Package ‘ocd’

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Accessor functions to attributes of class ChangepointDetector

**Description**

Accessor functions to attributes of class ChangepointDetector

**Usage**

data_dim(detector)

ocdMethod(detector)

n_obs(detector)

patience(detector)

param(detector)

thresholds(detector)

baselineMean(detector)

baselineSD(detector)

tracked(detector)

statistics(detector)

status(detector)
**ChangepointDetector**

**Arguments**

- `detector`: Object of S3 class 'ChangepointDetector'

**Details**

Obtain various attributes of the class 'ChangepointDetector'

**See Also**

- `ChangepointDetector`

---

**ChangepointDetector**  
*Constructor for the ChangepointDetector S3 class*

**Description**

Constructor for the ChangepointDetector S3 class

**Usage**

```r
ChangepointDetector(dim, method = c("ocd", "Mei", "XS", "Chan"), thresh, patience = 5000, MC_reps = 100, beta = 1, sparsity = "auto", b = beta/sqrt(dim), p0 = 1/sqrt(dim), w = 200, lambda = sqrt(8) - 2)
```

**Arguments**

- `dim`: Data dimension, all new data must be of this dimension
- `method`: Four methods are implemented: ocd, Mei, XS and Chan. They correspond to the methods proposed in Chen, Wang and Samworth (2020), Mei (2010), Xie and Siegmund (2013) and Chan (2017). The constructed detector will be of 'OCD', 'Mei', 'XS' and 'Chan' subclass respectively.
- `thresh`: A numeric vector or the character string 'MC'. If 'MC' is specified then the correct threshold will be computed by Monte Carlo simulation (the patience argument should be specified for this). Otherwise, for method ocd, a vector of length 3 (corresponding to the diagonal statistic, off-diagonal dense statistic and off-diagonal sparse statistic) should be specified; for method Mei, a vector of length two (corresponding to the max and sum statistics) should be specified; for methods XS and Chan, a single positive real number should be specified;
- `patience`: Required patience (average run length without change) of the online changepoint procedure. This is optional if the thresholds for detection are manually specified, but is required if Monte Carlo thresholds are used.
- `MC_reps`: Number of Monte Carlo repetitions to use to estimate the thresholds. Only used when `thresh='MC'`.
- `beta`: lower bound on the 1_2 norm of the vector of mean change to be detected. This argument is used by the ocd method.
sparsity  Parameter used by the ocd. If sparsity='sparse', then only the diagonal and off-diagonal sparse statistics are used. If sparsity='dense', then only the diagonal and off-diagonal sparse statistics are used. If sparsity='auto', all three statistics are used to detect both sparse and dense change adaptively.

b  Lower bound on the per-coordinate magnitude of mean change be detected. This argument is used by the 'Mei' method. If b is unspecified but beta is specified, the default b = beta/sqrt(dim) will be used.

p0  A real number between 0 and 1. Sparsity parameter used by XS and Chan methods. It is the assumed fraction of nonzero coordinates of change. Default to 1/sqrt(dim).

w  Window size parameter used by XS and Chan methods. Number of most recent data points to keep track in memory. Default is 200.

lambda  A tuning parameter used by the Chan method. Default is sqrt(8)-2.

Details

This function is a wrapper. The new_OCD, new_Mei, new_XS and new_Chan carry out the actual constructor implementation.

Value

An object of S3 class 'ChangepointDetector'. Depending on the method argument specified, the object also belongs to a subclass 'OCD', 'Mei', 'XS' or 'Chan' corresponding to method='ocd'. It contains the following attributes:

- class - S3 class and subclass
- data_dim - data dimension
- method - method used for changepoint detection
- param - a list of parameters used in the specific method: beta and sparsity for method ocd; b for method Mei; p0 and w for method XS; p0, w and lambda for method Chan.
- threshold - a named vector of thresholds used for detection (see the thresh argument)
- n_obs - number of observations, initialised to 0
- baseline_mean - vector of pre-change mean, initialised to a vector of 0, can be estimated by setting the changepoint detector into baseline mean and standard deviation estimating status, see setStatus, or set directly using setBaselineMean.
- baseline_sd - vector of standard deviation, initialised to a vector of 1, can be estimated by setting the changepoint detector into baseline mean and standard deviation estimating status, see setStatus, or set directly using setBaselineSD.
- tracked - a list of information tracked online by the changepoint detector: matrices A and tail for method ocd; vector R for method Mei; matrices X_recent and CUSUM for methods XS and Chan.
- statistics - a named vector of test statistics for changepoint detection: statistics with names diag, off_d and off_s for method ocd (note if sparsity is 'dense' or 'sparse', then only (S^diag, S^off,d) and (S^diag, S^off,s) are included in stat respectively.); statistics with names max and sum for method Mei; a single numeric value for methods XS and Chan.
• status - one of the following: 'estimating' (the detector is estimating the baseline mean and standard deviation with new data points), 'monitoring' (the detector is detecting changes from the baseline mean from new data points) and an integer recording the time of declaration of changepoint.

