Package ‘ccid’

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ccid ccid: a change-point detection method for estimating dynamic functional connectivity

Description

The ccid package implements the Cross-Covariance Isolate Detect (CCID) methodology for the estimation of the number and location of multiple change-points in the second-order (cross-covariance or network) structure of multivariate, possibly high-dimensional time series. The method is motivated by the detection of change points in functional connectivity networks for functional magnetic resonance imaging (fMRI), electroencephalography (EEG), magnetencephalography (MEG) and electrocorticography (ECoG) data. The stopping rules used for the change-point detection rely either on thresholding or on the optimization of a model selection criterion. The main routines of the package are detect.th and detect.ic. The functions have been extensively tested on fMRI data, therefore, their parameters have been tuned to work well on this data and the functions might not work well in other structures, such as time series that are negatively serially correlated.

Author(s)

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References


See Also

detect.th and detect.ic.

Examples

# See Examples for the function `detect.th`. 
**detect.ic**

*Multiple change-point detection in the cross-covariance structure of multivariate high-dimensional time series using a model selection criterion optimisation*

**Description**

This function detects multiple change-points in the cross-covariance structure of a multivariate time series using a model selection criterion optimisation.

**Usage**

```r
detect.ic(
    X,
    approach = c("euclidean", "infinity"),
    th_max = 2.1,
    th_sum = 0.5,
    pointsgen = 10,
    scales = -1,
    alpha_gen = 0.1,
    preaverage_gen = FALSE,
    scal_gen = 3,
    min_dist = 1
)
```

**Arguments**

- **X**
  
  A numerical matrix representing the multivariate time series, with the columns representing its components.

- **approach**
  
  A character string, which defines the metric to be used in order to detect the change-points. If `approach = "euclidean"`, which is also the default value, then the $L_2$ metric will be followed for the detection. If `approach = "infinity"`, then the $L_\infty$ metric will be used for the detection.

- **th_max**
  
  A positive real number with default value equal to 2.1. It is used to define the threshold for the change-point overestimation step if the $L_\infty$ metric is chosen in `approach`.

- **th_sum**
  
  A positive real number with default value equal to 0.5. It is used to define the threshold for the change-point overestimation step if the $L_2$ metric is chosen in `approach`.

- **pointsgen**
  
  A positive integer with default value equal to 10. It defines the distance between two consecutive end- or start-points of the right- or left-expanding intervals, respectively; see Details for more information.

- **scales**
  
  Negative integers for wavelet scales, with a small negative integer representing a fine scale. The default value is equal to -1.

- **alpha_gen**
  
  A positive real number with default value equal to 0.1. It is used to define how strict the user wants to be with the penalty used.
preaverage_gen  A logical variable with default value equal to FALSE. If FALSE, then pre-averaging the data is not required. If TRUE, then we need to pre-average the data before proceeding with the detection of the change-points.

scal_gen    A positive integer number with default value equal to 3. It is used to define the way we pre-average the given data sequence only if preaverage_gen = TRUE. See the Details in preaverage for more information on how we pre-average.

min_dist    A positive integer number with default value equal to 1. It is used in order to provide the minimum distance acceptable between detected change-points if such restrictions apply.

Details
The time series $X_t$ is of dimensionality $p$ and we are looking for changes in the cross-covariance structure between the different time series components $X^{(1)}_t, X^{(2)}_t, \ldots, X^{(p)}_t$. We first use a wavelet-based approach for the various given scales in scales in order to transform the given time series $X_t$ to a multiplicative model $Y^{(k)}_t = \sigma^{(k)}_t (Z^{(k)}_t)^2; t = 1, 2, \ldots, T; k = 1, 2, \ldots, d$, where $Z^{(k)}_t$ is a sequence of standard normal random variables, $E(Y^{(k)}_t) = \sigma^{(k)}_t$, and $d$ is the new dimensionality, which depends on the value given in scales. The function has been extensively tested on fMRI data, hence, its parameters have been tuned for this data type. The function might not work well in other structures, such as time series that are negatively serially correlated.

Value
A list with the following components:

- changepoints  The locations of the detected change-points.
- no.of.cpts     The number of the detected change-points.
- sol_path       A vector containing the solution path.
- ic_curve       A vector with values of the information criterion for different number of change-points.

