

Package ‘binsegRcpp’

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Type Package

Title Efficient Implementation of Binary Segmentation

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Maintainer Toby Dylan Hocking <toby.hocking@r-project.org>

Description Standard template library
containers are used to implement an efficient binary segmentation
algorithm, which is log-linear on average and quadratic in the
worst case.

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LinkingTo Rcpp

URL <https://github.com/tdhock/binsegRcpp>

BugReports <https://github.com/tdhock/binsegRcpp/issues>

Imports data.table, Rcpp

Suggests covr, penaltyLearning, directlabels, ggplot2, testthat,
knitr, markdown, neuroblastoma, changepoint, quadprog

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Author Toby Dylan Hocking [aut, cre]

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binseg	<i>Binary segmentation</i>
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Description

Efficient C++ implementation of the classic binary segmentation algorithm for finding changepoints in a sequence of N data, which attempt to minimize a given loss function. Output includes columns which can be used to compute parameters for a single model in log-linear time, using coef method.

Usage

```
binseg(distribution.str,
      data.vec, max.segments = NULL,
      is.validation.vec = rep(FALSE,
                                length(data.vec)),
      position.vec = seq_along(data.vec),
      weight.vec = rep(1,
                       length(data.vec)),
      min.segment.length = NULL,
      container.str = "priority_queue")
```

Arguments

distribution.str	String indicating distribution/loss function, use get_distribution_info to see possible values.
data.vec	Vector of numeric data to segment.
max.segments	Maximum number of segments to compute, default=NULL which means to compute the largest number possible, given <code>is.validation.vec</code> and <code>min.segment.length</code> . Note that the returned number of segments may be less than this, if there are min segment length constraints.
is.validation.vec	logical vector indicating which data are to be used in validation set, default=all FALSE (no validation set).
position.vec	integer vector of positions at which data are measured, default=1:length(data.vec).
weight.vec	Numeric vector of non-negative weights for each data point.
min.segment.length	Positive integer, minimum number of data points per segment. Default NULL means to use min given distribution.str.
container.str	C++ container to use for storing breakpoints/cost. Most users should leave this at the default "priority_queue" for efficiency, but you could use "list" if you want to study the time complexity of an asymptotically slower implementation of binary segmentation.

Details

Each iteration involves first computing and storing the best split point on one or two segments, then looking up the segment with the best split so far. The best case time complexity occurs when splits are equal (N data split into two segments of size $N/2$), and the worst case is when splits are unequal (N data split into one big segment with $N-1$ data and one small segment with 1 data point). Looking up the segment with the best split so far is a constant $O(1)$ time operation using C++ multimap, so $O(K)$ overall for K iterations/segments. Storage of a new best split point/cost involves the multimap insert method which is logarithmic time in the size of the multimap, overall $O(K \log K)$ for equal splits and $O(K)$ for unequal splits. Computing the cost values, and overall time complexity, depends on the loss. For normal and poisson distributions the best case $O(N \log K)$ time for equal splits and worst case $O(N K)$ time for unequal splits. For l1/laplace distributions the best case is $O(N \log N \log K)$ time for equal splits and worst case is $O(N \log N K)$ time for unequal splits.

Value

list of class `binsegRcpp` with elements `min.segment.length`, `distribution.str`, `param.names`, `subtrain.borders` (positions used for assignment of segment means to validation data) and `splits`, which is a `data.table` with columns:

segments	number of segments
loss	total subtrain loss
validation.loss	total validation loss

end index of last data point per segment
 depth number of splits to reach segment
 before params before changepoint
 after params after changepoint
 before.size number of data before changepoint
 after.size number of data after changepoint
 invalidates.index index of param invalidated by this split.
 invalidates.after indicates if before/after params invalidated by this split.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```

data.table::setDTthreads(1)

x <- c(0.1, 0, 1, 1.1, 0.1, 0)
## Compute full path of binary segmentation models from 1 to 6
## segments.
(models <- binsegRcpp::binseg("mean_norm", x))

## Plot loss values using base graphics.
plot(models)

## Same loss values using ggplot2.
if(require("ggplot2")){
  ggplot()+
    geom_point(aes(
      segments, loss),
      data=models$splits)
}

