Package ‘breakfast’

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Author  Andreas Anastasiou [aut],
        Yining Chen [aut, cre],
        Haeran Cho [aut],
        Piotr Fryzlewicz [aut]

Maintainer  Yining Chen <y.chen101@lse.ac.uk>

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breakfast-package

Description

A developing software suite for multiple change-point detection/estimation (data segmentation) in data sequences.

Details

The current version implements methods for detecting changes in the data sequence modelled as (i) a piecewise-constant function plus i.i.d. Gaussian noise, (ii) a piecewise-constant function plus autoregressive time series, (iii) a piecewise-linear and continuous function plus i.i.d. Gaussian noise, and (iv) a piecewise-linear and discontinuous function plus i.i.d. Gaussian noise. This is carried out via a two-stage procedure combining solution path generation and model selection methodologies. Change-point detection in breakfast is carried out in two stages, first the computation of a solution path, followed by a model selection step along the path. A variety of solution path and model selection methods are included, which can be accessed individually, or through breakfast. Currently supported solution path methods are: sol.idetect, sol.idetect_seq, sol.wbs, sol.wbs2, sol.not, sol.tguh and sol.wcm.

Currently supported model selection methods are: model.ic, model.lp, model.sdll, model.thresh and model.gsa.

Check back future versions for more change-point models and the corresponding methods.

Author(s)

- Andreas Anastasiou
- Yining Chen
- Haeran Cho
- Piotr Fryzlewicz

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breakfast

See Also

browseVignettes(package = "breakfast") contains a detailed comparative simulation study of
various methods implemented in breakfast for the models (i), (iii) and (iv).

Methods for fast detection of multiple change-points

Description

This function estimates the number and locations of change-points in a univariate data sequence,
which is modelled as (i) a piecewise-constant function plus i.i.d. Gaussian noise, (ii) a piecewise-
constant function plus autoregressive time series, (iii) a piecewise-linear and continuous function
plus i.i.d. Gaussian noise, or (iv) a piecewise-linear and discontinuous function plus i.i.d. Gaussian
noise. This is carried out via a two-stage procedure combining solution path generation and model
selection methodologies.

Usage

breakfast(
  x,
  type = c("const", "lin.cont", "lin.discont"),
  solution.path = NULL,
  model.selection = NULL
)

Arguments

x A numeric vector containing the data to be processed

type The type of change-point models fitted to the data; currently supported models
  are: piecewise constant signals (type = "const", chosen by default), piecewise
  linear and continuous signals (type = "lin.cont") and piecewise linear and
  discontinuous signals (type = "lin.discont").

solution.path A string or a vector of strings containing the name(s) of solution path generating method(s); if individual methods are accessed via this option, default tuning parameters are used. Alternatively, you can directly access each solution path generating method via sol.[method]. If both solution.path and model.selection are unspecified, we return the output from the suggested combinations based on their performance, which depends on type as below:

  When type = "const": ("idetect", "ic"), ("idetect_seq", "thresh"), ("not", "ic"), ("tguh", "lp"), ("wbs", "ic"), ("wbs2", "sdll") and ("wcm", "gsa").

  When type = "lin.cont" or type = "lin.discont": ("idetect_seq", "thresh"), ("not", "ic") and ("idetect", "sdll").

If solution.path is specified but model.selection is not, we return the output from the specified solution.path methods combined with the suggested model selection methods (respectively) as above.
"idetect"  IDetect, supporting type = "const", "lin.cont", "lin.discont", see sol.idetect
"idetect_seq"  Sequential IDetect, supporting type = "const", "lin.cont", "lin.discont", see sol.idetect_seq
"not"  Narrowest-Over-Threshold, supporting type = "const", "lin.cont", "lin.discont", see sol.not
"tguh"  Tail-Greedy Unbalanced Haar, supporting type = "const", see sol.tguh
"wbs"  Wild Binary Segmentation, supporting type = "const", see sol.wbs
"wbs2"  Wild Binary Segmentation 2, supporting type = "const", see sol.wbs2
"wcm"  Wild Contrast Maximisation, supporting type = "const" in combination with model.gsa handling model (ii), see sol.wcm
"all"  All of the above that support the type

model.selection
A string or a vector of strings containing the name(s) of model selection method(s); if individual methods are accessed via this option, default tuning parameters are used. Alternatively, you can directly access each model selection method via model.[method]. If both solution.path and model.selection are unspecified, we return the output from the suggested combinations based on their performance, see solution.path. If model.selection is specified but solution.path is not, we return the output from the specified model.selection methods combined with the suggested solution path methods (respectively). Not all solution.path methods are supported by all model.selection methods; check the individual functions for more information.

