Package ‘PSCBS’

October 23, 2021

Version 0.66.0

Depends R (>= 3.2.0)

Imports R.methodsS3 (>= 1.8.1), R.oo (>= 1.24.0), R.utils (>= 2.11.0),
    R.cache (>= 0.15.0), matrixStats (>= 0.61.0), aroma.light (>=
    2.4.0), DNAcopy (>= 1.42.0), listenv (>= 0.8.0), future (>=
    1.22.1), parallel, graphics, grDevices, stats, utils

Suggests Hmisc, R.rsp (>= 0.44.0), R.devices (>= 2.17.0), ggplot2 (>=
    3.2.1)

SuggestsNote BioC (>= 3.1)

VignetteBuilder R.rsp

Title Analysis of Parent-Specific DNA Copy Numbers

Description Segmentation of allele-specific DNA copy number data and detection of regions with ab-
    normal copy number within each parental chromosome. Both tumor-normal paired and tumor-
    only analyses are supported.

License GPL (>= 2)

LazyLoad TRUE

ByteCompile TRUE

biocViews aCGH, CopyNumberVariants, SNP, Microarray, OneChannel,
    TwoChannel, Genetics

URL https://github.com/HenrikBengtsson/PSCBS

BugReports https://github.com/HenrikBengtsson/PSCBS/issues

NeedsCompilation no

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    Hmisc::wtd.quantile())
PSCBS-package

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Repository  CRAN
Date/Publication  2021-10-23 07:40:02 UTC

R topics documented:

PSCBS-package ................................................. 2
callSegmentationOutliers ................................. 3
CBS ............................................................ 4
findLargeGaps ............................................... 6
gapsToSegments.data.frame ............................. 7
NonPairedPSCBS ........................................... 8
PairedPSCBS ................................................. 9
PSCBS ....................................................... 11
segmentByCBS ............................................. 12
segmentByNonPairedPSCBS ............................. 17
segmentByPairedPSCBS ................................. 20

Index 25

PSCBS-package Package PSCBS

Description
Segmentation of allele-specific DNA copy number data and detection of regions with abnormal copy number within each parental chromosome. Both tumor-normal paired and tumor-only analyses are supported..

This package should be considered to be in an alpha or beta phase. You should expect the API to be changing over time.

Installation and updates
To install this package, use install.packages("PSCBS").

To get started
To get started, see:

1. Vignettes 'Parent-specific copy-number segmentation using Paired PSCBS' and 'Total copy-number segmentation using CBS'.
2. segmentByCBS() - segments total copy-numbers, or any other unimodal genomic signals, using the CBS method [3,4].
3. segmentByPairedPSCBS() - segments allele-specific tumor signal from a tumor with a matched normal using the Paired PSCBS method [1,2].
4. segmentByNonPairedPSCBS() - segments allele-specific tumor signal from a tumor without a matched normal using the Non-Paired PSCBS method adopted from [1,2].
How to cite


License

GPL (>= 2).

Author(s)

Henrik Bengtsson

References

lar binary segmentation for the analysis of array-based DNA copy number data, Biostatistics, 2004

callSegmentationOutliers

Calls/drops single-locus outliers along the genome

Description

Calls/drops single-locus outliers along the genome that have a signal that differ significantly from the neighboring loci.

Usage

```r
## Default S3 method:
callSegmentationOutliers(y, chromosome=0, x=NULL, method="DNAcopy::smooth.CNA", ..., verbose=FALSE)
## S3 method for class 'data.frame'
callSegmentationOutliers(y, ...)

## Default S3 method:
dropSegmentationOutliers(y, ...)
## S3 method for class 'data.frame'
dropSegmentationOutliers(y, ...)
```
Arguments

- **y**
  A **numeric vector** of J genomic signals to be segmented.
- **chromosome**
  (Optional) An **integer** scalar (or a **vector** of length J contain a unique value). Only used for annotation purposes.
- **x**
  Optional **numeric vector** of J genomic locations. If **NULL**, index locations 1:J are used.
- **method**
  A **character** string specifying the method used for calling outliers.
- **...**
  Additional arguments passed to internal outlier detection method.
- **verbose**
  See **Verbose**.

Value

callSegmentationOutliers() returns a **logical vector** of length J. dropSegmentationOutliers() returns an object of the same type as argument **y**, where the signals for which outliers were called have been set to **NA**.

Missing and non-finite values

Signals as well as genomic positions may contain missing values, i.e. **NAs** or **NaNs**. By definition, these cannot be outliers.

Author(s)

Henrik Bengtsson

See Also

Internally **smooth.CNA** is utilized to identify the outliers.

---

CBS

*The CBS class*

Description

A CBS object holds results from the Circular Binary Segmentation (CBS) method for *one* sample for one or more chromosomes.

Package: PSCBS

Class CBS

```
list
~~|   
~~++--AbstractCBS
~~~~~~|   
~~~~~~~~++--CBS
```
Directly known subclasses:

public abstract static class CBS
extends AbstractCBS

Usage
CB(…)

Arguments
…
Arguments passed to the constructor of AbstractCBS.