## Compute data table of segments to plot.
(segs.dt <- coef(models, 2:4))

## Plot data, segments, changepoints.
if(require("ggplot2")){
  ggplot()+
    theme_bw()+
    theme(panel.spacing=grid::unit(0, "lines"))+
    facet_grid(segments ~ ., labeller=label_both)+
    geom_vline(aes(
      xintercept=start.pos),
      color="green",
      data=segs.dt[1<start])+
    geom_segment(aes(
      start.pos, mean,
```

```

        xend=end.pos, yend=mean),
        data=segs.dt,
        color="green")+
xlab("Position/index")+
ylab("Data/mean value")+
geom_point(aes(
  pos, x),
  data=data.frame(x, pos=seq_along(x)))
}

## Use min.segment.length to constrain segment sizes.
(constrained.models <- binsegRcpp::binseg("mean_norm", x, min.segment.length = 2L))

## Demonstration of model selection using cross-validation in
## simulated data.
seg.mean.vec <- 1:5
data.mean.vec <- rep(seg.mean.vec, each=20)
set.seed(1)
n.data <- length(data.mean.vec)
data.vec <- rnorm(n.data, data.mean.vec, 0.2)
plot(data.vec)

library(data.table)
loss.dt <- data.table(seed=1:10)[, {
  set.seed(seed)
  is.valid <- sample(rep(c(TRUE,FALSE), l=n.data))
  bs.model <- binsegRcpp::binseg("mean_norm", data.vec, is.validation.vec=is.valid)
  bs.model$splits[, data.table(
    segments,
    validation.loss)]
}, by=seed]
loss.stats <- loss.dt[, .(
  mean.valid.loss=mean(validation.loss)
), by=segments]
plot(
  mean.valid.loss ~ segments, loss.stats,
  col=ifelse(
    mean.valid.loss==min(mean.valid.loss),
    "black",
    "red"))

selected.segments <- loss.stats[which.min(mean.valid.loss), segments]
full.model <- binsegRcpp::binseg("mean_norm", data.vec, selected.segments)
(segs.dt <- coef(full.model, selected.segments))
if(require("ggplot2")){
  ggplot()+
    theme_bw()+
    theme(panel.spacing=grid::unit(0, "lines"))+
    geom_vline(aes(
      xintercept=start.pos),
      color="green",
      data=segs.dt[1<start])+
    geom_segment(aes(

```

```

      start.pos, mean,
      xend=end.pos, yend=mean),
      data=segs.dt,
      color="green")+
    xlab("Position/index")+
    ylab("Data/mean value")+
    geom_point(aes(
      pos, data.vec),
      data=data.frame(data.vec, pos=seq_along(data.vec)))
  }

## Demo of poisson loss, weights.
data.vec <- c(3,4,10,20)
(fit1 <- binsegRcpp::binseg("poisson", data.vec, weight.vec=c(1,1,1,10)))
coef(fit1, 2L)
(fit2 <- binsegRcpp::binseg("poisson", data.vec, weight.vec=c(1,1,10,1)))
coef(fit2, 2L)

```

binseg_interface	<i>binseg interface</i>
------------------	-------------------------

Description

Low-level interface to binary segmentation algorithm.

Usage

```

binseg_interface(data_vec,
  weight_vec, max_segments,
  min_segment_length,
  distribution_str,
  container_str, is_validation_vec,
  position_vec)

```

Arguments

data_vec	data_vec
weight_vec	weight_vec
max_segments	max_segments
min_segment_length	min_segment_length
distribution_str	distribution_str
container_str	container_str
is_validation_vec	is_validation_vec
position_vec	position_vec

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

binseg_normal

Binary segmentation, normal change in mean

Description

Calls `binseg` to compute a binary segmentation model for change in mean with constant variance, max normal likelihood = min square loss.

Usage

