

# 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](https://doi.org/10.1080/01621459.2020.1758115)> and surrogate data testing methods by Schreiber and Schmitz (1996) <[doi:10.1103/PhysRevLett.77.635](https://doi.org/10.1103/PhysRevLett.77.635)>.

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autoplot.xi_acf	<i>Plot Xi-ACF Comparison</i>
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## 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	<i>Plot Directional Xi-CCF Comparison</i>
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**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.

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autoplot.xi_matrix	<i>Plot Multivariate Xi-Correlogram Matrix</i>
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**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	<i>Extract Individual Xi-CCF from Xi-Matrix</i>
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**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**

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

**Value**

An object of class `xi_ccf`.

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generate_miaaft_surrogate_cpp	<i>Generate a Single MIAAFT Surrogate Matrix</i>
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---

**Description**

Generate a Single MIAAFT Surrogate Matrix

**Usage**

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

**Arguments**

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

**Value**

A numeric matrix representing the generated MIAAFT surrogate.

---

print.xi_acf	<i>Print method for xi_acf objects</i>
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---

**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	<i>Print method for xi_ccf objects</i>
--------------	--

---

**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.

---

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.

---

xi_acf	<i>Xi-ACF Test for Time Series</i>
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---

**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	<i>Directional Xi-CCF Test for Multivariate Time Series</i>
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---

**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	<i>Calculate Chatterjee's Rank Correlation Coefficient (Xi)</i>
----------------	---

---

**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	<i>Multivariate Xi-Correlogram Matrix</i>
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**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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