"ic"  Strengthened Schwarz information criterion, supporting type = "const", "lin.cont", "lin.discont", see model.ic
"lp"  Localised pruning, supporting type = "const", see model.lp
"sdll"  Steepest Drop to Low Levels method, supporting type = "const", "lin.cont", "lin.discont", see model.sdll
"thresh"  Thresholding, supporting type = "const", "lin.cont", "lin.discont", see model.thresh
"gsa"  gappy Schwarz algorithm, supporting type = "const" in combination with sol.wcm handling model (ii), see model.gsa
"all"  All of the above that support the given type

Details
Please also take a look at the vignette for tips/suggestions/examples of using the breakfast package.

Value
An S3 object of class breakfast.cpts, which contains the following fields:

x  Input vector x

cptmodel.list  A list containing S3 objects of class cptmodel; each contains the following fields:

  solution.path  The solution path method used

  model.selection  The model selection method used to return the final change-point estimators object
**model.fixednum**

- **no.of.cpt** The number of estimated change-points in the piecewise-constant mean of the vector `cptpath.object$x`
- **cpts** The locations of estimated change-points in the piecewise-constant mean of the vector `cptpath.object$x`. These are the end-points of the corresponding constant-mean intervals
- **est** An estimate of the piecewise-constant mean of the vector `cptpath.object$x`; the values are the sample means of the data (replicated a suitable number of times) between each pair of consecutive detected change-points

**References**


**Examples**

```r
f <- rep(rep(c(0, 1), each = 50), 10)
x <- f + rnorm(length(f)) * .5
breakfast(x)
```

**model.fixednum**

*Estimate the location of change-points when the number of them is fixed*

**Description**

Return a solution with the given number of change-points or change-point-type features from the solution path

**Usage**

```r
model.fixednum(cptpath.object, fixednum = NULL)
```
model.fixednum

Arguments

cptpath.object  A solution-path object, returned by a sol.[name] routine. Note that the field
cptpath.object$x contains the input data sequence.

fixednum        The number of change-points or change-point-type features

Details

The model selection method which returns results with a given number of change-points or change-
point-type features. If there are multiple such elements on the solution path, the one with the smaller
residual sum of squares will be returned. On the other hand, if no such element exists, an empty set
(i.e. with no change-points) will be returned.

Value

An S3 object of class cptmodel, which contains the following fields:

solution.path  The solution path method used to obtain cptpath.object

type           The model type used, inherited from the given cptpath.object

model.selection The model selection method used to return the final change-point or change-
point-type feature estimators object, here its value is "ic"

no.of.cpt      The number of estimated features in the mean of the vector cptpath.object$x

based on the given type of the model

cpts           The locations of estimated features in the mean of the vector cptpath.object$x.

These are the end-points of the corresponding constant-mean or constant-slope intervals

est            An estimate of the mean of the vector cptpath.object$x; for piecewise-constant

signals, the values are the sample means of the data (replicated a suitable number

of times) between each pair of consecutive detected change-points; for piecewise-

linear but discontinuous signals, the values are the estimated linear trend (repli-

cated a suitable number of times) between each pair of consecutive detected

change of slopes; for piecewise-linear and continuous signals, it is similar to

the previous case but with the continuity constraint enforced, which envolves

solving a global least squares problem.

See Also

sol.idetect, sol.not, sol.tguh, sol.wbs, sol.wbs2, sol.wcm, breakfast

Examples

x <- c(rep(0, 100), rep(1, 100), rep(0, 100)) + rnorm(300)
model.fixednum(sol.wbs(x), 2)
model.fixednum(sol.not(x), 2)
model.gsa

Estimating change-points in the piecewise-constant mean of a noisy data sequence with auto-regressive noise via gappy Schwarz algorithm

Description
This function estimates the number and locations of change-points in the piecewise-constant mean of a noisy data sequence with auto-regressive noise via gappy Schwarz algorithm from a candidate model sequence generated by sol.wcm.

Usage
model.gsa(cptpath.object, p.max = 10, pen = log(length(cptpath.object$x)) ^ 1.01)

Arguments
- cptpath.object A solution-path object, returned by a sol.wcm routine. Note that the field cptpath.object$x contains the input data sequence.
- p.max The maximum AR order. The default is p.max = 10.
- pen Penalty used for the Schwarz criterion. log(length(cptpath.object$x)) ^ 1.01 is used as default.

Details
From the largest to the smallest (i.e. empty) candidate models generated by sol.wcm, gappy Schwarz algorithm locally evaluates the Schwarz criterion (SC, under piecewise constant signal + AR(p) noise model, with the AR order p to be determined adaptively) and its modification SC0 on each segment determined by the next smallest candidate model. It selects the larger model as the final model if over each segment, all newly introduced estimators are deemed 'significant' according to SC and SC0; see Cho and Fryzlewicz (2023) for details.