```
binseg_normal(data.vec,
  max.segments = sum(!is.validation.vec),
  is.validation.vec = rep(FALSE,
    length(data.vec)),
  position.vec = seq_along(data.vec))
```

Arguments

<code>data.vec</code>	Vector of numeric data to segment.
<code>max.segments</code>	Maximum number of segments to compute, default=number of FALSE entries in <code>is.validation.vec</code> .
<code>is.validation.vec</code>	logical vector indicating which data are to be used in validation set, default=all FALSE (no validation set).
<code>position.vec</code>	integer vector of positions at which data are measured, default=1:length(<code>data.vec</code>).

Value

List output from `binseg` which represents a binary segmentation model (loss is total square loss).

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```
data.table::setDTthreads(1)

x <- c(0.1, 0, 1, 1.1, 0.1, 0)
## Compute full path of binary segmentation models from 1 to 6
## segments.
(models <- binsegRcpp::binseg_normal(x))

## Plot loss values using base graphics.
```

```

plot(models)

## Same loss values using ggplot2.
if(require("ggplot2")){
  ggplot()+
    geom_point(aes(
      segments, loss),
      data=models$splits)
}

## Compute data table of segments to plot.
(segs.dt <- coef(models, 2:4))

## Plot data, segments, changepoints.
if(require("ggplot2")){
  ggplot()+
    theme_bw()+
    theme(panel.spacing=grid::unit(0, "lines"))+
    facet_grid(segments ~ ., labeller=label_both)+
    geom_vline(aes(
      xintercept=start.pos),
      color="green",
      data=segs.dt[1<start])+
    geom_segment(aes(
      start.pos, mean,
      xend=end.pos, yend=mean),
      data=segs.dt,
      color="green")+
    xlab("Position/index")+
    ylab("Data/mean value")+
    geom_point(aes(
      pos, x),
      data=data.frame(x, pos=seq_along(x)))
}

## Demonstration of model selection using cross-validation in
## simulated data.
seg.mean.vec <- 1:5
data.mean.vec <- rep(seg.mean.vec, each=20)
set.seed(1)
n.data <- length(data.mean.vec)
data.vec <- rnorm(n.data, data.mean.vec, 0.2)
plot(data.vec)

library(data.table)
loss.dt <- data.table(seed=1:10)[, {
  set.seed(seed)
  is.valid <- sample(rep(c(TRUE,FALSE), 1=n.data))
  bs.model <- binsegRcpp::binseg_normal(data.vec, is.validation.vec=is.valid)
  bs.model$splits[, data.table(
    segments,
    validation.loss)]
}, by=seed]

```



```

loss.stats <- loss.dt[, .(
  mean.valid.loss=mean(validation.loss)
), by=segments]
plot(
  mean.valid.loss ~ segments, loss.stats,
  col=ifelse(
    mean.valid.loss==min(mean.valid.loss),
    "black",
    "red"))

selected.segments <- loss.stats[which.min(mean.valid.loss), segments]
full.model <- binsegRcpp::binseg_normal(data.vec, selected.segments)
(segs.dt <- coef(full.model, selected.segments))
if(require("ggplot2")){
  ggplot()+
    theme_bw()+
    theme(panel.spacing=grid::unit(0, "lines"))+
    geom_vline(aes(
      xintercept=start.pos),
      color="green",
      data=segs.dt[1<start])+
    geom_segment(aes(
      start.pos, mean,
      xend=end.pos, yend=mean),
      data=segs.dt,
      color="green")+
    xlab("Position/index")+
    ylab("Data/mean value")+
    geom_point(aes(
      pos, data.vec),
      data=data.frame(data.vec, pos=seq_along(data.vec)))
}

```

binseg_normal_cv

Binary segmentation, normal change in mean, cross-validation for model selection

Description

Efficient implementation of binary segmentation for change in mean, with automatic model selection via cross-validation.

Usage

```

binseg_normal_cv(data.vec,
  max.segments = length(data.vec),
  position.vec = seq_along(data.vec),
  n.validation.sets = 100L,
  prop.validation = 0.5)

```

Arguments

data.vec Vector of numeric data to segment.
max.segments Maximum number of segments to compute, default=length(data.vec).
position.vec integer vector of positions at which data are measured, default=1:length(data.vec).
n.validation.sets Number of validation sets.
prop.validation Proportion of validation set.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```

data.table::setDTthreads(1)

seg.mean.vec <- 1:5
data.mean.vec <- rep(seg.mean.vec, each=20)
set.seed(1)
n.data <- length(data.mean.vec)
data.vec <- rnorm(n.data, data.mean.vec, 0.2)
plot(data.vec)
(fit <- binsegRcpp::binseg_normal_cv(data.vec))
seg.dt <- coef(fit)
model.color <- "red"
seg.dt[, segments(start.pos, mean, end.pos, mean, col=model.color)]
seg.dt[start>1, abline(v=start.pos, col=model.color)]