Fields and Methods

Methods:

as -
c -
estimateStandardDeviation Estimates the whole-genome standard deviation of the signals.
plotTracks Plots copy numbers along the genome.
pruneBySdUndo Prune the CBS profile by dropping change points that are too small.
segmentByCBS -
seqOfSegmentsByDP -
writeSegments Writes the table of segments to file.

Methods inherited from AbstractCBS:
adjustPloidyScale, all.equal, append, as.data.frame, clearCalls, drawChangePoints, drawKnownSegments, dropChangePoint, dropChangePoints, dropRegion, dropRegions, extractCNs, extractChromosome, extractChromosomes, extractRegions, extractSegments, extractWIG, getChangePoints, getChromosomeOffsets, getChromosomeRanges, getChromosomes, getLocusData, getLocusSignalNames, getMeanEstimators, getSampleName, getSegmentSizes, getSegmentTrackPrefixes, getSegments, load, mergeThreeSegments, mergeTwoSegments, nbrOfChangePoints, nbrOfChromosomes, nbrOfLoci, nbrOfSegments, normalizeTotalCNs, ploidy, ploidy<-, plotTracks, print, pruneByDP, pruneByHCust, renameChromosomes, report, resegment, resetSegments, sampleCNs, sampleName, sampleName<-, save, seqOfSegmentsByDP, setLocusData, setMeanEstimators, setPloidy, setSampleName, setSegments, shiftTCN, tileChromosomes, updateMeans, writeWIG

Methods inherited from list:
Ops,nonStructure, vector-method, Ops, structure, vector-method, Ops, vector, nonStructure-method, Ops, vector, structure-method, all.equal, as.data.frame, attachLocally, averageQuantile, callHooks, coerce, ANY, list-method, coerce, Matrix, vector-method, coerce, abIndex, vector-method, coerce, dgCMatrix, vector-method, coerce, dsCMatrix, vector-method, coerce, list, indMatrix-method, coerce, sparseVector, vector-method, contents, ggplot_add, latex, normalizeAverage, normalizeDifferencesToAverage, normalizeQuantileRank, normalizeQuantileSpline, plotDensity, relist, scale_type, type.convert, within
findLargeGaps

Difference to DNAcopy object

A CBS object is similar to DNAcopy objects with the major difference that a CBS object holds only one sample, whereas a DNAcopy object can hold more than one sample.

See also

The `segmentByCBS()` method returns an object of this class.

Author(s)

Henrik Bengtsson

findLargeGaps

Identifies gaps of a genome where there exist no observations

Description

Identifies gaps of a genome where there exist no observations.

Usage

```r
## Default S3 method:
findLargeGaps(chromosome=NULL, x, minLength, resolution=1L, ...)
```

Arguments

- **chromosome** *(Optional)* An `integer vector` of length J of chromosome indices.
- **x** A `numeric vector` of J of genomic locations.
- **minLength** A positive `numeric scalar` specifying the minimum length of a gap.
- **resolution** A non-negative `numeric` specifying the minimum length unit, which by default equals one nucleotide/base pair.
- **...** Not used.

Value

Returns `data.frame` zero or more rows and with columns chromosome (if given), start, stop, and length.

Author(s)

Henrik Bengtsson

See Also

Use `gapsToSegments()` to turn the set of identified gaps into the complementary set of segments such that they can be passed to `segmentByCBS()`, `segmentByPairedPSCBS()` and `segmentByNonPairedPSCBS()` via argument knownSegments.
gapsToSegments.data.frame

*Gets the genomic segments that are complementary to the gaps*

Description

Gets the genomic segments that are complementary to the gaps, with default chromosome boundaries being \(-\text{Inf}\) and \(\text{+Inf}\).

Usage

```r
## S3 method for class 'data.frame'
gapsToSegments(gaps, resolution=1L, minLength=0L, dropGaps=FALSE, ...)
```

Arguments

- `gaps`: A `data.frame` with columns `chromosome`, `start`, and `stop`. Any overlapping gaps will throw an error.
- `resolution`: A non-negative `numeric` specifying the minimum length unit, which by default equals one nucleotide/base pair.
- `minLength`: Minimum length of segments to be kept.
- `dropGaps`: If `TRUE`, the gaps themselves are not part of the output.
- `...`: Not used.

Value

Returns a `data.frame` of at least one row with columns `chromosome`, `start`, `stop`, and `length`. The segments are ordered along the genome.

Author(s)

Henrik Bengtsson

See Also

- `findLargeGaps()`.
The NonPairedPSCBS class

Description

Package: PSCBS
Class NonPairedPSCBS

```
list
~|  
~~|---AbstractCBS
~~~~|  
~~~~~~|---PSCBS
~~~~~~~~|  
~~~~~~~~~|---NonPairedPSCBS
```

Directly known subclasses:

public abstract static class **NonPairedPSCBS** extends **PSCBS**

A NonPairedPSCBS is an object containing the results from the Non-paired PSCBS method.

Usage

```R
NonPairedPSCBS(fit=list(), ...)
```

Arguments

- **fit**: A **list** structure containing the Non-paired PSCBS results.
- **...**: Not used.

Fields and Methods

Methods:
No methods defined.

