

# Package ‘VARDetect’

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**Type** Package

**Title** Multiple Change Point Detection in Structural VAR Models

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**Description** Implementations of Thresholded Block Segmentation Scheme (TBSS) and Low-rank plus Sparse Two Step Procedure (LSTSP) algorithms for detecting multiple changes in structural VAR models. The package aims to address the problem of change point detection in piecewise stationary VAR models, under different settings regarding the structure of their transition matrices (autoregressive dynamics); specifically, the following cases are included: (i) (weakly) sparse, (ii) structured sparse, and (iii) low rank plus sparse. It includes multiple algorithms and related extensions from Safikhani and Shojai (2020) <doi:10.1080/01621459.2020.1770097> and Bai, Safikhani and Michailidis (2020) <doi:10.1109/TSP.2020.2993145>.

**License** GPL-2

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detection_check	<i>Function for detection performance check</i>
-----------------	---

---

### Description

Function for detection performance check

### Usage

```
detection_check(pts.final, brk, nob, critval = 5)
```

### Arguments

pts.final	a list of estimated change points
brk	the true change points
nob	length of time series
critval	critical value for selection rate. Default value is 5. Specifically, to compute the selection rate, a selected break point is counted as a “success” for the $j$ -th true break point, $t_j$ , if it falls in the interval $[t_j - (t_j - t_{j-1})/critval, t_j + (t_{j+1} - t_j)/critval]$ , $j = 1, \dots, m_0$ .

### Value

a matrix of detection summary results, including the absolute error, selection rate and relative location. The absolute error of the locations of the estimated break points is defined as  $error_j = |\tilde{t}_j^f - t_j|$ ,  $j = 1, \dots, m_0$ .

**Examples**

```

# an example of 10 replicates result
set.seed(1)
nob <- 1000
brk <- c(333, 666, nob+1)
cp.list <- vector('list', 10)
for(i in 1:10){
  cp.list[[i]] <- brk[1:2] + sample(c(-50:50),1)
}
# some replicate fails to detect all the change point
cp.list[[2]] <- cp.list[[2]][1]
cp.list[4] <- list(NULL) # setting 4'th element to NULL.
# some replicate overestimate the number of change point
cp.list[[3]] <- c(cp.list[[3]], 800)
cp.list
res <- detection_check(cp.list, brk, nob, critval = 5)
res
# use a stricter critical value
res <- detection_check(cp.list, brk, nob, critval = 10)
res

```

---

eval\_func

*Evaluation function, return the performance of simulation results*


---

**Description**

Evaluation function, return the performance of simulation results

**Usage**

```
eval_func(true_mats, est_mats)
```

**Arguments**

true_mats	a list of true matrices for all segments, the length of list equals to the true number of segments
est_mats	a list of estimated matrices for all simulation replications, for each element, it is a list of numeric matrices, representing the estimated matrices for segments

**Value**

A list, containing the results for all measurements

**sensitivity** A numeric vector, containing all the results for sensitivity over all replications

**specificity** A numeric vector, including all the results for specificity over all replications

**accuracy** A numeric vector, the results for accuracy over all replications

**mcc** A numeric vector, the results for Matthew's correlation coefficients over all replications

**false\_reps** An integer vector, recording all the replications which falsely detects the change points, over-detect or under-detect

**Examples**

```

true_mats <- vector('list', 2)
true_mats[[1]] <- matrix(c(1, 0, 0.5, 0.8), 2, 2, byrow = TRUE)
true_mats[[2]] <- matrix(c(0, 0, 0, 0.75), 2, 2, byrow = TRUE)
est_mats <- vector('list', 5)
for(i in 1:5){
  est_mats[[i]] <- vector('list', 2)
  est_mats[[i]][[1]] <- matrix(sample(c(0, 1, 2), size = 4, replace = TRUE), 2, 2, byrow = TRUE)
  est_mats[[i]][[2]] <- matrix(sample(c(0, 1), size = 4, replace = TRUE), 2, 2, byrow = TRUE)
}
perf_eval <- eval_func(true_mats, est_mats)

```

---

hausdorff\_check

*Function for Hausdorff distance computation*


---

**Description**

The function includes two Hausdorff distance. The first one is `hausdorff_true_est` ( $d(A_n, \tilde{A}_n^f)$ ): for each estimated change point, we find the closest true CP and compute the distance, then take the maximum of distances. The second one is `hausdorff_est_true` ( $d(\tilde{A}_n^f, A_n)$ ): for each true change point, find the closest estimated change point and compute the distance, then take the maximum of distances.