## plot method shows number of times selected.
plot(fit)

if(requireNamespace("neuroblastoma")){
  data(neuroblastoma, package="neuroblastoma", envir=environment())
  library(data.table)
  profiles.dt <- data.table(neuroblastoma$profiles)
  one.chrom <- profiles.dt[profile.id=="4" & chromosome=="2"]
  fit <- one.chrom[, binsegRcpp::binseg_normal_cv(
    logratio, position.vec=position)]
  selected.segs <- coef(fit)
  if(require(ggplot2)){
    ggplot()+
      geom_point(aes(
        position, logratio),
        data=one.chrom)+
      geom_segment(aes(
        start.pos, mean,
        xend=end.pos, yend=mean),
        data=selected.segs,
        color=model.color)+
      geom_vline(aes(

```

```
        xintercept=start.pos),
        data=selected.segs[start>1],
        color=model.color)
    }
}
```

case.colors	case colors
-------------	-------------

Description

Character vector giving default colors for cases, ordered from worst to best.

Usage

"case.colors"

case.sizes	case sizes
------------	------------

Description

Numeric vector giving default sizes for cases.

Usage

"case.sizes"

check_sizes	check sizes
-------------	-------------

Description

Checks types and values of size inputs.

Usage

```
check_sizes(N.data, min.segment.length,
            n.segments)
```

Arguments

N.data	N.data
min.segment.length	min.segment.length
n.segments	n.segments

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

coef.binsegRcpp	<i>coef binsegRcpp</i>
-----------------	------------------------

Description

Compute a data table of segment start/end/mean values for all models given by segments.

Usage

```
## S3 method for class 'binsegRcpp'
coef(object,
      segments = 1:min(nrow(object$splits),
                        10), ...)
```

Arguments

object	data.table from binseg .
segments	integer vector, model sizes in number of segments.
...	ignored.

Value

data.table with one row for each segment.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
coef.binseg_normal_cv  coef binseg normal cv
```

Description

Compute a data table of segment start/end/mean values for all models given by segments.

Usage

```
## S3 method for class 'binseg_normal_cv'
coef(object,
      segments = max(nrow(object$splits)),
      ...)
```

Arguments

object	data.table from binseg_normal_cv .
segments	integer vector, model sizes in number of segments. default=number of selected segments.
...	ignored.

Value

data.table with one row for each segment.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
cum_median          cum median
```

Description

Efficient log-linear cumulative median.

Usage

```
cum_median(data.vec,
            weight.vec = rep(1,
                             length(data.vec)))
```

Arguments

data.vec	Numeric vector of data.
weight.vec	Numeric vector of weights.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

cum_median_interface *cum median interface*

Description

Efficient log-linear cumulative median.

Usage

```
cum_median_interface(data_vec,
  weight_vec)
```

Arguments

data_vec	data_vec
weight_vec	weight_vec

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

depth_first_interface *depth first interface*

Description

Use depth first search to compute a data.frame with one row for each segment, and columns splits and depth, number/depth of candidate splits that need to be computed after splitting that segment.

Usage

```
depth_first_interface(n_data,
  min_segment_length)
```

Arguments

n_data	n_data
min_segment_length	min_segment_length

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

get_complexity	get_complexity
----------------	----------------

Description

Get empirical and extreme split counts, in order to compare the empirical and theoretical time complexity of the binary segmentation algorithm.

Usage