Methods inherited from PSCBS:
- `as.data.frame`, `c`, `drawChangePoints`, `extractChromosomes`, `extractWIG`, `getLocusData`, `getLocusSignalNames`, `getSegmentTrackPrefixes`, `isLocallyPhased`, `isSegmentSplitter`, `normalizeTotalCNs`, `writeSegments`

Methods inherited from AbstractCBS:
- `adjustPloidyScale`, `all.equal`, `append`, `as.data.frame`, `clearCalls`, `drawChangePoints`, `drawKnownSegments`, `dropChangePoint`, `dropChangePoints`, `dropRegion`, `dropRegions`, `extractCNs`, `extractChromosomem`, `extractChromosomes`, `extractRegions`, `extractSegments`, `extractWIG`, `getChangePoints`, `getLocusData`, `getLocusSignalNames`, `getSegmentTrackPrefixes`, `isLocallyPhased`, `isSegmentSplitter`, `normalizeTotalCNs`, `writeSegments`
getChromosomeOffsets, getChromosomeRanges, getChromosomes, getLocusData, getLocusSignalNames, getMeanEstimators, getSampleName, getSegmentSizes, getSegmentTrackPrefixes, getSegments, load, mergeThreeSegments, mergeTwoSegments, nbrOfChangePoints, nbrOfChromosomes, nbrOfLoci, nbrOfSegments, normalizeTotalCNs, ploidy, ploidy<-, plotTracks, print, pruneByDP, pruneByHClust, renameChromosomes, report, resegment, resetSegments, sampleCNs, sampleName, sampleName<-, save, seqOfSegmentsByDP, setLocusData, setMeanEstimators, setPloidy, setSampleName, setSegments, shiftTCN, tileChromosomes, updateMeans, writeWIG

Methods inherited from list:
Ops, nonStructure, vector-method, Ops, structure, vector-method, Ops, vector, nonStructure-method, Ops, vector, structure-method, all.equal, as.data.frame, attachLocally, averageQuantile, callHooks, coerce, ANY, list-method, coerce, Matrix, vector-method, coerce, abIndex, vector-method, coerce, dgCMatrix, vector-method, coerce, dscMatrix, vector-method, coerce, list, indMatrix-method, coerce, sparseVector, vector-method, contents, ggplot_add, latex, normalizeAverage, normalizeDifferencesToAverage, normalizeQuantileRank, normalizeQuantileSpline, plotDensity, relist, scale_type, type.convert, within

Author(s)
Henrik Bengtsson

See Also
The `segmentByNonPairedPSCBS()` method returns an object of this class.

---

**PairedPSCBS**

*The PairedPSCBS class*

**Description**

Package: PSCBS

Class `PairedPSCBS`

```
list
~~|  
~~+---AbstractCBS
~~~~~~|  
~~~~~~~~+---PSCBS
~~~~~~~~~~|  
~~~~~~~~~~~~+---PairedPSCBS

Directly known subclasses:

public abstract static class `PairedPSCBS`

extends `PSCBS`

A PairedPSCBS is an object containing the results from the Paired PSCBS method.
Usage

PairedPSCBS(fit=list(), ...)

Arguments

fit    A list structure containing the Paired PSCBS results.
...
Not used.

Fields and Methods

Methods:

callAB          Calls segments that are in allelic balance.
callCopyNeutral Calls segments that have a neutral total copy number.
callGNL         Calls segments that are gained, copy neutral, or lost.
callGNLByTCNofAB -
callGainNeutralLoss -
callLOH         Calls segments that are in LOH.
callNTCN        -
callROH         Calls segments that are in ROH.
estimateDeltaAB Estimate a threshold for calling allelic balance from DH.
estimateDeltaLOH Estimate a threshold for calling LOH from DH.
estimateKappa   Estimate global background in segmented copy numbers.
extractCNs      -
hasBootstrapSummaries -
plotTracks     Plots parental specific copy numbers along the genome.

Methods inherited from PSCBS:
as.data.frame, c, drawChangePoints, extractChromosomes, extractWIG, getLocusData, getLocusSignalNames, getSegmentTrackPrefixes, isLocallyPhased, isSegmentSplitter, normalizeTotalCNs, writeSegments

Methods inherited from AbstractCBS:
adjustPloidyScale, all.equal, append, as.data.frame, clearCalls, drawChangePoints, drawKnownSegments, dropChangePoint, dropChangePoints, dropRegion, dropRegions, extractCNs, extractChromosome, extractChromosomes, extractRegions, extractSegments, extractWIG, getChangePoints, getChromosomeOffsets, getChromosomeRanges, getChromosomes, getLocusData, getLocusSignalNames, getMeanEstimators, getName, getSampleName, getSegmentSizes, getSegmentTrackPrefixes, getSegments, load, mergeThreeSegments, mergeTwoSegments, nbofChangePoints, nbofChromosomes, nbofLoci, nbofSegments, normalizeTotalCNs, ploidy, ploidy<-, plotTracks, print, pruneByDP, pruneByHClust, renameChromosomes, report, resegment, resetSegments, sampleCNs, sampleName, sampleName<-, save, seqOfSegmentsByDP, setLocusData, setMeanEstimators, setPloidy, setSampleName, setSegments, shiftTCN, tileChromosomes, updateMeans, writeWIG
**Methods inherited from list:**
Ops, nonStructure, vector-method, Ops, structure, vector-method, Ops, vector, nonStructure-method, Ops, vector, structure-method, all.equal, as.data.frame, attachLocally, averageQuantile, callHooks, coerce, ANY, list-method, coerce, Matrix, vector-method, coerce, abIndex, vector-method, coerce, dgCMatrix, vector-method, coerce, dsCMatrix, vector-method, coerce, list, indMatrix-method, coerce, sparseVector, vector-method, contents, ggplot_add, latex, normalizeAverage, normalizeDifferencesToAverage, normalizeQuantileRank, normalizeQuantileSpline, plotDensity, relist, scale_type, type.convert, within

**Author(s)**
Henrik Bengtsson

**See Also**
The `segmentByPairedPSCBS()` method returns an object of this class.

---

**PSCBS**
The PSCBS class

---

**Description**
Package: PSCBS  
Class PSCBS