Value
An S3 object of class cptmodel, which contains the following fields:
- solution.path The solution path method used to obtain cptpath.object, here its value is "wcm"
- model.selection The model selection method used to return the final change-point estimators object, here its value is "gsa"
- no.of.cpt The number of estimated change-points in the piecewise-constant mean of the vector cptpath.object$x
- cpts The locations of estimated change-points in the piecewise-constant mean of the vector cptpath.object$x. These are the end-points of the corresponding constant-mean intervals
- est An estimate of the piecewise-constant mean of the vector cptpath.object$x; the values are the sample means of the data (replicated a suitable number of times) between each pair of consecutive detected change-points
References


See Also

sol.wcm

Examples

```r
set.seed(111)
f <- rep(c(0, 5, 2, 8, 1, -2), c(100, 200, 200, 50, 200, 250))
x <- f + arima.sim(list(ar = c(.75, -.5), ma = c(.8, .7, .6, .5, .4, .3)), n = length(f), sd = 1)
model.gsa(sol.wcm(x))
```

---

**Description**

This function estimates the number and locations of change-points or change-point-type features in the mean of a noisy data sequence via the sSIC (strengthened Schwarz information criterion) method.

**Usage**

```r
model.ic(cptpath.object, alpha = 1.01, q.max = NULL)
```

**Arguments**

- `cptpath.object`: A solution-path object, returned by a `sol.[name]` routine. Note that the field `cptpath.object$x` contains the input data sequence.
- `alpha`: The parameter associated with the sSIC. The default value is 1.01. Note that the SIC is recovered when `alpha = 1`.
- `q.max`: The maximum number of features allowed. If nothing or `NULL` is provided, the default value of `\min(100, n/\log(n))` (rounded to an integer) will be used.

**Details**

Value

An S3 object of class cptmodel, which contains the following fields:

- **solution.path**
  - The solution path method used to obtain `cptpath.object`

- **type**
  - The model type used, inherited from the given `cptpath.object`

- **model.selection**
  - The model selection method used to return the final change-point or change-point-type feature estimators object, here its value is "ic"

- **no.of.cpt**
  - The number of estimated features in the mean of the vector `cptpath.object$x` based on the given type of the model

- **cpts**
  - The locations of estimated features in the mean of the vector `cptpath.object$x`. These are the end-points of the corresponding constant-mean or constant-slope intervals

- **est**
  - An estimate of the mean of the vector `cptpath.object$x`; for piecewise-constant signals, the values are the sample means of the data (replicated a suitable number of times) between each pair of consecutive detected change-points; for piecewise-linear but discontinuous signals, the values are based on the estimated linear trend between each pair of consecutive detected change of slopes; for piecewise-linear and continuous signals, it is similar to the previous case but with the continuity constraint enforced, which envolves solving a global least squares problem.

References


See Also

- `sol.idetect`, `sol.not`, `sol.tguh`, `sol.wbs`, `sol.wbs2`, `breakfast`

Examples

```r
x <- c(rep(0, 100), rep(1, 100), rep(0, 100)) + rnorm(300)
model.ic(sol.wbs(x))
model.ic(sol.not(x))
```
Estimating change-points in the piecewise-constant mean of a noisy data sequence via the localised pruning

Description

This function estimates the number and locations of change-points in the piecewise-constant mean of a noisy data sequence via the localised pruning method, which performs a Schwarz criterion-based model selection on the given candidate set in a localised way.

Usage

```r
model.lp(
  cptpath.object,
  min.d = 5,
  penalty = c("log", "polynomial"),
  pen.exp = 1.01,
  do.thr = TRUE,
  th.const = 0.5
)
```

Arguments

- **cptpath.object**: A solution-path object, returned by a `sol.[name]` routine. Note that the field `cptpath.object$x` contains the input data sequence.
- **min.d**: A number specifying the minimal spacing between change points; `min.d = 5` by default.
- **penalty**: A string specifying the type of penalty term to be used in Schwarz criterion; possible values are: "log" Use `penalty = log(length(x))^pen.exp` "polynomial" Use `penalty = length(x)^pen.exp`
- **pen.exp**: Exponent for the penalty term (see `penalty`).
- **do.thr**: If `do.thr = TRUE`, mild thresholding on the CUSUM test statistics is performed after internal standardisation step in order to "pre-prune down" the candidates
- **th.const**: A constant multiplied to `sqrt(2*log(length(x)))` to form a mild threshold; if not supplied, a default value (0.5* the value suggested in Fryzlewicz (2020)) is used, see `th.const` in `model.sdll`

