Package 'xiacf'

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Type Package

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

Version 0.4.1

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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 Xi-Autocorrelation Function (Xi-ACF) and Xi-Cross-Correlation Function (Xi-CCF). The package allows users to test for non-linear dependence using Iterative Amplitude Adjusted Fourier Transform (IAAFT) surrogate data. Main functions include xi_acf() and xi_ccf() for computation, along with matrix extraction tools. Methodologies are based on Chatterjee (2021) <doi:10.1080/01621459.2020.1758115> and surrogate data testing methods by Schreiber and Schmitz (1996) <doi:10.1103/PhysRevLett.77.635>.

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Imports dplyr (>= 1.1.4), doFuture, foreach, future, ggplot2 (>= 4.0.1), latex2exp, progressr, Rcpp (>= 1.1.0), stats

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Contents

`autoplot.xi_acf` *Plot Xi-ACF Comparison*

Description

Visualizes the comparison between the standard linear Autocorrelation Function (ACF) and the non-linear Chatterjee's Xi coefficient, including their respective significance thresholds.

Usage

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

Arguments

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

Value

A `ggplot` object representing the correlogram.

autoplot.xi_ccf *Plot Directional Xi-CCF Comparison*

Description

Visualizes the comparison between the standard linear Cross-Correlation Function (CCF) and the non-linear Chatterjee's Xi cross-correlation across two directions (X leads Y, Y leads X).

Usage

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

Arguments

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

Value

A ggplot object representing the directional cross-correlogram.

autoplot.xi_matrix *Plot Multivariate Xi-Correlogram Matrix*

Description

Visualizes the result of a multivariate Xi-matrix analysis using a facet grid. Rows represent the leading (predictor) variable, and columns represent the lagging (response) variable.

Usage

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

Arguments

object	An object of class xi_matrix.
...	Additional arguments (currently ignored).

Value

A ggplot object.

compute_xi_acf_iaaft *Compute Xi-ACF for Multiple Lags (Core Engine)*

Description

Calculates Chatterjee's Xi coefficient for multiple lags and generates IAAFT (Iterative Amplitude Adjusted Fourier Transform) surrogates to establish confidence intervals for non-linear dependence.

Usage

```
compute_xi_acf_iaaft(x, max_lag, n_surr)
```

Arguments

x	A numeric vector (time series).
max_lag	An integer specifying the maximum number of lags to compute.
n_surr	An integer specifying the number of surrogate datasets to generate.

Value

A list containing `xi_original` (the Xi coefficients for the original series) and `xi_surrogates` (a matrix of Xi coefficients for the surrogate datasets).

compute_xi_ccf_miaaft *Compute MIAAFT-based Directional Xi-CCF*

Description

Compute MIAAFT-based Directional Xi-CCF

Usage

```
compute_xi_ccf_miaaft(x, y, max_lag, n_surr)
```

Arguments

x	First time series (numeric vector, potential cause)
y	Second time series (numeric vector, potential effect)
max_lag	Maximum positive lag to evaluate
n_surr	Number of surrogate datasets to generate

Value

A list containing forward (X leads Y) and backward (Y leads X) Xi coefficients and surrogates.

`compute_xi_matrix_miaaft` *Compute Pairwise Directional Xi-CCF for a Multivariate Matrix*

Description

Compute Pairwise Directional Xi-CCF for a Multivariate Matrix

Usage

```
compute_xi_matrix_miaaft(x, max_lag, n_surr)
```

Arguments

`x`	A numeric matrix (rows = time, cols = variables).
`max_lag`	An integer specifying the maximum positive lag.
`n_surr`	An integer specifying the number of surrogate datasets.

Value

A list containing flat vectors for lead/lag variable indices, lags, original Xi values, and a matrix of surrogate Xi values.

`extract_xi_acf` *Extract Individual Xi-ACF from Xi-Matrix*

Description

Extracts the autocorrelation results for a specific variable from a `xi_matrix` object and converts it into a `xi_acf` S3 object.

Usage

```
extract_xi_acf(object, var, x_raw = NULL)
```

Arguments

`object`	An object of class `xi_matrix`.
`var`	A character string specifying the variable name to extract.
`x_raw`	Optional. The original multivariate data (matrix or data.frame) used to compute the matrix. If provided, standard linear ACF will be re-calculated.

Value

An object of class `xi_acf`.

extract_xi_ccf *Extract Individual Xi-CCF from Xi-Matrix*

Description

Extracts the cross-correlation results for a specific pair of variables from a `xi_matrix` object and converts it into a `xi_ccf` S3 object.

Usage

```
extract_xi_ccf(object, var_x, var_y, x_raw = NULL)
```

Arguments

`object`	An object of class `xi_matrix`.
`var_x`	A character string for the first variable (X).
`var_y`	A character string for the second variable (Y).
`x_raw`	Optional. The original multivariate data used to compute the matrix.

Value

An object of class `xi_ccf`.

generate_miaaft_surrogate_cpp *Generate a Single MIAAFT Surrogate Matrix*

Description

Generate a Single MIAAFT Surrogate Matrix

Usage

```
generate_miaaft_surrogate_cpp(x, max_iter = 100L)
```

Arguments

`x`	A numeric matrix (rows = time, cols = variables).
`max_iter`	An integer specifying the maximum number of iterations.