**Usage**

```
hausdorff_check(pts.final, brk)
```

**Arguments**

<code>pts.final</code>	a list of estimated change points
<code>brk</code>	the true change points

**Value**

Hausdorff distance summary results, including mean, standard deviation and median.

**Examples**

```

## an example of 10 replicates result
set.seed(1)
nob <- 1000
brk <- c(333, 666, nob+1)
cp.list <- vector('list', 10)
for(i in 1:10){
  cp.list[[i]] <- brk[1:2] + sample(c(-50:50),1)
}
# some replicate fails to detect all the change point
cp.list[[2]] <- cp.list[[2]][1]

```

```

cp.list[4] <- list(NULL)      # setting 4'th element to NULL.
# some replicate overestimate the number of change point
cp.list[[3]] <- c(cp.list[[3]], 800)
cp.list
res <- hausdorff_check(cp.list, brk)
res

```

---

lag_selection	<i>Select the lag of the VAR model using total BIC method</i>
---------------	---

---

### Description

Select the lag of the VAR model (if the lag is unknown) using BIC method for total segments

### Usage

```

lag_selection(
  data,
  method = c("sparse", "group sparse", "fLS"),
  lag_candidates
)

```

### Arguments

data            input data matrix, each column represents the time series component  
method            method is sparse  
lag\_candidates    potential lag selection set

### Value

selected lag for VAR series

**select\_lag** An integer no less than 1 represents the selected lag of time series.

### Examples

```

nob <- 1000; p <- 15
brk <- c(floor(nob / 2), nob + 1)
m <- length(brk)
q.t <- 2 # the lag of VAR model for simulation
signals <- c(-0.8, 0.6, 0.4)
try <- simu_var(method = "sparse", nob = nob, k = p, brk = brk,
               signals = signals, lags_vector = c(1, 2),
               sp_pattern = "off-diagonal")
data <- try$series; data <- as.matrix(data)

# Apply lag selection to determine the lag for the given time series
lag_candi <- c(1, 2, 3, 4)

```

```
select_lag <- lag_selection(data = data,
                           method = "sparse", lag_candidates = lag_candi)
print(select_lag)
```

---

 lstsp

---

*Main function for the low rank plus sparse structure VAR model*


---

## Description

Main function for the low-rank plus sparse structure VAR model

## Usage

```
lstsp(
  data,
  lambda.1 = NULL,
  mu.1 = NULL,
  lambda.1.seq = NULL,
  mu.1.seq = NULL,
  lambda.2 = NULL,
  mu.2 = NULL,
  lambda.3 = NULL,
  mu.3 = NULL,
  alpha_L = 0.25,
  omega = NULL,
  h = NULL,
  step.size = NULL,
  tol = 1e-04,
  niter = 100,
  backtracking = TRUE,
  skip = 5,
  cv = FALSE,
  nfold = NULL,
  verbose = FALSE
)
```

## Arguments

<code>data</code>	A $n$ by $p$ dataset matrix
<code>lambda.1</code>	tuning parameter for sparse component for the first step
<code>mu.1</code>	tuning parameter for low rank component for the first step
<code>lambda.1.seq</code>	a sequence of <code>lambda</code> to the left segment for cross-validation, it's not mandatory to provide
<code>mu.1.seq</code>	a sequence of <code>mu</code> to the left segment, low rank component tuning parameter
<code>lambda.2</code>	tuning parameter for sparse for the second step

mu.2	tuning parameter for low rank for the second step
lambda.3	tuning parameter for estimating sparse components
mu.3	tuning parameter for estimating low rank components
alpha_L	a positive numeric value, indicating the restricted space of low rank component, default is 0.25
omega	tuning parameter for information criterion, the larger of omega, the fewer final selected change points
h	window size of the first rolling window step
step.size	rolling step
tol	tolerance for the convergence in the second screening step, indicates when to stop
niter	the number of iterations required for FISTA algorithm
backtracking	A boolean argument to indicate use backtrack to FISTA model
skip	The number of observations need to skip near the boundaries
cv	A boolean argument, indicates whether the user will apply cross validation to select tuning parameter, default is FALSE
nfold	An positive integer, the number of folds for cross validation
verbose	If is TRUE, then it will print all information about current step.