Details

Further information can be found in Cho and Kirch (2022).
Value

An S3 object of class `cptmodel`, which contains the following fields:

- `solution.path`: The solution path method used to obtain `cptpath.object`
- `model.selection`: The model selection method used to return the final change-point estimators object, here its value is "lp"
- `no.of.cpt`: The number of estimated change-points in the piecewise-constant mean of the vector `cptpath.object$x`
- `cpts`: The locations of estimated change-points in the piecewise-constant mean of the vector `cptpath.object$x`. These are the end-points of the corresponding constant-mean intervals
- `est`: An estimate of the piecewise-constant mean of the vector `cptpath.object$x`; the values are the sample means of the data (replicated a suitable number of times) between each pair of consecutive detected change-points

References


See Also

`sol.idetect`, `sol.idetect_seq`, `sol.not`, `sol.tguh`, `sol.wbs`, `sol.wbs2`, `breakfast`

Examples

```r
f <- rep(rep(c(0, 1), each = 50), 10)
x <- f + rnorm(length(f)) * .5
model.lp(sol.not(x))
```

Description

This function estimates the number and locations of change-points in the piecewise-constant or piecewise-linear mean of a noisy data sequence via the Steepest Drop to Low Levels method.
Usage

```r
model.sdll(
  cptpath.object,
  sigma = stats::mad(diff(cptpath.object$x)/sqrt(2)),
  universal = TRUE,
  th.const = NULL,
  th.const.min.mult = 0.3,
  lambda = 0.9
)
```

Arguments

cptpath.object  A solution-path object, returned by a sol.[name] routine. The `cptpath.object$type` variable decides the model type: piecewise-constant (`type == "const"`), piecewise-linear and continuous (`type == "lin.cont"`) or piecewise-linear and discontinuous (`type == "lin.discont"`). In the piecewise-constant model, SDLL model selection should work well when `cptpath.object` is an object returned by the `sol.wbs2` routine. In the piecewise-linear model (whether continuous or not), the output of `sol.idetect` should be supplied as `cptpath.object`. Note that the field `cptpath.object$x` contains the input data sequence.

sigma  An estimate of the standard deviation of the noise in the data `cptpath.object$x`. Can be a functional of `cptpath.object$x` or a specific value if known. The default in the piecewise-constant model is the Median Absolute Deviation of the vector `diff(cptpath.object$x)/sqrt(2)`, tuned to the Gaussian distribution. In the piecewise-linear models, `diff(cptpath.object$x, differences = 2)/sqrt(6)` is used by default. Note that `model.sdll` works particularly well when the noise is i.i.d. Gaussian.

universal  If `TRUE`, then the threshold that decides if there are any change-points is chosen automatically, so that the probability of type-I error (i.e. indicating change-points if there are none) is approximately `1 - alpha`. If `FALSE`, then `th.const` must be specified.

th.const  Only relevant if `universal = FALSE`; in that case a numerical value must be provided. Used to create the threshold (applicable to the contrast magnitudes stored in `cptpath.object`) that decides if there are any change-points in the mean vector; that threshold is then `th.const * sqrt(2 * log(n)) * sigma`, where `n` is the length of the data vector `cptpath.object$x`.

th.const.min.mult  A fractional multiple of the threshold, used to decide the lowest magnitude of contrasts from `cptpath.object` still considered by the SDLL model selection criterion as potentially change-point-carrying.

lambda  Only relevant if `universal = TRUE`; can be set to 0.9 or 0.95. The approximate probability of not detecting any change-points if the truth does not contain any.

Details

Value

An S3 object of class cptmodel, which contains the following fields:

- `solution.path`: The solution path method used to obtain `cptpath.object`
- `type`: The model type used, inherited from the given `cptpath.object`
- `model.selection`: The model selection method used to return the final change-point estimators object, here its value is "sd11"
- `no.of.cpt`: The number of estimated change-points
- `cpts`: The locations of estimated change-points
- `est`: An estimate of the mean of the vector `cptpath.object$x`

References


See Also

`sol.idetect, sol.idetect_seq, sol.not, sol.tguh, sol.wbs, sol.wbs2, breakfast`

Examples

```r
f <- rep(rep(c(0, 1), each = 50), 10)
x <- f + rnorm(length(f))
model.sdill(sol.wbs2(x))
```

Description

This function estimates the number and locations of change-points in the piecewise-constant or piecewise-linear mean of a noisy data sequence via thresholding.