```
get_complexity(models,  
  y.increment = 0.1)
```

Arguments

models	result of binseg .
y.increment	Offset for y column values of totals output table.

Value

List of class "complexity" which has a plot method. Elements include "iterations" which is a data table with one row per model size, and column splits with number of splits to check after computing that model size; "totals" which is a data table with total number of splits for each case.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```
## Example 1: empirical=worst case.  
data.vec <- rep(0:1, 1=8)  
plot(data.vec)  
worst.model <- binsegRcpp::binseg_normal(data.vec)  
worst.counts <- binsegRcpp::get_complexity(worst.model)  
plot(worst.counts)  
  
## Example 2: empirical=best case for full path.  
data.vec <- 1:8  
plot(data.vec)  
full.model <- binsegRcpp::binseg_normal(data.vec)  
full.counts <- binsegRcpp::get_complexity(full.model)  
plot(full.counts)  
  
## Example 3: empirical=best case for all partial paths.  
data.vec <- c(0,3,6,10,21,22,23,24)  
plot(data.vec)  
best.model <- binsegRcpp::binseg_normal(data.vec)  
best.counts <- binsegRcpp::get_complexity(best.model)
```

```

plot(best.counts)

## ggplot comparing examples 1-3.
if(require("ggplot2")){
  library(data.table)
  splits.list <- list()
  for(data.type in names(worst.counts)){
    splits.list[[data.type]] <- rbind(
      data.table(data="worst", worst.counts[[data.type]]),
      data.table(data="best always", best.counts[[data.type]]),
      data.table(data="best full", full.counts[[data.type]])
    )
  }
  ggplot()+
    facet_grid(data ~ .)+
    geom_line(aes(
      segments, cum.splits, color=case, size=case),
      data=splits.list$iterations[case!="empirical"])+
    geom_point(aes(
      segments, cum.splits, color=case),
      data=splits.list$iterations[case=="empirical"])+
    scale_color_manual(
      values=binsegRcpp::case.colors,
      breaks=names(binsegRcpp::case.colors))+
    scale_size_manual(
      values=binsegRcpp::case.sizes,
      guide="none")
}

## Example 4: empirical case between best/worst.
data.vec <- rep(c(0,1,10,11),8)
plot(data.vec)
m.model <- binsegRcpp::binseg_normal(data.vec)
m.splits <- binsegRcpp::get_complexity(m.model)
plot(m.splits)

## Example 5: worst case for normal change in mean and variance
## model.
mv.model <- binsegRcpp::binseg("meanvar_norm", data.vec)
mv.splits <- binsegRcpp::get_complexity(mv.model)
plot(mv.splits)

## Compare examples 4-5 using ggplot2.
if(require("ggplot2")){
  library(data.table)
  splits.list <- list()
  for(data.type in names(m.splits)){
    splits.list[[data.type]] <- rbind(
      data.table(model="mean and variance", mv.splits[[data.type]]),
      data.table(model="mean only", m.splits[[data.type]])
    )
  }
  ggplot()+
    facet_grid(model ~ .)+
    geom_line(aes(

```



```

    segments, splits, color=case, size=case),
    data=splits.list$iterations[case!="empirical"])+
geom_point(aes(
  segments, splits, color=case),
  data=splits.list$iterations[case=="empirical"])+
geom_text(aes(
  x, y,
  label=label,
  color=case),
  hjust=1,
  data=splits.list$totals)+
scale_color_manual(
  values=binsegRcpp::case.colors,
  guide="none")+
scale_size_manual(
  values=binsegRcpp::case.sizes,
  guide="none")
}

## Compare cumsums.
if(require("ggplot2")){
  library(data.table)
  splits.list <- list()
  for(data.type in names(m.splits)){
    splits.list[[data.type]] <- rbind(
      data.table(model="mean and variance", mv.splits[[data.type]]),
      data.table(model="mean only", m.splits[[data.type]]))
  }
  ggplot()+
  facet_grid(model ~ .)+
  geom_line(aes(
    segments, cum.splits, color=case, size=case),
    data=splits.list$iterations[case!="empirical"])+
  geom_point(aes(
    segments, cum.splits, color=case),
    data=splits.list$iterations[case=="empirical"])+
  scale_color_manual(
    values=binsegRcpp::case.colors,
    breaks=names(binsegRcpp::case.colors))+
  scale_size_manual(
    values=binsegRcpp::case.sizes,
    guide="none")
}

```

get_complexity_best_heuristic_equal_breadth_full

get complexity best heuristic equal breadth full

Description

Compute a fast approximate best case based on equal size splits.

Usage

```
get_complexity_best_heuristic_equal_breadth_full(N.data,  
  min.segment.length)
```

Arguments

N.data	N.data
min.segment.length	min.segment.length

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
get_complexity_best_heuristic_equal_depth_full  
  get complexity best heuristic equal depth full
```

Description

Heuristic depth first.

Usage

```
get_complexity_best_heuristic_equal_depth_full(N.data,  
  min.segment.length)
```

Arguments

N.data	N.data
min.segment.length	min.segment.length

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
get_complexity_best_optimal_cost
```

get complexity best optimal cost

Description

Dynamic programming for computing lower bound on number of split candidates to compute / best case of binary segmentation. The dynamic programming recursion is on $f(d,s)$ = best number of splits for segment of size s which is split d times. Need to optimize $f(d,s) = g(s) + \min f(d1,s1) + f(d2,s2)$ over $s1,d1$ given that $s1+s2=s$, $d1+d2+1=d$, and $g(s)$ is the number of splits for segment of size s .