References


See Also

accessor functions such as `data_dim`, the main function for processing a new data point `getData`, other methods for the ChangepointDetector class including `reset`, `setBaselineMean`, `setBaselineSD`, `setStatus`, `normalisedStatistics` and `checkChange`.

Examples

```r
detector_ocd <- ChangepointDetector(dim=100, method='ocd', thresh=c(11.6, 179.5, 54.9), beta=1)
detector_Mei <- ChangepointDetector(dim=100, method='Mei', thresh=c(8.6, 125.1), b=0.1)
detector_XS <- ChangepointDetector(dim=100, method='XS', thresh=55.1)
detector_Chan <- ChangepointDetector(dim=100, method='Chan', thresh=8.7)
```

Description

This function implements the `getData` function to perform the online changepoint detection for the 'Chan' class.

Usage

```r
Chan_update(x_new, X_recent, CUSUM, p0, w, lambda)
```
Arguments

- **x_new**: a new data point
- **X_recent**: matrix of \( w \) most recent observations
- **CUSUM**: tail partial sums of different lengths to be tracked online
- **p0**: sparsity parameter
- **w**: window parameter
- **\( \lambda \)**: a tuning parameter for the 'Chan' method

Value

A list of

- **stat**: test statistic for the 'Chan' class.
- **X_recent**: the updated X_recent matrix
- **CUSUM**: the updated CUSUM matrix

References


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checkChange: Check if a mean change has occurred.

Description

Check if a mean change has occurred.

Usage

```r
checkChange(detector)
```

Arguments

- **detector**: Object of class 'Changepoint Detector'

Details

The `normalisedStatistics` function is used to check if any of the test statistics are above the threshold level. If this happens, the status of the detector is changed to record the time of change and a message is printed to the standard output declaring the change.

Value

Updated object detector

See Also

`normalisedStatistics, setStatus`
getData

Processing a new data point

Description

This is the main function for the 'ChangepointDetector' class.

Usage

gedata(detector, x_new)

## S3 method for class 'OCD'
getdata(detector, x_new)

## S3 method for class 'Mei'
getdata(detector, x_new)

## S3 method for class 'XS'
getdata(detector, x_new)

## S3 method for class 'Chan'
getdata(detector, x_new)

Arguments

detector Object of class 'Changepoint Detector'
x_new A new data point. It must be of the same dimension as specified in the data_dim attribute of detector.

Details

If the status of the detector object is 'estimating', the new data point is used to update the current estimate of pre-change mean and standard deviation. If the status of the detector object is 'monitoring', the new data point is used to detect if a mean change has occurred.

Value

Updated object detector

Methods (by class)

- OCD: Process a new data for subclass 'OCD'
- Mei: Process a new data for subclass 'Mei'
- XS: Process a new data for subclass 'XS'
- Chan: Process a new data for subclass 'Chan'
See Also

setBaselineMean for updating the pre-change mean estimate, setBaselineSD for updating the standard deviation estimate, checkChange for checking for change.

---

**MC_Chan**

*Compute Monte Carlo thresholds for the Chan method*

### Description

Compute Monte Carlo thresholds for the Chan method

### Usage

MC_Chan(dim, patience, p0, w, lambda, MC_reps)

### Arguments

- **dim**: Data dimension
- **patience**: Nominal patience of the procedure
- **p0**: Assumed fraction of nonzero coordinates of change.
- **w**: Window size
- **lambda**: Tuning parameter for Chan (2017) method
- **MC_reps**: number of Monte Carlo repetitions to use

### Value

A numeric vector of computed thresholds.

---

**MC_Mei**

*Compute Monte Carlo thresholds for the Mei method*

### Description

Compute Monte Carlo thresholds for the Mei method

### Usage

MC_Mei(dim, patience, b, MC_reps)

### Arguments

- **dim**: Data dimension
- **patience**: Nominal patience of the procedure
- **b**: Lower bound on per-coordinate magnitude of change
- **MC_reps**: Number of Monte Carlo repetitions to use
**MC_ocd**

*Compute Monte Carlo thresholds for the OCD method*

**Value**

A numeric vector of computed thresholds.