Usage

```r
model.thresh(cptpath.object, sigma = NULL, th.const = NULL)
```
model.thresh

Arguments

cptpath.object  A solution-path object, returned by a sol.[name] routine. The cptpath.object$type variable decides the model type: piecewise-constant (type == "const"), piecewise-linear and continuous (type == "lin.cont") or piecewise-linear and discontinuous (type == "lin.discont"). In the piecewise-linear model (whether continuous or not), the output of sol.idetect_seq or sol.not should be supplied as cptpath.object. Note that the field cptpath.object$x contains the input data sequence.

sigma  An estimate of the standard deviation of the noise in the data cptpath.object$x. Can be a functional of cptpath.object$x or a specific value if known. The default in the piecewise-constant model is the Median Absolute Deviation of the vector diff(cptpath.object$x)/sqrt(2), tuned to the Gaussian distribution. In the piecewise-linear models, diff(cptpath.object$x, differences = 2)/sqrt(6) is used by default. Note that model.thresh works particularly well when the noise is i.i.d. Gaussian.

th.const  A positive real number used to define the threshold for the detection process. The default used in the piecewise-constant model is 1.15, while in the piecewise-linear model, the value is taken equal to 1.4.

Value

An S3 object of class cptmodel, which contains the following fields:

solution.path  The solution path method used to obtain cptpath.object

type  The model type used, inherited from the given cptpath.object

model.selection  The model selection method used to return the final change-point estimators object, here its value is "thresh"

no.of cpt  The number of estimated change-points

cpts  The locations of estimated change-points

est  An estimate of the mean of the vector cptpath.object$x

See Also

sol.idetect, sol.idetect_seq, sol.not, sol.tguh, sol.wbs, sol.wbs2, breakfast

Examples

f <- rep(rep(c(0, 1), each = 50), 10)
x <- f + rnorm(length(f))
model.thresh(sol.idetect_seq(x))
plot.breakfast.cpts  
*Change-points estimated by the "breakfast" routine*

**Description**

Plot method for objects of class breakfast.cpts

**Usage**

```r
## S3 method for class 'breakfast.cpts'
plot(x, display.data = TRUE, ...)
```

**Arguments**

- `x`  
a breakfast.cpts object
- `display.data`  
if `display.data = TRUE`, change-point estimators are plotted against the data by method. If `display.data = FALSE`, only the estimators are plotted; this option is recommended when `length(x)` is large.
- `...`  
current not in use

**Examples**

```r
f <- rep(rep(c(0, 1), each = 50), 5)
x <- f + rnorm(length(f)) * .5
plot(breakfast(x, solution.path = 'all', model.selection = 'all'), display.data = TRUE)
plot(breakfast(x), display.data = FALSE)
```

print.breakfast.cpts  
*Change-points estimated by the "breakfast" routine*

**Description**

Print method for objects of class breakfast.cpts

**Usage**

```r
## S3 method for class 'breakfast.cpts'
print(x, by = c("method", "estimator"), ...)
```

**Arguments**

- `x`  
a breakfast.cpts object
- `by`  
if `by = 'method'`, change-point estimators are printed by method; if `by = 'estimator'`, each change-point estimator is printed with the methods that detect it.
- `...`  
current not in use
Examples

```r
f <- rep(rep(c(0, 1), each = 50), 5)
x <- f + rnorm(length(f)) * .5
print(breakfast(x, solution.path = 'all', model.selection = 'all'), by = 'method')
print(breakfast(x), by = 'estimator')
```

print.cptmodel

```
Change-points estimated by solution path generation + model selection methods
```

Description

Print method for objects of class `cptmodel`

Usage

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

Arguments

- `x`: a `cptmodel` object
- `...`: current not in use

Examples

```r
f <- rep(rep(c(0, 1), each = 50), 5)
x <- f + rnorm(length(f)) * .5
print(model.ic(sol.idetect(x)))
```

sol.idetect

```
Solution path generation via the Isolate-Detect method
```

Description

This function arranges all possible change-points in the mean of the input vector, or in its linear trend, in the order of importance, via the Isolate-Detect (ID) method. It is developed to be used with the sdll and information criterion (ic) model selection rules.

Usage

```r
sol.idetect(
  x,
  type = "const",
  thr_ic_cons = 0.9,
  thr_ic_lin = 1.25,
  points = 3
)
```
Arguments

- **x**: A numeric vector containing the data to be processed.
- **type**: The model type considered. type = "const", type = "lin.cont", type = "lin.discont" mean, respectively, that the signal (mean of x) is piecewise constant, piecewise linear and continuous, and piecewise linear but not necessarily continuous. If not given, the default is type = "const"
- **thr_ic_cons**: A positive real number with default value equal to 0.9. It is used to create the solution path for the piecewise-constant model. The lower the value, the longer the solution path.
- **thr_ic_lin**: A positive real number with default value 1.25. Used to create the solution path if type == "lin.cont" or type == "lin.discont"
- **points**: A positive integer with default value equal to 3. It defines the distance between two consecutive end- or start-points of the right- or left-expanding intervals, as described in the Isolate-Detect methodology.