If the minimum distance between the detected change-points is less than the value given in min_dist, then only the number and the locations of the “pruned” change-points are returned.

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References

See Also
detect.th.
Examples

```r
set.seed(11)
A <- matrix(rnorm(10*200), nrow = 200) ## No change-point
M1 <- detect.ic(A, approach = 'euclidean', scales = -1)
M2 <- detect.ic(A, approach = 'infinity', scales = -1)
M1$changepoints
M2$changepoints

detect.th(1)
num.nodes <- 30 # number of nodes
etaA.1 <- 0.95
etaA.2 <- 0.05
pcor1 <- GeneNet::ggm.simulate.pcor(num.nodes, etaA = etaA.1)
pcor2 <- GeneNet::ggm.simulate.pcor(num.nodes, etaA = etaA.2)

n <- 50
data1 <- GeneNet::ggm.simulate.data(n, pcor1)
data2 <- GeneNet::ggm.simulate.data(n, pcor2)
X1 <- rbind(data1, data2, data1, data2) ## change-points at 50, 100, 150
N1 <- detect.ic(X1, approach = 'euclidean', scales = -1)
N2 <- detect.ic(X1, approach = 'infinity', scales = -1)
N1$changepoints
N2$changepoints
N1$no.of.cpts
N2$no.of.cpts
N1$sol_path
N2$sol_path
```

Description

This function detects multiple change-points in the cross-covariance structure of a multivariate high-dimensional time series using a thresholding based procedure and, wherever possible, extraction of the component time series where the changes occurred.