### Value

A list object including

**data** the original dataset

**q** the time lag for the time series, in this case, it is 1

**cp** Final estimated change points

**sparse\_mats** Final estimated sparse components

**lowrank\_mats** Final estimated low rank components

**est\_phi** Final estimated model parameter, equals to sum of low rank and sparse components

**time** Running time for the LSTSP algorithm

### Examples

```
nob <- 100
p <- 15
brk <- c(50, nob+1)
rank <- c(1, 3)
signals <- c(-0.7, 0.8)
singular_vals <- c(1, 0.75, 0.5)
info_ratio <- rep(0.35, 2)
try <- simu_var(method = "LS", nob = nob, k = p, lags = 1, brk = brk,
               sigma = as.matrix(diag(p)), signals = signals,
               rank = rank, singular_vals = singular_vals, info_ratio = info_ratio,
               sp_pattern = "off-diagonal", spectral_radius = 0.9)
```

```

data <- try$series

lambda1 = lambda2 = lambda3 <- c(2.5, 2.5)
mu1 = mu2 = mu3 <- c(15, 15)
fit <- lstsp(data, lambda.1 = lambda1, mu.1 = mu1,
             lambda.2 = lambda2, mu.2 = mu2,
             lambda.3 = lambda3, mu.3 = mu3, alpha_L = 0.25,
             step.size = 5, niter = 20, skip = 5,
             cv = FALSE, verbose = FALSE)
summary(fit)
plot(fit, data, display = "cp")
plot(fit, data, display = "param")

```

---

plot.VARDetect.result *Plotting the output from VARDetect.result class*

---

## Description

Plotting method for S3 object of class `VARDetect.result`

## Usage

```

## S3 method for class 'VARDetect.result'
plot(
  x,
  display = c("cp", "param", "granger", "density"),
  threshold = 0.1,
  layout = c("circle", "star", "nicely"),
  ...
)

```

## Arguments

<code>x</code>	a <code>VARDetect.result</code> object
<code>display</code>	a character string, indicates the object the user wants to plot; possible values are " <code>cp</code> " input time series together with the estimated change points " <code>param</code> " estimated model parameters " <code>granger</code> " present the model parameters through Granger causal networks " <code>density</code> " plot the sparsity levels across all segments
<code>threshold</code>	a positive numeric value, indicates the threshold to present the entries in the sparse matrices
<code>layout</code>	a character string, indicating the layout of the Granger network
<code>...</code>	not in use



**Value**

A plot for change points or a series of plots for Granger causal networks for estimated model parameters

**Examples**

```
nob <- 1000
p <- 15
brk <- c(floor(nob / 3), floor(2 * nob / 3), nob + 1)
m <- length(brk)
q.t <- 1
try <- simu_var('sparse', nob=nob, k=p, lags=q.t, brk=brk, sp_pattern="off-diagonal", seed = 1)
data <- try$series
data <- as.matrix(data)
fit <- tbss(data, method = "sparse", q = q.t)
plot(fit, display = "cp")
plot(fit, display = "param")
plot(fit, display = "granger", threshold = 0.2, layout = "nicely")
plot(fit, display = "density", threshold = 0.2)
```

---

plot\_density

*Function to plot the sparsity levels for estimated model parameters*


---

**Description**

A function to plot lineplot for sparsity levels of estimated model parameters

**Usage**

```
plot_density(est_mats, threshold = 0.1)
```

**Arguments**

est_mats	A list of numeric matrices, the length of list equals to the number of estimated segments
threshold	A numeric value, set as a threshold, the function only counts the non-zeros with absolute magnitudes larger than threshold

**Value**

A plot for sparsity density across over all estimated segments

**Examples**

```
set.seed(1)
est_mats <- list(matrix(rnorm(400, 0, 2), 20, 20), matrix(rnorm(400), 20, 20))
plot_density(est_mats, threshold = 0.25)
```

---

plot_granger	<i>Function to plot Granger causality networks</i>
--------------	--