**MC_XS**

*Compute Monte Carlo thresholds for the XS method*

**Description**

Compute Monte Carlo thresholds for the XS method

**Usage**

MC_XS(dim, patience, p0, w, MC_reps)

**Arguments**

- **dim**: Data dimension
- **patience**: Nominal patience of the procedure
- **p0**: Assumed fraction of nonzero coordinates of change.
- **w**: Window size
- **MC_reps**: Number of Monte Carlo repetitions to use

**Value**

A numeric vector of computed thresholds.
Value

A numeric vector of computed thresholds.

Description

This function implements the `getData` function to perform the online changepoint detection for the 'Mei' class.

Usage

```r
Mei_update(x_new, R, b)
```

Arguments

- `x_new` a new data point
- `R` vector of of tail CUSUMs that will be tracked and updated online
- `b` a user specified lower bound on per-coordinate magnitude of the vector of change to be detected.

Value

a list of

- `stat`: a vector of 2 test statistics for the 'Mei' class.
- `R`: the updated R vector

References

new_Chan

**constructor for subclass 'Chan' in class 'ChangepointDetector'**

### Description

constructor for subclass 'Chan' in class 'ChangepointDetector'

### Usage

```r
ew_Chan(dim, thresh, p0, w, lambda)
```

### Arguments

- **dim**: Data dimension, all new data must be of this dimension
- **thresh**: Detection threshold. A positive real number.
- **p0**: A sparsity parameter between 0 and 1. It is the assumed fraction of nonzero coordinates of change. Default to $1/\sqrt{\text{dim}}$.
- **w**: Window size parameter. Number of most recent data points to keep track in memory. Default is 200.
- **lambda**: A tuning parameter used by the Chan (2017) method. Default is $\sqrt{8}-2$.

### Details

It is preferred to use `ChangepointDetector` for construction.

### Value

An object of S3 subclass 'Chan' in class 'ChangepointDetector'.

### References


### Examples

```r
detector <- new_Chan(dim=100, thresh=8.7, p0=0.1, w=200, lambda=sqrt(8)-2)
```
new_Mei

constructor of subclass ‘Mei’ in class ‘ChangepointDetector’

Description

constructor of subclass ‘Mei’ in class ‘ChangepointDetector’

Usage

new_Mei(dim, thresh, b)

Arguments

dim      | Data dimension, all new data must be of this dimension
thresh   | Detection threshold. A numeric vector of length two (corresponding to the max and sum statistics) should be specified.
b        | Lower bound on the per-coordinate magnitude of mean change be detected.

Details

It is preferred to use ChangepointDetector for construction.

Value

An object of S3 subclass ‘Mei’ in class ‘ChangepointDetector’.

References


Examples

detector <- new_Mei(dim=100, thresh=c(8.6, 125.1), b=0.1)

new_OCD

constructor of subclass ‘OCD’ in class ‘ChangepointDetector’

Description

constructor of subclass ‘OCD’ in class ‘ChangepointDetector’

Usage

new_OCD(dim, thresh, beta, sparsity)
new_XS

Arguments

- **dim**: Data dimension, all new data must be of this dimension.
- **thresh**: A numeric vector of length 3 (corresponding to the diagonal statistic, off-diagonal dense statistic and off-diagonal sparse statistic) should be specified.
- **beta**: Lower bound on the $L_2$ norm of the vector of mean change to be detected.
- **sparsity**: If `sparsity='sparse'`, then only the diagonal and off-diagonal sparse statistics are used. If `sparsity='dense'`, then only the diagonal and off-diagonal sparse statistics are used. If `sparsity='auto'`, all three statistics are used to detect both sparse and dense change adaptively.

Details

It is preferred to use `ChangepointDetector` for construction.

Value

An object of S3 subclass 'OCD' in class 'ChangepointDetector'.

References


Examples

```r
detector <- new_OCD(dim=100, thresh=c(11.6, 179.5, 54.9), beta=1, sparsity='auto')
```

Description

constructor of subclass 'XS' in class 'ChangepointDetector'

Usage

```r
new_XS(dim, thresh, p0, w)
```

Arguments

- **dim**: Data dimension, all new data must be of this dimension.
- **thresh**: Detection threshold. A positive real number.
- **p0**: A sparsity parameter between 0 and 1. It is the assumed fraction of nonzero coordinates of change. Default to $1/\sqrt{\dim}$.
- **w**: Window size parameter. Number of most recent data points to keep track in memory. Default is 200.
normalisedStatistics

Details

It is preferred to use `ChangepointDetector` for construction.