Details


Value

An S3 object of class cptpath, which contains the following fields:

- **solutions.nested**: TRUE, i.e., the change-point outputs are nested
- **solution.path**: Locations of possible change-points in the mean of x, arranged in decreasing order of change-point importance
- **solution.set**: Empty list
- **x**: Input vector x
- **type**: The input parameter type
- **cands**: Matrix of dimensions length(x) - 1 by 4. The first two columns are (start, end)-points of the detection intervals of the corresponding possible change-point location in the third column. The fourth column is a measure of strength of the corresponding possible change-point. The order of the rows is the same as the order returned in solution.path
- **method**: The method used, which has value "idetect" here

References


See Also

sol.idetect_seq, sol.not, sol.wbs, sol.wbs2, sol.tguh
Examples

```r
r3 <- rnorm(1000) + c(rep(0,300), rep(2,200), rep(-4,300), rep(0,200))
sol.idetect(r3)
```

**Description**

This function arranges all possible change-points in the mean of the input vector, or in its linear trend, in the order of importance, via the Isolate-Detect (ID) method. It is developed to be used with the thresholding model selection rule.

**Usage**

```r
sol.idetect_seq(x, type = "const", points = 4)
```

**Arguments**

- **x**: A numeric vector containing the data to be processed.
- **type**: The model type considered. `type = "const"`, `type = "lin.cont"`, `type = "lin.discont"` mean, respectively, that the signal (mean of `x`) is piecewise constant, piecewise linear and continuous, and piecewise linear but not necessarily continuous. If not given, the default is `type = "const"`.
- **points**: A positive integer with default value equal to 4. It defines the distance between two consecutive end- or start-points of the right- or left-expanding intervals, as described in the Isolate-Detect methodology.

**Details**


**Value**

An S3 object of class `cptpath`, which contains the following fields:

- **solutions.nested**: TRUE, i.e., the change-point outputs are nested.
- **solution.path**: Locations of possible change-points, arranged in decreasing order of change-point importance.
- **solution.set**: Empty list.
- **x**: Input vector `x`.
- **type**: The input parameter `type`.

**sol.idetect_seq**: Solution path generation using the sequential approach of the Isolate-Detect method.
sol.not

Matrix of dimensions length(x) - 1 by 4. The first two columns are (start, end)-points of the detection intervals of the corresponding possible change-point location in the third column. The fourth column is a measure of strength of the corresponding possible change-point. The order of the rows is the same as the order returned in solution.path

method
The method used, which has value "idetect_seq" here

References

See Also
sol.idetect, sol.not, sol.wbs, sol.wbs2, sol.tguh

Examples
r3 <- rnorm(1000) + c(rep(0,300), rep(2,200), rep(-4,300), rep(0,200))
sol.idetect_seq(r3)

sol.not

Solution path generation via the Narrowest-Over-Threshold method

Description
This function arranges all possible features (e.g. change in the mean, change in the slope, etc) of the input vector in the order of importance, via the Narrowest-Over-Threshold (NOT) method.

Usage
sol.not(x, type = "const", M = 10000, systematic.intervals = TRUE, seed = NULL)

Arguments
x
A numeric vector containing the data to be processed

type
The model type considered. type = "const" means the signals are the piecewise constant, type = "lin.cont" means the signals are the piecewise linear and continuous, and type = "lin.discont" means the signals are the piecewise linear but not necessarily continuous. If not given, the default is type = "const"

M
The maximum number of all data sub-samples at the beginning of the algorithm. The default is M = 10000

systematic.intervals
When drawing the sub-intervals, whether to use a systematic (and fixed) or random scheme. The default is systematic.intervals = TRUE

seed
If a random scheme is used, a random seed can be provided so that every time the same sets of random sub-intervals would be drawn. The default is seed = NULL, which means that this option is not taken
Details


Value

An S3 object of class `cptpath`, which contains the following fields:

- `solutions.nested`:
  - FALSE, i.e., the change-point outputs are not nested
- `solution.path`:
  - Empty list
- `solution.set`:
  - Locations of possible change-points in the mean of `x` for each threshold level (in the decreasing order), arranged in the form of a list of lists
- `solution.set.th`:
  - A list that contains threshold levels corresponding to the detections in `solution.set`
- `x`:
  - Input vector `x`
- `type`:
  - The model type used, which is given in the input. If not given, the default is `type="const"`
- `M`:
  - Input parameter `M`
- `cands`:
  - Matrix of dimensions `length(x) - 1` by `4`. The first two columns are (start, end)-points of the detection intervals of the corresponding possible change-point location in the third column resulted from applying NOT to all threshold levels. The fourth column is a measure of strength of the corresponding possible change-point. The order of the rows reflect the strength of each detection in decreasing order. To avoid repetition, each possible location would appear at most once in the matrix (with the sub-interval that carries its highest possible strength)
- `method`:
  - The method used, which has value "not" here

References


See Also

`sol.idetect`, `sol.idetect_seq`, `sol.tguh`, `sol.wbs`, `sol.wbs2`

Examples

```r
r3 <- rnorm(1000) + c(rep(0,300), rep(2,200), rep(-4,300), rep(0,200))
sol.not(r3)
```
Solution path generation via the Tail-Greedy Unbalanced Haar method

Description

This function arranges all possible change-points in the mean of the input vector in the order of importance, via the Tail-Greedy Unbalanced Haar method.

Usage

sol.tguh(x, type = "const", p = 0.01)

Arguments

- **x**: A numeric vector containing the data to be processed
- **type**: The model type considered. **type = "const"** means piecewise-constant; this is the only type currently supported in sol.tguh
- **p**: Specifies the number of region pairs merged in each pass through the data, as the proportion of all remaining region pairs. The default is **p = 0.01**

Details


Value

An S3 object of class cptpath, which contains the following fields:

- **solutions.nested**: TRUE, i.e., the change-point outputs are nested
- **solution.path**: Locations of possible change-points in the mean of x, arranged in decreasing order of change-point importance
- **solution.set**: Empty list
- **x**: Input vector x
- **type**: Input parameter type
- **p**: Input parameter p
- **cands**: Matrix of dimensions length(x) - 1 by 4. The first two columns are (start, end)-points of the detection intervals of the corresponding possible change-point location in the third column. The fourth column is a measure of strength of the corresponding possible change-point. The order of the rows is the same as the order returned in solution.path
- **method**: The method used, which has value "tguh" here
References


See Also

`sol.idetect`, `sol.idetect_seq`, `sol.not`, `sol.wbs`, `sol.wbs2`

Examples

```r
r3 <- rnorm(1000) + c(rep(0, 300), rep(2, 200), rep(-4, 300), rep(0, 200))
sol.tguh(r3)
```

---

**sol.wbs**  
*Solution path generation via the Wild Binary Segmentation method*

Description

This function arranges all possible change-in-mean features of the input vector in the order of importance, via the Wild Binary Segmentation (WBS) method.

Usage

```r
sol.wbs(x, type = "const", M = 10000, systematic.intervals = TRUE, seed = NULL)
```

Arguments

- `x`: A numeric vector containing the data to be processed
- `type`: The model type considered. Currently `type = "const"` is the only accepted value. This assumes that the mean of the input vector is piecewise-constant.
- `M`: The maximum number of all data sub-samples at the beginning of the algorithm. The default is `M = 10000`
- `systematic.intervals`: When drawing the sub-intervals, whether to use a systematic (and fixed) or random scheme. The default is `systematic.intervals = TRUE`
- `seed`: If a random scheme is used, a random seed can be provided so that every time the same sets of random sub-intervals would be drawn. The default is `seed = NULL`, which means that this option is not set

Details

Value

An S3 object of class `cptpath`, which contains the following fields:

- `solutions.nested`: `TRUE`, i.e., the change-point outputs are nested
- `solution.path`: Locations of possible change-points in the mean of `x`, arranged in decreasing order of change-point importance
- `solution.set`: Empty list
- `x`: Input vector `x`
- `type`: The input parameter `type`
- `M`: Input parameter `M`
- `cands`: Matrix of dimensions `length(x) - 1` by `4`. The first two columns are (start, end)-points of the detection intervals of the corresponding possible change-point location in the third column. The fourth column is a measure of strength of the corresponding possible change-point. The order of the rows is the same as the order returned in `solution.path`
- `method`: The method used, which has value "wbs" here

References


See Also

- `sol.idetect`, `sol.idetect_seq`, `sol.not`, `sol.tguh`, `sol.wbs2`

Examples

```r
r3 <- rnorm(1000) + c(rep(0,300), rep(2,200), rep(-4,300), rep(0,200))
sol.wbs(r3)
```

Description

This function arranges all possible change-points in the mean of the input vector in the order of importance, via the Wild Binary Segmentation 2 method.