Usage

```
get_complexity_best_optimal_cost(N.data,  
  min.segment.length = 1L,  
  n.segments = NULL)
```

Arguments

N.data	positive integer number of data.
min.segment.length	positive integer min segment length.
n.segments	positive integer number of segments.

Value

data table with one row for each $f(d,s)$ value computed.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```
binsegRcpp::get_complexity_best_optimal_cost(  
  N.data = 19L,  
  min.segment.length = 3L,  
  n.segments = 4L)
```

```
get_complexity_best_optimal_splits
  get complexity best optimal splits
```

Description

Convert output of `get_complexity_best_optimal_tree` to counts of candidate splits that need to be considered at each iteration.

Usage

```
get_complexity_best_optimal_splits(node.dt,
  min.segment.length)
```

Arguments

```
node.dt      node.dt
min.segment.length
              min.segment.length
```

Value

Data table with one row for each segment.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
get_complexity_best_optimal_tree
  get complexity best optimal tree
```

Description

decoding.

Usage

```
get_complexity_best_optimal_tree(f.dt)
```

Arguments

```
f.dt      f.dt
```

Value

Data table with one row for each node in the tree.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```
N.data <- 19L
min.seg.len <- 3L
max.segments <- 4L
cost.dt <- binsegRcpp::get_complexity_best_optimal_cost(
  N.data, min.seg.len, max.segments)
binsegRcpp::get_complexity_best_optimal_tree(cost.dt)
```

get_complexity_empirical

get complexity empirical

Description

Get empirical split counts. This is a sub-routine of [get_complexity](#), which should typically be used instead.

Usage

```
get_complexity_empirical(model.dt,
  min.segment.length = 1L)
```

Arguments

`model.dt` splits data table from [binseg](#) result list.
`min.segment.length` Minimum segment length, positive integer.

Value

data.table with one row per model size, and column splits with number of splits to check after computing that model size.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
get_complexity_extreme
```

```
get_complexity_extreme
```

Description

Compute best and worst case number of splits.

Usage

```
get_complexity_extreme(N.data,
  min.segment.length = 1L,
  n.segments = NULL)
```

Arguments

N.data	number of data to segment, positive integer.
min.segment.length	minimum segment length, positive integer.
n.segments	number of segments, positive integer.

Value

data.table with one row per model size, and column splits with number of splits to check after computing that model size. Column case has values best (equal segment sizes, min splits to check) and worst (unequal segment sizes, max splits to check).

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
get_complexity_worst get_complexity_worst
```

Description

Get full sequence of splits which results in worst case time complexity.

Usage

```
get_complexity_worst(N.data,
  min.segment.length)
```

Arguments

N.data	N.data
min.segment.length	min.segment.length

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

get_distribution_info *get distribution info*

Description

Compute a data.frame with one row for each distribution implemented in the C++ code, and columns distribution.str, parameters, description.

Usage

```
get_distribution_info()
```

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

get_tree_empirical *get tree empirical*

Description

Compute tree for empirical binary segmentation model.

Usage

```
get_tree_empirical(fit)
```

Arguments

fit	fit
-----	-----

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

plot.binsegRcpp	<i>plot binsegRcpp</i>
-----------------	------------------------

Description

Plot loss values from binary segmentation.

Usage

```
## S3 method for class 'binsegRcpp'  
plot(x, ...)
```

Arguments

x	data.table from binseg .
...	ignored.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

plot.binseg_normal_cv	<i>plot binseg normal cv</i>
-----------------------	------------------------------

Description

Plot loss values from binary segmentation.

Usage

```
## S3 method for class 'binseg_normal_cv'  
plot(x,  
      ...)
```

Arguments

x	data.table from binseg_normal_cv .
...	ignored.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

plot.complexity	<i>plot complexity</i>
-----------------	------------------------

Description

Plot comparing empirical number of splits to best/worst case.

Usage