```
list  
~~|  
~~+++AbstractCBS  
~~~~~~~|  
~~~~~~~~+++PSCBS
```

**Directly known subclasses:**
*NonPairedPSCBS, PairedPSCBS*

public abstract static class PSCBS  
extends AbstractCBS

A PSCBS is an object containing results from parent-specific copy-number (PSCN) segmentation.

**Usage**
PSCBS(fit=list(), ...)

**Arguments**

- `fit` A list structure containing the PSCN segmentation results.
- `...` Not used.
Fields and Methods

Methods:

- isLocallyPhased
- normalizeTotalCNs
- writeSegments

Writes the table of segments to file.

Methods inherited from AbstractCBS:
adjustPloidyScale, all.equal, append, as.data.frame, clearCalls, drawChangePoints, drawKnownSegments, dropChangePoint, dropChangePoints, dropRegion, dropRegions, extractCNs, extractChromosome, extractChromosomes, extractRegions, extractSegments, extractWIG, getChangePoints, getChromosomeOffsets, getChromosomeRanges, getChromosomes, getLocusData, getLocusSignalNames, getMeanEstimators, getSampleName, getSegmentSizes, getSegmentTrackPrefixes, getSegments, load, mergeThreeSegments, mergeTwoSegments, nbrOfChangePoints, nbrOfChromosomes, nbrOfLoci, nbrOfSegments, normalizeTotalCNs, ploidy, ploidy<-, plotTracks, print, pruneByDP, pruneByHClust, renameChromosomes, report, resegment, resetSegments, sampleCNs, sampleName, sampleName<-, save, seqOfSegmentsByDP, setLocusData, setMeanEstimators, setPloidy, setName, setSegments, shiftTCN, tileChromosomes, updateMeans, writeWIG

Methods inherited from list:
Ops,nonStructure,vector-method, Ops,structure,vector-method, Ops,vector,nonStructure-method, Ops,vector,structure-method, all.equal, as.data.frame, attachLocally, averageQuantile, callHooks, coerce,ANY,list-method, coerce,Matrix,vector-method, coerce,abIndex,vector-method, coerce,dgCMatrix,vector-method, coerce,dsCMatrix,vector-method, coerce,list,indMatrix-method, coerce,sparseVector,vector-method, contents, ggplot_add, latex, normalizeAverage, normalizeDifferencesToAverage, normalizeQuantileRank, normalizeQuantileSpline, plotDensity, relist, scale_type, type.convert, within

Author(s)

Henrik Bengtsson

See Also

PairedPSCBS.

---

segmentByCBS  Segment genomic signals using the CBS method

### Description

Segment genomic signals using the CBS method of the DNAcopy package. This is a convenient low-level wrapper for the DNAcopy::segment() method. It is intended to be applied to a sample at the time. For more details on the Circular Binary Segmentation (CBS) method see [1,2].
Usage