---

**Description**

A function to plot Granger causal network for each segment via estimated sparse component

**Usage**

```
plot_granger(est_mats, threshold = 0.1, layout)
```

**Arguments**

est_mats	A list of numeric sparse matrices, indicating the estimated sparse components for each segment
threshold	A numeric positive value, used to determine the threshold to present the edges
layout	A character string, indicates the layout for the igraph plot argument

**Value**

A series of plots of Granger networks of VAR model parameters

**Examples**

```
set.seed(1)
est_mats <- list(matrix(rnorm(400, 0, 1), 20, 20))
plot_granger(est_mats, threshold = 2, layout = "circle")
plot_granger(est_mats, threshold = 2, layout = "star")
plot_granger(est_mats, threshold = 2, layout = "nicely")
```

---

plot_matrix	<i>Plot the AR coefficient matrix</i>
-------------	---------------------------------------

---

**Description**

Plot the AR coefficient matrix

**Usage**

```
plot_matrix(phi, p)
```

**Arguments**

phi	combined coefficient matrices for all lags
p	number of segments times number of lags

**Value**

a plot of AR coefficient matrix

**Examples**

```
nob <- 4 * 10^3
p <- 15
brk <- c(floor(nob / 3), floor(2 * nob / 3), nob + 1)
m0 <- length(brk) - 1
q.t <- 2
m <- m0 + 1
sp_density <- rep(0.05, m*q.t) #sparsity level (5%)
try <- simu_var("sparse", nob = nob, k = p, lags = q.t, brk = brk,
               sp_pattern = "random", sp_density = sp_density)
print(plot_matrix(do.call("cbind", try$model_param), m * q.t))
```

---

```
print.VARDetect.result
```

*Function to print the change points estimated by VARDetect*

---

**Description**

Print the estimated change points of class VARDetect.result

**Usage**

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

**Arguments**

x	a VARDetect.result class object
...	not in use

**Value**

Print the estimated change points

**Examples**

```
nob <- 1000
p <- 15
brk <- c(floor(nob / 3), floor(2 * nob / 3), nob + 1)
m <- length(brk)
q.t <- 1
try <- simu_var('sparse', nob=nob, k=p, lags=q.t, brk=brk, sp_pattern="off-diagonal", seed=1)
data <- try$series
```

```
data <- as.matrix(data)
fit <- tbss(data, method = "sparse", q = q.t)
print(fit)
```

---

simu\_lstsp

*Function to deploy simulation with LSTSP algorithm*

---

## Description

A function to generate simulation with LSTSP algorithm

## Usage

```
simu_lstsp(
  nreps,
  simu_method = c("LS"),
  nob,
  k,
  lags = 1,
  lags_vector = NULL,
  brk,
  sigma,
  skip = 50,
  group_mats = NULL,
  group_type = c("columnwise", "rowwise"),
  group_index = NULL,
  sparse_mats = NULL,
  sp_density = NULL,
  signals = NULL,
  rank = NULL,
  info_ratio = NULL,
  sp_pattern = c("off-diagonal", "diagonal", "random"),
  singular_vals = NULL,
  spectral_radius = 0.9,
  alpha_L = 0.25,
  lambda.1 = NULL,
  mu.1 = NULL,
  lambda.1.seq = NULL,
  mu.1.seq = NULL,
  lambda.2,
  mu.2,
  lambda.3,
  mu.3,
  omega = NULL,
  h = NULL,
  step.size = NULL,
  tol = 1e-04,
```

```

    niter = 100,
    backtracking = TRUE,
    rolling.skip = 5,
    cv = FALSE,
    nfold = NULL,
    verbose = FALSE
)