Value

An object of S3 subclass 'XS' in class 'ChangepointDetector'.

References


Examples

detector <- new_XS(dim=100, thresh=55.1, p0=0.1, w=200)

normalisedStatistics(detector)

Description

Compute maximum ratio between detection statistic and its threshold

Usage

`normalisedStatistics(detector)`

Arguments

detector Object of class 'Changepoint Detector'

Value

maximum of the ratio between the current test statistics and their respective thresholds.
Description

The ocd package provides the S3 class `ChangepointDetector` that processes data sequentially using the `getData` function and aims to detect change as soon as it occurs online subject to false alarm rates.

References


See Also

`ChangepointDetector` for detailed usage.

Examples

```r
set.seed(2020)
p <- 100
thresh <- setNames(c(11.62, 179.48, 54.87), c("Var diag", "off_d", "off_s"))
detector <- ChangepointDetector(dim=p, method=\'ocd\', beta=1, thresh=thresh)
old_mean <- rnorm(p); new_mean <- old_mean + c(rnorm(p/4), rep(0,3*p/4)) / sqrt(p/4)

# using functional semantics native in R
detector <- setStatus(detector, \'estimating\')
for (i in 1:10000){
  x_new <- rnorm(p, mean=old_mean)
  detector <- getData(detector, x_new)
}
print(detector)

detector <- setStatus(detector, \'monitoring\')
for (i in 1:200){
  x_new <- rnorm(p, old_mean * (i < 100) + new_mean * (i>=100))
  detector <- getData(detector, x_new)
}
print(detector)

## Not run:
# alternative way to write the above using the piping semantics
library(magrittr)
detector %>>% reset
detector %>>% setStatus(\'estimating\')
for (i in 1:10000){
  x_new <- rnorm(p, mean=old_mean)
  detector %>>% getData(x_new)
```

```r
ocd_update

Processing a new data point for the 'OCD' class

Description

This function implements the `getData` function to perform the online changepoint detection for the 'OCD' class.

Usage

```r
ocd_update(x_new, A, tail, beta, sparsity)
```n

Arguments

- `x_new`: a new data point
- `A`: matrix of tail CUSUMs that will be tracked and updated online
- `tail`: matrix of tail lengths that will be tracked and updated online
- `beta`: a user specified lower bound on the l_2 norm of the vector of change to be detected.
- `sparsity`: a user specified mode parameter. If the vector of change is known to be dense or sparse, then one should set sparsity to 'dense' or 'sparse' accordingly, otherwise, the default choice sparsity='auto' will run the algorithm adaptive to the sparsity level.

Value

A list of

- stat: a vector of the test statistics for the 'OCD' class
- A: the updated A matrix
- tail: the updated tail matrix

References

```
**ParkfieldSensors**  
*Parkfield seismic sensor data*

**Description**  
Processed data from 39 ground motion sensors at 13 stations near Parkfield, California from 2.00-2.16am on December 23, 2004, with an earthquake measured at duration magnitude 1.47Md hit near Atascadero, California at 02:09:54.01.

**Usage**  
data(ParkfieldSensors)

**Format**  
A matrix with 39 columns and 14998 rows, with each column corresponding to a sensor and each row corresponding to a time after 2am. Column names corresponds to names of the sensors and row names are number of seconds after 2am.

**Source**  
HRSN (2014), High Resolution Seismic Network. UC Berkeley Seismological Laboratory. Dataset. doi:10.7932/HRSN.