Usage

```r
sol.wbs2(x, type = "const", M = 1000, systematic.intervals = TRUE, seed = NULL)
```
Arguments

- **x**: A numeric vector containing the data to be processed.
- **type**: The model type considered. type = "const" means piecewise-constant; this is the only type currently supported in sol.wbs2.
- **M**: The maximum number of data sub-samples drawn at each recursive stage of the algorithm. The default is M = 1000. Setting M = 0 executes the standard binary segmentation.
- **systematic.intervals**: Whether data sub-intervals for CUSUM computation are drawn systematically (TRUE; start- and end-points taken from an approximately equispaced grid) or randomly (FALSE; obtained uniformly with replacement). The default is TRUE.
- **seed**: If a random scheme is used, a random seed can be provided so that every time the same sets of random sub-intervals would be drawn. The default is seed = NULL, which means that this option is not set.

Details


Value

An S3 object of class cptpath, which contains the following fields:

- **solutions.nested**: TRUE, i.e., the change-point outputs are nested
- **solution.path**: Locations of possible change-points in the mean of x, arranged in decreasing order of change-point importance
- **solution.set**: Empty list
- **x**: Input vector x
- **type**: Input parameter type
- **M**: Input parameter M
- **cands**: Matrix of dimensions length(x) - 1 by 4. The first two columns are (start, end)-points of the detection intervals of the corresponding possible change-point location in the third column. The fourth column is a measure of strength of the corresponding possible change-point. The order of the rows is the same as the order returned in solution.path
- **method**: The method used, which has value "wbs2" here

References

sol.wcm

See Also

sol.idetect, sol.idetect_seq, sol.not, sol.tguh, sol.wbs

Examples

```r
r3 <- rnorm(1000) + c(rep(0,300), rep(2,200), rep(-4,300), rep(0,200))
sol.wbs2(r3)
```

sol.wcm

Solution path generation via the Wild Contrast Maximisation method

Description

This function arranges all possible change-points in the mean of the input vector in the order of importance, via the Wild Binary Segmentation 2 method.

Usage

```r
sol.wcm(
  x,
  type = "const",
  M = 100,
  min.d = NULL,
  Q = floor(log(length(x))^1.9),
  max.iter = 5
)
```

Arguments

- **x**: A numeric vector containing the data to be processed.
- **type**: The type of change-point models fitted to the data; currently the class of piece-wise constant signals (type = "const") is supported.
- **M**: The maximum number of data sub-samples drawn at each recursive stage of the algorithm. The default is M = 100.
- **min.d**: The minimum distance between candidate change-point estimators; if min.d = NULL, it is set to be max(20, 10 + ceiling(log(length(x))^1.1)).
- **Q**: The maximum number of allowable change-points. The default is Q = floor(log(length(x))^1.9).
- **max.iter**: The maximum number of candidate change-point models considered; if a model with the number of change-point estimators exceeding Q is required to generate the sequence of required candidate models, this argument is ignored. The default is max.iter = 5.
Details

The Wild Contrast Maximisation (WCM) algorithm generates a nested sequence of candidate models by identifying large gaps in the solution path generated by WBS2, which aids the model selection step in the presence of large random fluctuations due to serial dependence. See Cho and Fryzlewicz (2023) for further details.

Value

An S3 object of class \texttt{cptpath}, which contains the following fields:

- \texttt{solutions.nested} \texttt{TRUE}, i.e., the change-point outputs are nested
- \texttt{solution.path} Locations of possible change-points in the mean of \( x \), arranged in decreasing order of change-point importance; this is not used by \texttt{model.gsa}
- \texttt{solution.set} A list of candidate change-point models. Each model contains possible change-points in the mean of \( x \); this is used by \texttt{model.gsa}
- \texttt{x} Input vector \( x \)
- \texttt{type} The type of the change-point model considered, which has value "const" here
- \texttt{M} Input parameter \( M \)
- \texttt{cands} Matrix of dimensions \( Q \) by 4. The first two columns are (start, end)-points of the detection intervals of the corresponding possible change-point location in the third column. The fourth column is a measure of strength of the corresponding possible change-point. The order of the rows is the same as the order returned in \texttt{solution.path}
- \texttt{method} The method used, which has value "wcm" here

References


See Also

\texttt{model.gsa}

Examples

```r
set.seed(111)
f <- rep(c(0, 5, 2, 8, 1, -2), c(100, 200, 200, 50, 200, 250))
x <- f + arima.sim(list(ar = c(.75, -.5), ma = c(.8, .7, .6, .5, .4, .3)), n = length(f), sd = 1)
sol.wcm(x)$solution.set
```
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