```
## Default S3 method:
segmentByCBS(y, chromosome=0L, x=NULL, index=seq_along(y), w=NULL, undo=0,
    avg=c("mean", "median"), ..., joinSegments=TRUE, knownSegments=NULL, seed=NULL,
    verbose=FALSE)
```

Arguments

- `y`: A numeric vector of J genomic signals to be segmented.
- `chromosome`: Optional numeric vector of length J, specifying the chromosome of each loci. If a scalar, it is expanded to a vector of length J.
- `x`: Optional numeric vector of J genomic locations. If NULL, index locations 1:J are used.
- `index`: An optional integer vector of length J specifying the genomewide indices of the loci.
- `w`: Optional numeric vector in [0,1] of J weights.
- `undo`: A non-negative numeric. If greater than zero, then arguments undo.splits="sundo" and undo.SD=undo are passed to DNAcopy::segment(). In the special case when undo is +Inf, the segmentation result will not contain any changepoints (in addition to what is specified by argument knownSegments).
- `avg`: A character string specifying how to calculating segment mean levels after change points have been identified.
- `...`: Additional arguments passed to the DNAcopy::segment() segmentation function.
- `joinSegments`: If TRUE, there are no gaps between neighboring segments. If FALSE, the boundaries of a segment are defined by the support that the loci in the segments provides, i.e. there exist a locus at each end point of each segment. This also means that there is a gap between any neighboring segments, unless the change point is in the middle of multiple loci with the same position. The latter is what DNAcopy::segment() returns.
- `knownSegments`: Optional data.frame specifying non-overlapping known segments. These segments must not share loci. See findLargeGaps() and gapsToSegments().
- `seed`: An (optional) integer specifying the random seed to be set before calling the segmentation method. The random seed is set to its original state when exiting. If NULL, it is not set.
- `verbose`: SeeVerbose.

Details

Internally `segment` of DNAcopy is used to segment the signals. This segmentation method supports weighted segmentation.

Value

Returns a CBS object.
Reproducibility

The DNAcopy::segment() implementation of CBS uses approximation through random sampling for some estimates. Because of this, repeated calls using the same signals may result in slightly different results, unless the random seed is set/fixed.

Missing and non-finite values

Signals may contain missing values (NA or NaN), but not infinite values (+/-Inf). Loci with missing-value signals are preserved and keep in the result.

Likewise, genomic positions may contain missing values. However, if they do, such loci are silently excluded before performing the segmentation, and are not kept in the results. The mapping between the input locus-level data and ditto of the result can be inferred from the index column of the locus-level data of the result.

None of the input data may have infinite values, i.e. -Inf or +Inf. If so, an informative error is thrown.

Author(s)

Henrik Bengtsson

References


See Also

To segment allele-specific tumor copy-number signals from a tumor with a matched normal, see segmentByPairedPSCBS(). For the same without a matched normal, see segmentByNonPairedPSCBS().

It is also possible to prune change points after segmentation (with identical results) using pruneBySdUndo().

Examples

# Simulating copy-number data
set.seed(0xBEEF)
J <- 1000
mu <- double(J)
mu[200:300] <- mu[200:300] + 1
mu[350:400] <- NA # centromere
mu[650:800] <- mu[650:800] - 1
eps <- rnorm(J, sd=1/2)
y <- mu + eps
x <- sort(runif(length(y), max=length(y))) * 1e5
w <- runif(J)
w[650:800] <- 0.001

# Segmentation
fit <- segmentByCBS(y, x=x)
print(fit)
plotTracks(fit)

xlab <- "Position (Mb)"
ylim <- c(-3,3)
xMb <- x/1e6
plot(xMb,y, pch=20, col="#aaaaaa", xlab=xlab, ylim=ylim)
drawLevels(fit, col="red", lwd=2, xScale=1e-6)

# TESTS
fit <- segmentByCBS(y, x=x, seed=0xBEEF)
print(fit)

## id chromosome start end nbrOfLoci mean
## 1 y 0 55167.82 20774251 201 0.0164
## 2 y 0 20774250.85 29320105 99 1.0474
## 3 y 0 29320104.86 65874675 349 -0.0227
## 4 y 0 65874675.06 81348129 151 -1.0813
## 5 y 0 81348129.20 99910827 200 -0.0612

# Test #1: Reverse the ordering and segment
fitR <- segmentByCBS(rev(y), x=rev(x), seed=0xBEEF)
# Sanity check
stopifnot(all.equal(getSegments(fitR), getSegments(fit)))
# Sanity check
stopifnot(all.equal(rev(getLocusData(fitR)$index), getLocusData(fit)$index))

# Test #2: Reverse, but preserve ordering of 'data' object
fitRP <- segmentByCBS(rev(y), x=rev(x), preserveOrder=TRUE)
stopifnot(all.equal(getSegments(fitRP), getSegments(fit)))

# Test #3: Change points inbetween data points at the same locus
x[650:654] <- x[649]
fitC <- segmentByCBS(rev(y), x=rev(x), preserveOrder=TRUE, seed=0xBEEF)

# Test #4: Allow for some missing values in signals
y[450] <- NA
fitD <- segmentByCBS(y, x=x, seed=0xBEEF)

# Test #5: Allow for some missing genomic annotations
x[495] <- NA
fitE <- segmentByCBS(y, x=x, seed=0xBEEF)

# Test #6: Undo all change points found
fitF <- segmentByCBS(y, x=x, undo=Inf, seed=0xBEEF)
print(fitF)
stopifnot(nbrOfSegments(fitF) == 1L)

# - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
# MISC.
# - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
# Emulate a centromere
x[650:699] <- NA
fit <- segmentByCBS(y, x=x, seed=0xBEEF)
xMb <- x/1e6
plot(xMb,y, pch=20, col="#aaaaaa", xlab=xlab, ylim=ylim)
drawLevels(fit, col="red", lwd=2, xScale=1e-6)

fitC <- segmentByCBS(y, x=x, joinSegments=FALSE, seed=0xBEEF)
drawLevels(fitC, col="blue", lwd=2, xScale=1e-6)

# - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
# Multiple chromosomes
# - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
# Appending CBS results
fit1 <- segmentByCBS(y, chromosome=1, x=x)
fit2 <- segmentByCBS(y, chromosome=2, x=x)
fit <- c(fit1, fit2)
print(fit)
plotTracks(fit, subset=NULL, lwd=2, Clim=c(-3,3))

# Segmenting multiple chromosomes at once
chromosomeWG <- rep(1:2, each=J)
xWG <- rep(x, times=2)
yWG <- rep(y, times=2)
fitWG <- segmentByCBS(yWG, chromosome=chromosomeWG, x=xWG)
print(fitWG)
plotTracks(fitWG, subset=NULL, lwd=2, Clim=c(-3,3))

# Assert same results
fit$data[,"index"] <- getLocusData(fitWG)[,"index"] # Ignore 'index'
stopifnot(all.equal(getLocusData(fitWG), getLocusData(fit)))
stopifnot(all.equal(getSegments(fitWG), getSegments(fit)))
Description

Segment total copy numbers and allele B fractions using the Non-paired PSCBS method [1]. This method does not require matched normals. This is a low-level segmentation method. It is intended to be applied to one tumor sample at the time.

Usage