**Examples**  
```r  
data(ParkfieldSensors)  
head(ParkfieldSensors)  

## Not run:  
plot(c(0, nrow(ParkfieldSensors) * 0.064), c(0, ncol(ParkfieldSensors)+1),  
pch=' ', xlab='seconds after 2004-12-23 02:00:00',  
ylab='sensor measurements')  
x <- as.numeric(rownames(ParkfieldSensors))  
for (j in 1:ncol(ParkfieldSensors)){  
y <- ParkfieldSensors[, j]  
y <- (y - max(ParkfieldSensors)) / diff(range(ParkfieldSensors)) + 0.5 + j  
points(x, y, pch='.')  
}  
abline(v = 9 * 60 + 54.01, col='blue', lwd=2, lty=3) # earthquake time  
library(magrittr)  
p <- ncol(ParkfieldSensors)  
train_ind <- as.numeric(rownames(ParkfieldSensors)) <= 240  
train <- ParkfieldSensors[train_ind, ]  
test <- ParkfieldSensors[!train_ind, ]  

# tuning parameters  
gamma <- 24 * 60 * 60 / 0.064 # patience = 1 day```
beta <- 150

# use theoretical thresholds suggested in Chen, Wang and Samworth (2020)
psi <- function(t){p - 1 + t + sqrt(2 * (p - 1) * t)}
th_diag <- log(24*p*gamma*log2(4*p))
th_off_s <- 8*log(24*p*gamma*log2(p))
th_off_d <- psi(th_off_s/4)
thresh <- setNames(c(th_diag, th_off_d, th_off_s), c('diag', 'off_d', 'off_s'))

# initialise ocd detector
detector <- ChangepointDetector(dim=p, method='ocd', beta=beta, thresh=thresh)

# use training data to update baseline mean and standard deviation
detector %<>% setStatus('estimating')
for (i in 1:nrow(train)) {
    detector %<>% getData(train[i, ])
}

# find changepoint in the test data
detector %<>% setStatus('monitoring')
for (i in 1:nrow(test)) {
    detector %<>% getData(test[i, ])
    if (is.numeric(detector %>% status)) break
}

if (is.numeric(detector %>% status)) {
    time_declared <- 240 + detector %>% status * 0.064
    abline(v = time_declared, col='orange', lwd=2, lty=3) # detection time
    cat('Change detected', time_declared, 'seconds after 2am.\n')
}

## End(Not run)

print.ChangepointDetector

Printing methods for the 'ChangepointDetector' class

Description

Printing methods for the 'ChangepointDetector' class

Usage

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

Arguments

  x                  object of the 'ChangepointDetector' class
  ...               other arguments used in print
reset

Reset changepoint detector to initial state

Description
Reset changepoint detector to initial state

Usage
reset(detector)

## S3 method for class 'OCD'
reset(detector)

## S3 method for class 'Mei'
reset(detector)

## S3 method for class 'XS'
reset(detector)

## S3 method for class 'Chan'
reset(detector)

Arguments
detector Object of class 'Changepoint Detector'

Value
Updated object detector

Methods (by class)
- OCD: Reset object of subclass 'OCD'
- Mei: Reset object of subclass 'Mei'
- XS: Reset object of subclass 'XS'
- Chan: Reset object of subclass 'Chan'
### setBaselineMean

**Set baseline mean**

**Description**
Set baseline mean

**Usage**

```r
setBaselineMean(detector, mean)
```

**Arguments**

- **detector**: Object of class 'Changepoint Detector'
- **mean**: vector of pre-change mean, must be of the same dimension as specified in the `data_dim` attribute of `detector`.

**Value**

Updated object `detector`

### setBaselineSD

**Set baseline standard deviation**

**Description**
Set baseline standard deviation

**Usage**

```r
setBaselineSD(detector, sd)
```

**Arguments**

- **detector**: Object of class 'Changepoint Detector'
- **sd**: vector of standard deviation, must be of the same dimension as specified in the `data_dim` attribute of `detector`.

**Value**

Updated object `detector`
setStatus

Set changepoint detector status

Description
Set changepoint detector status

Usage
setStatus(detector, new_status)

Arguments
- detector: Object of class 'Changepoint Detector'
- new_status: 'estimating' or 'monitoring'

Details
If the status is set to 'estimating', new observations are used to update current estimate of pre-change mean and standard deviation. If the status is set to 'monitoring', new observations are used to check if mean change has occurred.

Value
Updated object detector

update_param
compute new mean and sd from old ones with one additional observation

Description
compute new mean and sd from old ones with one additional observation

Usage
update_param(old_mean, old_sd, x_new, n_obs)

Arguments
- old_mean: vector of old means
- old_sd: vector of old standard deviation
- x_new: new observation vector
- n_obs: total number of observations (including x_new)

Value
list of two vectors: new mean and new standard deviation
XS_update

Processing a new data point for the ‘XS’ class

Description
This function implements the `getData` function to perform the online changepoint detection for the ‘XS’ class.

Usage
```
XS_update(x_new, X_recent, CUSUM, p0, w)
```

Arguments
- `x_new`: a new data point
- `X_recent`: matrix of `w` most recent observations
- `CUSUM`: tail partial sums of different lengths to be tracked online
- `p0`: sparsity parameter
- `w`: window parameter

Value
- a list of
  - `stat`: test statistic for the ‘XS’ class.
  - `X_recent`: the updated `X_recent` matrix
  - `CUSUM`: the updated CUSUM matrix

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