```

### Arguments

nreps	A positive integer, indicating the number of simulation replications
simu_method	the structure of time series: only available for "LS"
nob	sample size
k	dimension of transition matrix
lags	lags of VAR time series. Default is 1.
lags_vector	a vector of lags of VAR time series for each segment
brk	a vector of break points with (nob+1) as the last element
sigma	the variance matrix for error term
skip	an argument to control the leading data points to obtain a stationary time series
group_mats	transition matrix for group sparse case
group_type	type for group lasso: "columnwise", "rowwise". Default is "columnwise".
group_index	group index for group lasso.
sparse_mats	transition matrix for sparse case
sp_density	if we choose random pattern, we should provide the sparsity density for each segment
signals	manually setting signal for each segment (including sign)
rank	if we choose method is low rank plus sparse, we need to provide the ranks for each segment
info_ratio	the information ratio leverages the signal strength from low rank and sparse components
sp_pattern	a choice of the pattern of sparse component: diagonal, 1-off diagonal, random, custom
singular_vals	singular values for the low rank components
spectral_radius	to ensure the time series is piecewise stationary.
alpha_L	a positive numeric value, indicating the restricted space of low rank component, default is 0.25
lambda.1	tuning parameter for sparse component for the first step
mu.1	tuning parameter for low rank component for the first step
lambda.1.seq	a sequence of lambda to the left segment for cross-validation, it's not mandatory to provide

mu.1.seq	a sequence of mu to the left segment, low rank component tuning parameter
lambda.2	tuning parameter for sparse for the second step
mu.2	tuning parameter for low rank for the second step
lambda.3	tuning parameter for estimating sparse components
mu.3	tuning parameter for estimating low rank components
omega	tuning parameter for information criterion, the larger of omega, the fewer final selected change points
h	window size of the first rolling window step
step.size	rolling step
tol	tolerance for the convergence in the second screening step, indicates when to stop
niter	the number of iterations required for FISTA algorithm
backtracking	A boolean argument to indicate use backtrack to FISTA model
rolling.skip	The number of observations need to skip near the boundaries
cv	A boolean argument, indicates whether the user will apply cross validation to select tuning parameter, default is FALSE
nfold	An positive integer, the number of folds for cross validation
verbose	If is TRUE, then it will print all information about current step.

### Value

A S3 object of class `VARDetect.simu.result`, containing the following entries:

**sizes** A 2-d numeric vector, indicating the size of time series data

**true\_lag** True time lags for the process, here is fixed to be 1.

**true\_lagvector** A vector recording the time lags for different segments, not available under this model setting, here is fixed to be NULL

**true\_cp** True change points for simulation, a numeric vector

**true\_sparse** A list of numeric matrices, indicating the true sparse components for all segments

**true\_lowrank** A list of numeric matrices, indicating the true low rank components for all segments

**est\_cps** A list of estimated change points, including all replications

**est\_lag** A numeric value, estimated time lags, which is user specified

**est\_lagvector** A vector for estimated time lags, not available for this model, set as NULL.

**est\_sparse\_mats** A list of estimated sparse components for all replications

**est\_lowrank\_mats** A list of estimated low rank components for all replications

**est\_phi\_mats** A list of estimated model parameters, transition matrices for VAR model

**running\_times** A numeric vector, containing all running times

**Examples**

```
nob <- 100
p <- 15
brk <- c(50, nob+1)
rank <- c(1, 3)
signals <- c(-0.7, 0.8)
singular_vals <- c(1, 0.75, 0.5)
info_ratio <- rep(0.35, 2)
lambda1 = lambda2 = lambda3 <- c(2.5, 2.5)
mu1 = mu2 = mu3 <- c(15, 15)
try_simu <- simu_lstsp(nreps = 3, simu_method = "LS", nob = nob, k = p,
  brk = brk, sigma = diag(p), signals = signals,
  rank = rank, singular_vals = singular_vals,
  info_ratio = info_ratio, sp_pattern = "off-diagonal",
  spectral_radius = 0.9, lambda.1 = lambda1, mu.1 = mu1,
  lambda.2 = lambda2, mu.2 = mu2, lambda.3 = lambda3,
  mu.3 = mu3, step.size = 5, niter = 20, rolling.skip = 5,
  cv = FALSE, verbose = TRUE)
summary(try_simu, critical = 5)
```