```r
## Default S3 method:
segmentByNonPairedPSCBS(CT, betaT, ..., flavor=c("tcn", "tcn&dh", "tcn, dh", "sqrt(tcn), dh", "sqrt(tcn)&dh"), tauA=NA, tauB=1 - tauA, verbose=FALSE)
```

Arguments

- **CT**: A numeric vector of J tumor total copy number (TCN) ratios in \([0, +\text{Inf}]\) (due to noise, small negative values are also allowed). The TCN ratios are typically scaled such that copy-neutral diploid loci have a mean of two.
- **betaT**: A numeric vector of J tumor allele B fractions (BAFs) in \([0, 1]\) (due to noise, values may be slightly outside as well) or NA for non-polymorphic loci.
- **...**: Additional arguments passed to `segmentByPairedPSCBS()`.
- **flavor**: A character specifying what type of segmentation and calling algorithm to be used.
- **tauA, tauB**: Lower and upper thresholds (\(\tau_A < \tau_B\)) for calling SNPs heterozygous based on the tumor allele B fractions (betaT). If NA, then they are estimates from data.
- **verbose**: See `Verbose`.

Details

Internally `segmentByPairedPSCBS()` is used for segmentation. This segmentation method does not support weights.

Value

Returns the segmentation results as a `NonPairedPSCBS` object.

Reproducibility

The "DNAcopy::segment" implementation of CBS uses approximation through random sampling for some estimates. Because of this, repeated calls using the same signals may result in slightly different results, unless the random seed is set/fixed.
Whole-genome segmentation is preferred

Although it is possible to segment each chromosome independently using Paired PSCBS, we strongly recommend to segment whole-genome (TCN, BAF) data at once. The reason for this is that downstream CN-state calling methods, such as the AB and the LOH callers, performs much better on whole-genome data. In fact, they may fail to provide valid calls if done chromosome by chromosome.

Missing and non-finite values

The total copy number signals as well as any optional positions must not contain missing values, i.e. NAs or NaNs. If there are any, an informative error is thrown. Allele B fractions may contain missing values, because such are interpreted as representing non-polymorphic loci.

None of the input signals may have infinite values, i.e. -Inf or +Inf. If so, an informative error is thrown.

Non-Paired PSCBS with known genotypes

If allele B fractions for the matched normal (betaN) are not available, but genotypes (muN) are, then it is possible to run Paired PSCBS. See `segmentByPairedPSCBS()` for details.

Author(s)

Henrik Bengtsson

References


See Also

To segment paired tumor-normal total copy numbers and allele B fractions, see `segmentByPairedPSCBS()`.
To segment total copy numbers, or any other unimodal signals, see `segmentByCBS()`.

Examples

```r
verbose <- R.utils::Arguments$getVerbose(-10*interactive(), timestamp=TRUE)

# - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
# Load SNP microarray data
# - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
data <- PSCBS::exampleData("paired.chr01")
str(data)
```
# Paired PSCBS segmentation

# Drop single-locus outliers
```
dataS <- dropSegmentationOutliers(data)
```

# Speed up example by segmenting fewer loci
```
dataS <- dataS[seq(from=1, to=nrow(data), by=20),]
```

```
str(dataS)
```

```
R.oo::attachLocally(dataS)
```

# Non-Paired PSCBS segmentation

```
fit <- segmentByNonPairedPSCBS(CT, betaT=betaT,
    chromosome=chromosome, x=x,
    seed=0xBEEF, verbose=verbose)
```

```
print(fit)
```

# Bootstrap segment level estimates
# (used by the AB caller, which, if skipped here,
# will do it automatically)
```
fit <- bootstrapTCNandDHByRegion(fit, B=100, verbose=verbose)
```

```
print(fit)
```

# Calling segments in allelic balance (AB)
# NOTE: Ideally, this should be done on whole-genome data

```
deltaAB <- estimateDeltaAB(fit, flavor="qq(DH)", verbose=verbose)
```

```
print(deltaAB)
```

```
fit <- callAB(fit, delta=deltaAB, verbose=verbose)
```

```
print(fit)
```

# Even if not explicitly specified, the estimated
# threshold parameter is returned by the caller
```
stopifnot(fit$params$deltaAB == deltaAB)
```

# Calling segments in loss-of-heterozygosity (LOH)
# NOTE: Ideally, this should be done on whole-genome data

```
delta <- estimateDelta(fit, flavor="qq(DH)", verbose=verbose)
```

```
print(delta)
```

```
fit <- callAB(fit, delta=delta, verbose=verbose)
```

```
print(fit)
```

# Even if not explicitly specified, the estimated
# threshold parameter is returned by the caller
```
stopifnot(fit$params$deltaAB == deltaAB)
segmentByPairedPSCBS

Segment total copy numbers and allele B fractions using the Paired PSCBS method

Description

Segment total copy numbers and allele B fractions using the Paired PSCBS method [1]. This method requires matched normals. This is a low-level segmentation method. It is intended to be applied to one tumor-normal sample at the time.