```
## S3 method for class 'complexity'  
plot(x, ...)
```

Arguments

x	data.table from get_complexity .
...	ignored.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

print.binsegRcpp	<i>print binsegRcpp</i>
------------------	-------------------------

Description

Print method for binsegRcpp.

Usage

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

Arguments

x	data.table from binseg .
...	ignored.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

```
print.binseg_normal_cv
      print binseg normal cv
```

Description

Print method for `binseg_normal_cv`.

Usage

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

Arguments

<code>x</code>	data.table from <code>binseg_normal_cv</code> .
<code>...</code>	ignored.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

<code>qp.x</code>	<i>qp x</i>
-------------------	-------------

Description

Solve quadratic program to find x positions.

Usage

```
qp.x(target, y.up, y.lo)
```

Arguments

<code>target</code>	<code>target</code>
<code>y.up</code>	<code>y.up</code>
<code>y.lo</code>	<code>y.lo</code>

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

random_set_vec	<i>random set vec</i>
----------------	-----------------------

Description

Random set assignment.

Usage

```
random_set_vec(N, props.vec)
```

Arguments

N	integer, size of output vector.
props.vec	numeric vector of set proportions (must sum to one), with set names.

Value

Random vector of N set names.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```
library(data.table)
library(ggplot2)
library(binsegRcpp)
tvt.props <- c(test=0.19, train=0.67, validation=0.14)
tvt.N <- 1234567L
system.time({
  tvt.vec <- random_set_vec(tvt.N, tvt.props)
})
table(tvt.vec, useNA="ifany")/tvt.N

random_set_vec(6L, c(train=2/3, test=1/3))
random_set_vec(5L, c(train=2/3, test=1/3))
random_set_vec(4L, c(train=2/3, test=1/3))
random_set_vec(3L, c(train=2/3, test=1/3))

test.rev <- function(N, prop.vec, expected.vec){
  result <- list()
  for(fun.name in c("identity", "rev")){
    fun <- get(fun.name)
    ctab <- table(random_set_vec(N, fun(prop.vec)))
    result[[fun.name]] <- ctab
  }
  result$same <- sapply(
```

```

    result, function(tab)identical(as.numeric(tab), expected.vec))
  result
}
test.rev(4L, c(test=1/3, train=2/3), c(1, 3))
table(random_set_vec(3L, c(test=0.5, train=0.5)))
table(random_set_vec(3L, c(train=0.5, test=0.5)))
test.rev(3L, c(test=0.4, train=0.6), c(1, 2))
test.rev(3L, c(test=0.49, train=0.51), c(1, 2))
test.rev(3L, c(test=0.6, train=0.4), c(2, 1))
## 2 is optimal after prob=2/3.
test.rev(2L, c(test=0.6, train=0.4), c(1, 1))
test.rev(2L, c(test=0.7, train=0.3), c(2))

## visualize the likelihood as a function of the proportion of
## success.
test.prop <- seq(0, 1, by=0.01)
prob.dt.list <- list()
n.total <- 2
for(n.test in 0:n.total){
  prob.dt.list[[paste(n.test)]] <- data.table(
    n.test,
    test.prop,
    prob=dbinom(n.test, n.total, test.prop))
}
prob.dt <- do.call(rbind, prob.dt.list)
thresh.dt <- data.table(thresh=(1:2)/3)
gg <- ggplot()+
  geom_vline(aes(xintercept=thresh), data=thresh.dt)+
  geom_line(aes(
    test.prop, prob, color=n.test, group=n.test),
    data=prob.dt)
if(requireNamespace("directlabels")){
  directlabels::direct.label(gg, "last.polygons")
}else{
  gg
}

## visualize the binomial likelihood as a function of number of
## successes, for a given probability of success.
n.total <- 43
n.success <- 0:n.total
p.success <- 0.6
lik.dt <- data.table(
  n.success,
  prob=dbinom(n.success, n.total, p.success))
ggplot()+
  geom_point(aes(
    n.success, prob),
    data=lik.dt)+
  geom_vline(xintercept=(n.total+1)*p.success)

## visualize the multinomial likelihood as a function of number of
## successes, for a given probability of success.