Value

A numeric matrix representing the generated MIAAFT surrogate.

print.xi_acf *Print method for xi_acf objects*

Description

Print method for xi_acf objects

Usage

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

Arguments

x	An object of class "xi_acf".
...	Additional arguments.

Value

Invisibly returns the original object.

print.xi_ccf *Print method for xi_ccf objects*

Description

Print method for xi_ccf objects

Usage

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

Arguments

x	An object of class "xi_ccf".
...	Additional arguments.

Value

Invisibly returns the original object.

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. Called primarily for its side effect of printing the matrix to the console.

run_rolling_xi_analysis *Rolling Xi-ACF Analysis*

Description

Performs a rolling window analysis using Chatterjee's Xi coefficient to assess the time-varying non-linear dependence structure of a time series.

Usage

```
run_rolling_xi_analysis(
  x,
  time_index = NULL,
  window_size,
  step_size = 1,
  max_lag = 20,
  n_surr = 100,
  sig_level = 0.95,
  n_cores = NULL,
  save_dir = NULL
)
```

Arguments

x	A numeric vector representing the time series (e.g., log-returns).
time_index	Optional vector of timestamps (e.g., Date, POSIXct) corresponding to x.
window_size	An integer specifying the size of the rolling window.
step_size	An integer specifying the step size by which the window is shifted. Default is 1.
max_lag	An integer specifying the maximum lag to compute Chatterjee's Xi for.
n_surr	An integer specifying the number of surrogate datasets for the null hypothesis test.
sig_level	A numeric value specifying the significance level for the confidence intervals. Default is 0.95.
n_cores	An integer specifying the number of cores for parallel execution. If NULL, runs sequentially.
save_dir	A character string specifying the directory path to save intermediate window results as RDS files. If NULL (default), results are not saved to disk.

Value

A data.frame containing the rolling window results, including timestamps if provided.

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run_rolling_xi_ccf *Rolling Multivariate 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.

Usage

```
run_rolling_xi_ccf(
  x,
  y,
  time_index = NULL,
  window_size,
  step_size = 1,
  max_lag = 20,
  n_surr = 100,
  bidirectional = TRUE,
  sig_level = 0.95,
  n_cores = NULL,
  save_dir = NULL
)
```

Arguments

x	A numeric vector representing the first time series (predictor/lead candidate).
y	A numeric vector representing the second time series (response/lag candidate).
time_index	Optional vector of timestamps (e.g., Date, POSIXct) corresponding to x and y.
window_size	An integer specifying the size of the rolling window.
step_size	An integer specifying the step size by which the window is shifted. 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 for the null hypothesis test.
bidirectional	Logical. If TRUE (default), computes both "X leads Y" and "Y leads X".
sig_level	A numeric value specifying the significance level for the confidence intervals. Default is 0.95.
n_cores	An integer specifying the number of cores for parallel execution. If NULL, runs sequentially.
save_dir	A character string specifying the directory path to save intermediate window results as RDS files. If NULL (default), results are not saved to disk.

Value

A data.frame containing the rolling window results in a tidy long-format.

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xi_acf *Xi-ACF Test for Time Series*

Description

Calculates Chatterjee's Xi and the standard Autocorrelation Function (ACF) along with their respective significance thresholds.

Usage

```
xi_acf(x, max_lag = 20, n_surr = 100, sig_level = 0.95)

xi_test(x, max_lag = 20, n_surr = 100)
```

Arguments

x	A numeric vector representing the time series data.
max_lag	An integer specifying the maximum number of lags to compute.
n_surr	An integer specifying the number of surrogate datasets to generate for the IAAFT test.
sig_level	A numeric value between 0 and 1 specifying the significance level. Default is 0.95.

Value

An object of class "xi_acf" containing the computed statistics and metadata.

`xi_ccf` *Directional Xi-CCF Test for Multivariate Time Series*

Description

Calculates Chatterjee's Xi cross-correlation and the standard Cross-Correlation Function (CCF) across positive lags to evaluate directional lead-lag relationships.

Usage

```
xi_ccf(
  x,
  y,
  max_lag = 20,
  n_surr = 100,
  bidirectional = TRUE,
  sig_level = 0.95
)
```

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 positive lag.
n_surr	An integer specifying the number of MIAAFT surrogate datasets.
bidirectional	Logical. If TRUE (default), computes both directions.
sig_level	A numeric value between 0 and 1 specifying the significance level. Default is 0.95.

Value

An object of class "xi_ccf".

xi_coefficient *Calculate Chatterjee's Rank Correlation Coefficient (Xi)*

Description

Computes Chatterjee's rank correlation coefficient (Xi) between two numeric vectors. Ties are broken uniformly at random to ensure strict inequalities.

Usage

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

Arguments

x	A numeric vector.
y	A numeric vector of the same length as x.

Value

A numeric scalar representing the Chatterjee's Xi coefficient.

xi_matrix *Multivariate Xi-Correlogram Matrix*

Description

Computes the pairwise directional Chatterjee's Xi coefficient for a multivariate time series dataset. It evaluates both "Lead -> Lag" and "Lag -> Lead" relationships across all variable pairs, as well as the Xi-ACF (autocorrelation) for individual variables.

Usage

```
xi_matrix(x, max_lag = 20, n_surr = 100, sig_level = 0.95)
```

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.
n_surr	An integer specifying the number of MIAAFT surrogate datasets for hypothesis testing.
sig_level	A numeric value between 0 and 1 specifying the significance level for the surrogate threshold. Default is 0.95.

Value

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

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