Usage

```r
## Default S3 method:
segmentByPairedPSCBS(CT, thetaT=NULL, thetaN=NULL, betaT=NULL, betaN=NULL, muN=NULL, 
rho=NULL, chromosome=0, x=NULL, alphaTCN=0.009, alphaDH=0.001, undoTCN=0, undoDH=0, 
..., avgTCN=c("mean", "median"), avgDH=c("mean", "median"), 
flavor=c("tcn&dh" ,"tcn,"dh", "sqrt(tcn),dh", "sqrt(tcn)&dh", "tcn"), tbn=is.null(rho), 
joinSegments=TRUE, knownSegments=NULL, dropMissingCT=TRUE, seed=NULL, verbose=FALSE, 
preserveScale=FALSE)
```

Arguments

- **CT**
  - A numeric vector of J tumor total copy number (TCN) ratios in \([0,+\infty]\) (due to noise, small negative values are also allowed). The TCN ratios are typically scaled such that copy-neutral diploid loci have a mean of two.

- **thetaT, thetaN**
  - (alternative) As an alternative to specifying tumor TCN ratios relative to the match normal by argument CT, on may specify total tumor and normal signals separately, in which case the TCN ratios CT are calculated as \(CT = 2 * thetaT/thetaN\).

- **betaT**
  - A numeric vector of J tumor allele B fractions (BAFs) in \([0,1]\) (due to noise, values may be slightly outside as well) or NA for non-polymorphic loci.

- **betaN**
  - A numeric vector of J matched normal BAFs in \([0,1]\) (due to noise, values may be slightly outside as well) or NA for non-polymorphic loci.

- **muN**
  - An optional numeric vector of J genotype calls in \([0,1/2,1]\) for AA, AB, and BB, respectively, and NA for non-polymorphic loci. If not given, they are estimated from the normal BAFs using callNaiveGenotypes as described in [2].
segmentByPairedPSCBS

rho (alternative to betaT and betaN/muN) A numeric vector of J decrease-of-heterozygosity signals (DHs) in [0,1] (due to noise, values may be slightly larger than one as well). By definition, DH should be NA for homozygous loci and for non-polymorphic loci.

chromosome (Optional) An integer scalar (or a vector of length J), which can be used to specify which chromosome each locus belongs to in case multiple chromosomes are segments. This argument is also used for annotation purposes.

x Optional numeric vector of J genomic locations. If NULL, index locations 1:J are used.

alphaTCN, alphaDH The significance levels for segmenting total copy numbers (TCNs) and decrease-in-heterozygosity signals (DHs), respectively.

undoTCN, undoDH Non-negative numerics. If greater than 0, then a cleanup of segmentions post segmentation is done. See argument undo of segmentByCBS() for more details.

avgTCN, avgDH A character string specifying how to calculating segment mean levels after change points have been identified.

... Additional arguments passed to segmentByCBS().

flavor A character specifying what type of segmentation and calling algorithm to be used.

tbn If TRUE, betaT is normalized before segmentation using the TumorBoost method [2], otherwise not.

joinSegments If TRUE, there are no gaps between neighboring segments. If FALSE, the boundaries of a segment are defined by the support that the loci in the segments provides, i.e. there exist a locus at each end point of each segment. This also means that there is a gap between any neighboring segments, unless the change point is in the middle of multiple loci with the same position. The latter is what DNAcopy::segment() returns.

knownSegments Optional data.frame specifying non-overlapping known segments. These segments must not share loci. See findLargeGaps() and gapsToSegments().

dropMissingCT If TRUE, loci for which 'CT' is missing are dropped, otherwise not.

seed An (optional) integer specifying the random seed to be set before calling the segmentation method. The random seed is set to its original state when exiting. If NULL, it is not set.

verbose See Verbose.

preserveScale Defunct - gives an error is specified.

Details

Internally segmentByCBS() is used for segmentation. The Paired PSCBS segmentation method does not support weights.

Value

Returns the segmentation results as a PairedPSCBS object.
**Reproducibility**

The "DNAcopy::segment" implementation of CBS uses approximation through random sampling for some estimates. Because of this, repeated calls using the same signals may result in slightly different results, unless the random seed is set/_fixed.

**Whole-genome segmentation is preferred**

Although it is possible to segment each chromosome independently using Paired PSCBS, we strongly recommend to segment whole-genome (TCN,BAF) data at once. The reason for this is that downstream CN-state calling methods, such as the AB and the LOH callers, performs much better on whole-genome data. In fact, they may fail to provide valid calls if done chromosome by chromosome.

**Missing and non-finite values**

The total copy number signals as well as any optional positions must not contain missing values, i.e. `NA` or `NaN`. If there are any, an informative error is thrown. Allele B fractions may contain missing values, because such are interpreted as representing non-polymorphic loci. None of the input signals may have infinite values, i.e. `-Inf` or `+Inf`. If so, an informative error is thrown.