Usage

```r
detect.th(
  X,
  approach = c("euclidean", "infinity"),
  th_max = 2.25,
  th_sum = 0.65,
  pointsgen = 10,
  scales = -1,
)```
preaverage_gen = FALSE,
scal_gen = 3,
min_dist = 1 )

Arguments

X  A numerical matrix representing the multivariate time series, with the columns representing its components.

approach  A character string, which defines the metric to be used in order to detect the change-points. If approach = “euclidean”, which is also the default value, then the $L_2$ metric will be followed for the detection. If approach = “infinity”, then the $L_\infty$ metric will be used for the detection.

th_max  A positive real number with default value equal to 2.25. It is used to define the threshold if the $L_\infty$ metric is chosen in approach.

th_sum  A positive real number with default value equal to 0.65. It is used to define the threshold if the $L_2$ metric is chosen in approach.

pointsgen  A positive integer with default value equal to 10. It defines the distance between two consecutive end- or start-points of the right- or left-expanding intervals, respectively; see Details for more information.

scales  Negative integers for wavelet scales, with a small negative integer representing a fine scale. The default value is equal to -1.

preaverage_gen  A logical variable with default value equal to FALSE. If FALSE, then pre-averaging the data is not required. If TRUE, then we need to pre-average the data before proceeding with the detection of the change-points.

scal_gen  A positive integer number with default value equal to 3. It is used to define the way we pre-average the given data sequence only if preaverage_gen = TRUE. See the Details in preaverage for more information on how we pre-average.

min_dist  A positive integer number with default value equal to 1. It is used in order to provide the minimum distance acceptable between detected change-points if such restrictions apply.

Details

The time series $X_t$ is of dimensionality $p$ and we are looking for changes in the cross-covariance structure between the different time series components $X^{(1)}_t, X^{(2)}_t, \ldots, X^{(p)}_t$. We first use a wavelet-based approach for the various given scales in scales in order to transform the given time series $X_t$ to a multiplicative model $Y^{(k)}_t = \sigma^{(k)}_t (Z^{(k)}_t)^2; t = 1, 2, \ldots, T; k = 1, 2, \ldots, d$, where $Z^{(k)}_t$ is a sequence of standard normal random variables, $E(Y^{(k)}_t) = \sigma^{(k)}_t$, and $d$ is the new dimensionality, which depends on the value given in scales. The function has been extensively tested on fMRI data, hence, its parameters have been tuned for this data type. The function might not work well in other structures, such as time series that are negatively serially correlated.

Value

A list with the following components:
detect.th

changepoints  The locations of the detected change-points.
no.of.cpts  The number of the detected change-points.
time_series  A list with two components that indicates which combinations
            of time series are responsible for each change-point detected. See the outcome
            values time_series_indicator and most_important of the function
            match.cpt.ts for more information.

If the minimum distance between the detected change-points is less than the value given in min_dist,
then only the number and the locations of the “pruned” change-points are returned.

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References

“Cross-covariance isolate detect: a new change-point method for estimating dynamic functional

See Also

detect.ic.

Examples

set.seed(111)
A <- matrix(rnorm(20*400), nrow = 400) ## No change-point
M1 <- detect.th(A, approach = 'euclidean', scales = -1)
M2 <- detect.th(A, approach = 'infinity', scales = -1)
M1
M2

set.seed(111)
num.nodes <- 40 # number of nodes
etA.1  <- 0.95
etA.2  <- 0.05
pcor1  <- GeneNet::ggm.simulate.pcor(num.nodes, etaA = etaA.1)
pcor2  <- GeneNet::ggm.simulate.pcor(num.nodes, etaA = etaA.2)
n <- 100
data1  <- GeneNet::ggm.simulate.data(n, pcor1)
data2  <- GeneNet::ggm.simulate.data(n, pcor2)

X1 <- rbind(data1, data2) ## change-point at 100
N1 <- detect.th(X1, approach = 'euclidean', scales = -1)
N2 <- detect.th(X1, approach = 'infinity', scales = -1)
N1$changepoints
N1$time_series
N2$changepoints
N2$time_series
match.cpt.ts

Associating the change-points with the component time series

Description

This function performs a contrast function based approach in order to match each change-point and time series. In simple terms, for a given change-point set this function associates each change-point with the respective data sequence (or sequences) from which it was detected.

Usage

match.cpt.ts(
  X,
  cpt,
  thr_const = 1,
  thr_fin = thr_const * sqrt(2 * log(nrow(X))),
  scales = -1,
  count = 5
)

Arguments

X
  A numerical matrix representing the multivariate periodograms. Each column contains a different periodogram which is the result of applying the wavelet transformation to the initial multivariate time series.

cpt
  A positive integer vector with the locations of the change-points. If missing, then our approach with the $L_2$ aggregation is called internally to extract the change-points in X.

thr_const
  A positive real number with default value equal to 1. It is used to define the threshold; see thr_fin.

thr_fin
  With $T$ the length of the data sequence, this is a positive real number with default value equal to $\text{thr}_\text{const} \times \log(T)$. It is the threshold, which is used in the detection process.

scales
  Negative integers for the wavelet scales used to create the periodograms, with a small negative integer representing a fine scale. The default value is equal to -1.

count
  Positive integer with default value equal to 5. It can be used so that the function will return only the count most important matches of each change-points with the time series.

Value

A list with the following components:

| time_series_indicator | A list of matrices. There are as many matrices as the number of change-points. Each change-point has its own matrix, with |

This function pre-processes the given data in order to remove serial correlation that might exist in the given data.
Arguments

\( X \)  
A numerical matrix representing the multivariate time series, with the columns representing its components.

\( scal \)  
A positive integer number with default value equal to 3. It is used to define the way we pre-average the data sequences.

Details

For a given natural number \( scal \) and data matrix \( X \) of dimensionality \( T \times d \), let us denote by \( Q = \lceil T/scal \rceil \). Then, \texttt{preaverage} calculates, for all \( j = 1, 2, ..., d \),

\[
\tilde{X}_{q,j} = \frac{1}{scal} \sum_{t=(q-1)*sc+1}^{q*sc} X_{t,j},
\]

for \( q = 1, 2, ..., Q-1 \), while

\[
\tilde{x}_{Q,j} = (T - (Q-1)*sc)^{-1} \sum_{t=(Q-1)*sc+1}^{T} X_{t,j}.
\]

Value

The “preaveraged” matrix \( \tilde{X} \) of dimensionality \( Q \times d \), as explained in Details.

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References


Examples

```r
A <- matrix(1:32, 8, 4)
A
A1 <- preaverage(A, scal = 3)
A1
```
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