```

```

n.total <- 43
prob.vec <- c(train=0.6, validation=0.3, test=0.1)
train.dt <- data.table(train=0:n.total)
grid.dt <- train.dt[, data.table(
  validation=0:(n.total-train)), by=train]
grid.dt[, prob := dmultinom(
  c(train, validation, n.total-train-validation),
  n.total,
  prob.vec),
  by=.(train, validation)]

train.bound <- (n.total+1)*prob.vec[["train"]]
validation.bound <- (n.total+1)*prob.vec[["validation"]]
guess.dt <- data.table(
  train=floor(train.bound),
  validation=floor(validation.bound))
max.dt <- grid.dt[which.max(prob)]#same
max.dt[, test := n.total-train-validation]

ggplot()+
  geom_tile(aes(
    train, validation, fill=prob),
    data=grid.dt)+
  scale_fill_gradient(low="white", high="red")+
  theme_bw()+
  geom_vline(
    xintercept=train.bound)+
  geom_hline(
    yintercept=validation.bound)+
  geom_point(aes(
    train, validation),
    shape=1,
    data=guess.dt)+
  coord_equal()

## visualize what happens when we start obs.seq variable above at 1
## or 0. starting at 0 is problematic e.g. 99% train/1% test with
## N=2 observations should return 2 train/0 test (and does when
## obs.seq starts with 1, but does NOT when obs.seq starts with 0).
random_set_vec(2L, c(train=0.99, test=0.01))
obs.dt.list <- list()
cum.dt.list <- list()
for(tvt.N in 2:4){
  obs.dt.list[[paste(tvt.N)]] <- data.table(tvt.N, rbind(
    data.table(start=0, obs=seq(0, tvt.N, l=tvt.N)),
    data.table(start=1, obs=seq(1, tvt.N, l=tvt.N))))
  not.round <- data.table(
    set=c("train", "test"),
    cum.thresh=tvt.N*c((tvt.N-2)/(tvt.N-1), 1))
  cum.dt.list[[paste(tvt.N)]] <- data.table(tvt.N, rbind(
    data.table(round=FALSE, not.round),
    not.round[, .(round=TRUE, set, cum.thresh=round(cum.thresh))]))
}

```

```

cum.dt <- do.call(rbind, cum.dt.list)
obs.dt <- do.call(rbind, obs.dt.list)
ggplot()+
  theme_bw()+
  theme(panel.spacing=grid::unit(0, "lines"))+
  facet_grid(tvt.N ~ .)+
  geom_point(aes(
    obs, start),
    data=obs.dt)+
  geom_vline(aes(
    xintercept=cum.thresh, color=round, linetype=round),
    data=cum.dt)

```

size_to_splits	<i>size to splits</i>
----------------	-----------------------

Description

Convert segment size to number of splits which must be computed during the optimization.

Usage

```

size_to_splits(size,
  min.segment.length)

```

Arguments

size	Segment size, positive integer.
min.segment.length	Minimum segment length, positive integer.

Value

Number of splits, integer.

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

tree_layout	<i>tree layout</i>
-------------	--------------------

Description

Compute x,y coordinates for graphing a tree.

Usage

```
tree_layout(node.dt,
            space = 0.5)
```

Arguments

node.dt	node.dt
space	space

Author(s)

Toby Dylan Hocking <toby.hocking@r-project.org> [aut, cre]

Examples

```
N.data <- 29L
min.seg.len <- 3L
max.segments <- 5L
cost.dt <- binsegRcpp::get_complexity_best_optimal_cost(
  N.data, min.seg.len, max.segments)
set.seed(1)
data.vec <- rnorm(N.data)
fit <- binsegRcpp::binseg_normal(data.vec, max.segments)
tree.list <- list(
  best=binsegRcpp::get_complexity_best_optimal_tree(cost.dt),
  empirical=binsegRcpp::get_tree_empirical(fit))
library(data.table)
tree.dt <- data.table(type=names(tree.list))[, {
  binsegRcpp::tree_layout(tree.list[[type]])
}, by=type]
total.dt <- tree.dt[, .(
  candidate.splits=sum(binsegRcpp::size_to_splits(size, min.seg.len))
), by=type]
join.dt <- total.dt[tree.dt, on="type"]
if(require(ggplot2)){
  ggplot()+
    facet_grid(. ~ type + candidate.splits, labeller=label_both)+
    geom_segment(aes(
      x, depth,
      xend=parent.x, yend=parent.depth),
      data=join.dt)+
```

```
geom_label(aes(  
  x, depth, label=size),  
  data=join.dt)+  
scale_y_reverse()  
}
```


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