**Paired PSCBS with only genotypes**

If allele B fractions for the matched normal (`betaN`) are not available, but genotypes (`muN`) are, then it is possible to run a version of Paired PSCBS where TumorBoost normalization of the tumor allele B fractions is skipped. In order for this to work, argument `tbn` must be set to `FALSE`.

**Author(s)**

Henrik Bengtsson

**References**


**See Also**

Internally, `callNaiveGenotypes` is used to call naive genotypes, `normalizeTumorBoost` is used for TumorBoost normalization, and `segmentByCBS()` is used to segment TCN and DH separately.

To segment tumor total copy numbers and allele B fractions without a matched normal, see `segmentByNonPairedPSCBS()`.
To segment total copy-numbers, or any other unimodal signals, see `segmentByCBS()`.
**Examples**

```r
verbose <- R.utils::Arguments$getVerbose(-10*interactive(), timestamp=TRUE)

# Load SNP microarray data
data <- PSCBS::exampleData("paired.chr01")
str(data)

# Paired PSCBS segmentation
# Drop single-locus outliers
dataS <- dropSegmentationOutliers(data)

# Speed up example by segmenting fewer loci
dataS <- dataS[seq(from=1, to=nrow(data), by=10),]
str(dataS)
R.oo::attachLocally(dataS)

# Paired PSCBS segmentation
fit <- segmentByPairedPSCBS(CT, betaT=betaT, betaN=betaN,
    chromosome=chromosome, x=x,
    seed=0xBEEF, verbose=verbose)
print(fit)

# Plot results
plotTracks(fit)

# Bootstrap segment level estimates
# (used by the AB caller, which, if skipped here,
# will do it automatically)
#
# Explicitly estimate the threshold in DH for calling AB
# (which be done by default by the caller, if skipped here)
deltaAB <- estimateDeltaAB(fit, flavor="qq(DH)", verbose=verbose)
print(deltaAB)
## [1] 0.1657131
```
fit <- callAB(fit, delta=deltaAB, verbose=verbose)
print(fit)
plotTracks(fit)

# Even if not explicitly specified, the estimated
# threshold parameter is returned by the caller
stopifnot(fit$params$deltaAB == deltaAB)

# - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
# Calling segments in loss-of-heterozygosity (LOH)
# NOTE: Ideally, this should be done on whole-genome data
# - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
# Explicitly estimate the threshold in C1 for calling LOH
# (which be done by default by the caller, if skipped here)
deltaLOH <- estimateDeltaLOH(fit, flavor="minC1|nonAB", verbose=verbose)
print(deltaLOH)
## [1] 0.625175
fit <- callLOH(fit, delta=deltaLOH, verbose=verbose)
print(fit)
plotTracks(fit)

# Even if not explicitly specified, the estimated
# threshold parameter is returned by the caller
stopifnot(fit$params$deltaLOH == deltaLOH)
Index

* IO
  callSegmentationOutliers, 3
  findLargeGaps, 6
  gapsToSegments.data.frame, 7
  segmentByCBS, 12
  segmentByNonPairedPSCBS, 17
  segmentByPairedPSCBS, 20
* classes
  CBS, 4
  NonPairedPSCBS, 8
  PairedPSCBS, 9
  PSCBS, 11
* methods
  callSegmentationOutliers, 3
  gapsToSegments.data.frame, 7
* package
  PSCBS-package, 2

AbstractCBS, 4, 5, 8, 9, 11
c, 5
callAB, 10
callCopyNeutral, 10
callGNL, 10
callLOH, 10
callNaiveGenotypes, 20, 22
callROH, 10
callSegmentationOutliers, 3
CBS, 4, 13
character, 4, 13, 17, 21
data.frame, 6, 7, 13, 21
dropSegmentationOutliers
  (callSegmentationOutliers), 3
estimateDeltaAB, 10
estimateDeltaLOH, 10
estimateKappa, 10
estimateStandardDeviation, 5
FALSE, 13, 21, 22
findLargeGaps, 6, 7, 13, 21
gapsToSegments, 6, 13, 21
gapsToSegments
  (gapsToSegments.data.frame), 7
gapsToSegments.data.frame, 7
Inf, 13, 14, 17, 18, 20, 22
integer, 4, 6, 13, 21
list, 8, 10, 11
logical, 4
NA, 4, 14, 17, 18, 20–22
NaN, 4, 14, 18, 22
NonPairedPSCBS, 8, 11, 17
normalizeTumorBoost, 22
NULL, 4, 13, 21
numeric, 4, 6, 7, 13, 17, 20, 21
PairedPSCBS, 9, 11, 12, 21
plotTracks, 5, 10
pruneBySdUndo, 5, 14
PSCBS, 8, 9, 11
PSCBS-package, 2
segment, 13
segmentByCBS, 2, 6, 12, 18, 21, 22
segmentByNonPairedPSCBS, 2, 6, 9, 14, 17, 22
segmentByPairedPSCBS, 2, 6, 11, 14, 17, 18, 20
smooth.CNA, 4
TRUE, 7, 13, 21
vector, 4, 6, 13, 17, 20, 21
Verbose, 4, 13, 17, 21
writeSegments, 5, 12