---

simu\_tbss

*Simulation function for TBSS algorithm*


---

**Description**

Function for deploying simulation using TBSS algorithm

**Usage**

```
simu_tbss(
  nreps,
  simu_method = c("sparse", "group sparse", "fLS"),
  nob,
  k,
  lags = 1,
  lags_vector = NULL,
  brk,
  sigma,
  skip = 50,
  group_mats = NULL,
  group_type = c("columnwise", "rowwise"),
  group_index = NULL,
  sparse_mats = NULL,
  sp_density = NULL,
  signals = NULL,
  rank = NULL,
  info_ratio = NULL,
```

```

sp_pattern = c("off-diagonal", "diagonal", "random"),
singular_vals = NULL,
spectral_radius = 0.9,
est_method = c("sparse", "group sparse", "fLS"),
q = 1,
tol = 0.01,
lambda.1.cv = NULL,
lambda.2.cv = NULL,
mu = NULL,
group.index = NULL,
group.case = c("columnwise", "rowwise"),
max.iteration = 100,
refit = FALSE,
block.size = NULL,
blocks = NULL,
use.BIC = TRUE,
an.grid = NULL,
verbose = FALSE
)

```

### Arguments

nreps	A numeric integer number, indicates the number of simulation replications
simu_method	the structure of time series: "sparse", "group sparse", and "fLS"
nob	sample size
k	dimension of transition matrix
lags	lags of VAR time series. Default is 1.
lags_vector	a vector of lags of VAR time series for each segment
brk	a vector of break points with (nob+1) as the last element
sigma	the variance matrix for error term
skip	an argument to control the leading data points to obtain a stationary time series
group_mats	transition matrix for group sparse case
group_type	type for group lasso: "columnwise", "rowwise". Default is "columnwise".
group_index	group index for group lasso.
sparse_mats	transition matrix for sparse case
sp_density	if we choose random pattern, we should provide the sparsity density for each segment
signals	manually setting signal for each segment (including sign)
rank	if we choose method is low rank plus sparse, we need to provide the ranks for each segment
info_ratio	the information ratio leverages the signal strength from low rank and sparse components
sp_pattern	a choice of the pattern of sparse component: diagonal, 1-off diagonal, random, custom



singular_vals	singular values for the low rank components
spectral_radius	to ensure the time series is piecewise stationary.
est_method	method: sparse, group sparse, and fixed low rank plus sparse. Default is sparse
q	the AR order
tol	tolerance for the fused lasso
lambda.1.cv	tuning parameter lambda_1 for fused lasso
lambda.2.cv	tuning parameter lambda_2 for fused lasso
mu	tuning parameter for low rank component, only available when method is set to "fLS"
group.index	group index for group sparse case
group.case	group sparse pattern: column, row.
max.iteration	max number of iteration for the fused lasso
refit	logical; if TRUE, refit the VAR model for parameter estimation. Default is FALSE.
block.size	the block size
blocks	the blocks
use.BIC	use BIC for k-means part
an.grid	a vector of an for grid searching
verbose	a Boolean argument; if TRUE, function provides detailed information. Default is FALSE

### Value

A S3 object of class, named `VARDetect.simu.result`

**est\_cps** A list of estimated change points, including all replications

**est\_sparse\_mats** A list of estimated sparse components for all replications

**est\_lowrank\_mats** A list of estimated low rank components for all replications

**est\_phi\_mats** A list of estimated model parameters, transition matrices for VAR model

**running\_times** A numeric vector, containing all running times

### Examples

```
nob <- 4000; p <- 15
brk <- c(floor(nob / 3), floor(2 * nob / 3), nob + 1)
m <- length(brk); q.t <- 1
sp_density <- rep(0.05, m * q.t)
signals <- c(-0.6, 0.6, -0.6)
try_simu <- simu_tbss(nreps = 3, simu_method = "sparse", nob = nob,
                     k = p, lags = q.t, brk = brk, sigma = diag(p),
                     signals = signals, sp_density = sp_density,
                     sp_pattern = "random", est_method = "sparse", q = q.t,
                     refit = TRUE)
```

---

 simu\_var

*Generate VAR(p) model data with break points*


---

### Description

This function is used for generate simulated time series

### Usage

```
simu_var(
  method = c("sparse", "group sparse", "fLS", "LS"),
  nob = 300,
  k = 20,
  lags = 1,
  lags_vector = NULL,
  brk,
  sigma = NULL,
  skip = 50,
  spectral_radius = 0.98,
  seed = NULL,
  sp_density = NULL,
  group_mats = NULL,
  group_index = NULL,
  group_type = c("columnwise", "rowwise"),
  sparse_mats = NULL,
  sp_pattern = c("off-diagonal", "diagonal", "random"),
  rank = NULL,
  info_ratio = NULL,
  signals = NULL,
  singular_vals = NULL
)
```

