algorithm. Default is 100.
...	Additional arguments (currently ignored).

Value

An object of class `xi_acf` containing the empirical ACF, pointwise thresholds, global threshold, and metadata.

xi_ccf *Bivariate Xi-Cross-Correlation Function*

Description

Computes the directional Chatterjee's Xi coefficient between two time series across multiple lags, with Family-Wise Error Rate (FWER) control.

Usage

```
xi_ccf(
  x,
  y,
  max_lag = 20,
  n_surr = 399,
  sig_level = 0.05,
  max_iter = 100,
  direction = c("both", "x_leads"),
  ...
)
```

Arguments

x	A numeric vector representing the first time series.
y	A numeric vector representing the second time series.
max_lag	An integer specifying the maximum lag to compute. Default is 20.
n_surr	An integer specifying the number of MIAAFT surrogate datasets. Default is 399.
sig_level	A numeric value specifying the significance level (FWER). Default is 0.05.
max_iter	An integer specifying the maximum iterations for the MIAAFT algorithm. Default is 100.
direction	A character string specifying the testing direction. "both" computes X->Y and Y->X. "x_leads" computes only X->Y. Default is "both".
...	Additional arguments.

Value

An S3 object of class xi_ccf.

xi_coefficient *Compute Chatterjee's Xi coefficient (Exported to R)*

Description

Compute Chatterjee's Xi coefficient (Exported to R)

Usage

```
xi_coefficient(x, y)
```

Arguments

x	A numeric vector.
y	A numeric vector.

Value

The Xi coefficient.

xi_matrix *Multivariate Xi-Correlogram Matrix*

Description

Computes the pairwise directional Chatterjee's Xi coefficient for a multivariate time series.

Usage

```
xi_matrix(x, max_lag = 10, n_surr = 399, sig_level = 0.05, max_iter = 100, ...)
```

Arguments

x	A numeric matrix or data.frame containing the multivariate time series (columns = variables).
max_lag	An integer specifying the maximum positive lag to compute. Default is 10.
n_surr	An integer specifying the number of MIAAFT surrogate datasets. Default is 399.
sig_level	A numeric value between 0 and 1 specifying the significance level. Default is 0.05.
max_iter	An integer specifying the maximum iterations for the MIAAFT algorithm. Default is 100.
...	Additional arguments.

Value

An S3 object of class `xi_matrix` containing a tidy data frame of pairwise results.

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