### Arguments

method	the structure of time series: "sparse", "group sparse", "fLS", "LS"
nob	sample size
k	dimension of transition matrix
lags	lags of VAR time series. Default is 1.
lags_vector	a vector of lags of VAR time series for each segment
brk	a vector of break points with (nob+1) as the last element
sigma	the variance matrix for error term
skip	an argument to control the leading data points to obtain a stationary time series
spectral_radius	to ensure the time series is piecewise stationary.

seed	an argument to control the random seed. Default seed is 1.
sp_density	if we choose random pattern, we should provide the sparsity density for each segment
group_mats	transition matrix for group sparse case
group_index	group index for group lasso.
group_type	type for group lasso: "columnwise", "rowwise". Default is "columnwise".
sparse_mats	transition matrix for sparse case
sp_pattern	a choice of the pattern of sparse component: diagonal, 1-off diagonal, random, custom
rank	if we choose method is low rank plus sparse, we need to provide the ranks for each segment
info_ratio	the information ratio leverages the signal strength from low rank and sparse components
signals	manually setting signal for each segment (including sign)
singular_vals	singular values for the low rank components

### Value

A list object, which contains the followings

**series** matrix of timeseries data

**noises** matrix of noise term data

**sparse\_mats** list of sparse matrix in the transition matrix

**lowrank\_mats** list of low-rank matrix in the transition matrix

### Examples

```
nob <- (10^3 * 4) # number of time points
p <- 15 # number of time series components
brk <- c(floor(nob / 3), floor(2 * nob / 3), nob + 1)
m0 <- length(brk) - 1 # number of break points
q.t <- 2 # the true AR order
m <- m0 + 1 # number of segments
sp_density <- rep(0.05, m * q.t) # sparsity level (5%)
try <- simu_var("sparse", nob = nob, k = p, lags = q.t, brk = brk,
               sp_pattern = "random", sp_density = sp_density)
print(plot_matrix(do.call("cbind", try$model_param), m * q.t))
```

---

```
summary.VARDetect.result
```

*Function to summarize the change points estimated by VARDetect*

---

### Description

Summary method for objects of class `VARDetect.result`

### Usage

```
## S3 method for class 'VARDetect.result'
summary(object, threshold = 0.1, ...)
```

### Arguments

<code>object</code>	a <code>VARDetect.result</code> object
<code>threshold</code>	A numeric positive value, used to determine the threshold of nonzero entries
<code>...</code>	not in use

### Value

A series of summary, including the estimated change points, running time

### Examples

```
nob <- 1000
p <- 15
brk <- c(floor(nob / 3), floor(2 * nob / 3), nob + 1)
m <- length(brk)
q.t <- 1
try <- simu_var('sparse', nob=nob, k=p, lags=q.t, brk=brk, sp_pattern="off-diagonal", seed=1)
data <- try$series
data <- as.matrix(data)
fit <- tbss(data, method = "sparse", q = q.t)
summary(fit)
```

---

```
summary.VARDetect.simu.result
```

*A function to summarize the results for simulation*

---

### Description

A function to summarize the results for simulation class `VARDetect.simu.result`

**Usage**

```
## S3 method for class 'VARDetect.simu.result'
summary(object, critical = 5, ...)
```

**Arguments**

<code>object</code>	A S3 object of class <code>VARDetect.simu.result</code>
<code>critical</code>	A positive integer, set as the critical value defined in selection rate, to control the range of success, default is 5
<code>...</code>	not in use

**Value**

A series of summary, including the selection rate, Hausdorff distance, and statistical measurements, running times

**Examples**

```
nob <- 4000; p <- 15
brk <- c(floor(nob / 3), floor(2 * nob / 3), nob + 1)
m <- length(brk); q.t <- 1
sp_density <- rep(0.05, m * q.t)
signals <- c(-0.6, 0.6, -0.6)
try_simu <- simu_tbss(nreps = 3, simu_method = "sparse", nob = nob,
                     k = p, lags = q.t, brk = brk, sigma = diag(p),
                     signals = signals, sp_density = sp_density,
                     sp_pattern = "random", est_method = "sparse",
                     q = q.t, refit = TRUE)
summary(try_simu, critical = 5)
```

---

 tbss

*Block segmentation scheme (BSS).*


---

**Description**

Perform the block segmentation scheme (BSS) algorithm to detect the structural breaks in large scale high-dimensional non-stationary VAR models.

**Usage**

```
tbss(
  data,
  method = c("sparse", "group sparse", "fLS"),
  group.case = c("columnwise", "rowwise"),
  group.index = NULL,
  lambda.1.cv = NULL,
```

```

lambda.2.cv = NULL,
mu = NULL,
q = 1,
max.iteration = 50,
tol = 10^(-2),
block.size = NULL,
blocks = NULL,
refit = FALSE,
use.BIC = TRUE,
an.grid = NULL,
verbose = FALSE
)

```

### Arguments

<code>data</code>	input data matrix, with each column representing the time series component
<code>method</code>	method: sparse, group sparse, and fixed low rank plus sparse. Default is sparse
<code>group.case</code>	group sparse pattern: column, row.
<code>group.index</code>	group index for group sparse case
<code>lambda.1.cv</code>	tuning parameter $\lambda_{1}$ for fused lasso
<code>lambda.2.cv</code>	tuning parameter $\lambda_{2}$ for fused lasso
<code>mu</code>	tuning parameter for low rank component, only available when method is set to "fLS"
<code>q</code>	the AR order
<code>max.iteration</code>	max number of iteration for the fused lasso
<code>tol</code>	tolerance for the fused lasso
<code>block.size</code>	the block size
<code>blocks</code>	the blocks
<code>refit</code>	logical; if TRUE, refit the VAR model for parameter estimation. Default is FALSE.
<code>use.BIC</code>	use BIC for k-means part
<code>an.grid</code>	a vector of an for grid searching
<code>verbose</code>	a boolean argument to determine whether provide detailed outputs for each step. Default is FALSE

### Value

S3 object of class `VARDetect.result`, which contains the followings

**data** the original dataset

**q** the time lag user specified, a numeric value

**cp** final estimated change points, a numeric vector

**sparse\_mats** estimated sparse components for each segment, a list of numeric matrices

**lowrank\_mats** estimated low rank components for each segment, a list of numeric matrices  
**est\_phi** estimated final model parameters, the summation of the sparse and the low rank components  
**time** computation time for each step

### Examples

```
#### sparse VAR model
nob <- (10^3) # number of time points
p <- 15; # number of time series components
brk <- c(floor(nob/3), floor(2*nob/3), nob+1); # true break points with nob+1 as the last element
m0 <- length(brk) -1; # number of break points
q.t <- 1; # the true AR order
m <- m0+1 #number of segments
try<-simu_var('sparse', nob=nob, k=p, lags=q.t, brk = brk, sp_pattern="off-diagonal", seed=1)
data <- try$series
data <- as.matrix(data)
#run the bss method
fit <- tbss(data, method = "sparse", q = q.t)
print(fit)
summary(fit)
plot(fit, data, display = "cp")
plot(fit, data, display = "param")
```

```
##### Example for fixed low rank plus sparse structure VAR model
nob <- 300
p <- 15
brk <- c(floor(nob/3), floor(2*nob/3), nob+1)
m <- length(brk)
q.t <- 1
signals <- c(-0.7, 0.7, -0.7)
rank <- c(2, 2, 2)
singular_vals <- c(1, 0.75)
info_ratio <- rep(0.35, 3)
try <- simu_var(method = "fLS", nob = nob, k = p, lags = 1, brk = brk,
               sigma = as.matrix(diag(p)), signals = signals, seed=1,
               rank = rank, singular_vals = singular_vals, info_ratio = info_ratio,
               sp_pattern = "off-diagonal", spectral_radius = 0.9)
data <- try$series
data <- as.matrix(data)
fit <- tbss(data, method = "fLS", mu = 150)
print(fit)
summary(fit)
plot(fit, data, display = "cp")
plot(fit, data, display = "param")
```

**Description**

weekly stock price data

**Usage**

```
data(weekly)
```

**Format**

An dataframe of weekly stock price data

**Examples**

```
data(weekly)  
head(weekly)
```



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