

Package ‘DMCHMM’

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Type Package

Title Differentially Methylated CpG using Hidden Markov Model

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Description A pipeline for identifying differentially methylated CpG sites using Hidden Markov Model in bisulfite sequencing data. DNA methylation studies have enabled researchers to understand methylation patterns and their regulatory roles in biological processes and disease. However, only a limited number of statistical approaches have been developed to provide formal quantitative analysis. Specifically, a few available methods do identify differentially methylated CpG (DMC) sites or regions (DMR), but they suffer from limitations that arise mostly due to challenges inherent in bisulfite sequencing data. These challenges include: (1) that read-depths vary considerably among genomic positions and are often low; (2) both methylation and autocorrelation patterns change as regions change; and (3) CpG sites are distributed unevenly. Furthermore, there are several methodological limitations: almost none of these tools is capable of comparing multiple groups and/or working with missing values, and only a few allow continuous or multiple covariates. The last of these is of great interest among researchers, as the goal is often to find which regions of the genome are associated with several exposures and traits. To tackle these issues, we have developed an efficient DMC identification method based on Hidden Markov Models (HMMs) called “DMCHMM” which is a three-step approach (model selection, prediction, testing) aiming to address the aforementioned drawbacks.

Depends R (>= 4.1.0), SummarizedExperiment, methods, S4Vectors, BiocParallel, GenomicRanges, IRanges, fdrtool

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Contents

| | |
|--------------------------------|----|
| DMCHMM-package | 3 |
| BSDData-class | 3 |
| BSDMCs-class | 4 |
| cBSDData-method | 5 |
| cBSDMCs-method | 7 |
| combine-method | 9 |
| data | 10 |
| findDMCs-method | 10 |
| manhattanDMCs-method | 12 |
| methHMEM-method | 13 |
| methHMMCMC-method | 14 |
| methLevels-method | 15 |
| methReads-method | 16 |
| methStates-method | 18 |
| methVars-method | 19 |
| params | 20 |
| qqDMCs-method | 22 |
| readBismark-method | 23 |
| totalReads-method | 24 |
| writeBED-method | 25 |

| | |
|--------------|-----------|
| Index | 27 |
|--------------|-----------|

DMCHMM-package

Differentially Methylated CpG using Hidden Markov Model

Description

DMCHMM is a novel profiling tool for identifying differentially methylated CpG sites using Hidden Markov Model in bisulfite sequencing data.

DMCHMM methods

[cBSData](#), [cBSDMCs](#), [methHMEM](#), [methHMMCMC](#), [findDMCs](#), [qqDMCs](#), [manhattanDMCs](#), [readBismark](#), [writeBED](#).

DMCHMM objects

[BSData-class](#), [BSDMCs-class](#)

BSData-class

BSData object

Description

The BSData object is an S4 class that represents BS-Seq Data.

Arguments

| | |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>methReads</code> | The matrix <code>methReads</code> contains the number of methylated reads spanning a CpG-site. The rows represent the CpG sites in <code>rowRanges</code> and the columns represent the samples in <code>colData</code> . |
| <code>totalReads</code> | The matrix <code>totalReads</code> contains the number of reads spanning a CpG-site. The rows represent the CpG sites in <code>rowRanges</code> and the columns represent the samples in <code>colData</code> . |

Value

A [BSData-class](#) object

Slots

`methReads` An integer matrix
`totalReads` An integer matrix

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

See Also

[SummarizedExperiment](#) objects.

Examples

```
nr <- 500; nc <- 16
metht<-matrix(as.integer(runif(nr * nc, 0, nr)), nr)
methc<-matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep("chr1", nr), IRanges(1:nr, width=1), strand="*")
names(r1) <- 1:nr
cd1<-DataFrame(Group=rep(c("G1", "G2"),each=nc/2),row.names=LETTERS[1:nc])
OBJ1<-cBSDData(rowRanges=r1,methReads=methc,totalReads=metht,colData=cd1)
OBJ1
```

BSDMCs-class

BSDMCs object

Description

The BSDMCs object is an S4 class that represents differentially methylated CpG sites (DMCs) in BS-Seq Data.

Arguments

| | |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| methReads | The matrix methReads contains the number of methylated reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| totalReads | The matrix totalReads contains the number of reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| methLevels | The matrix methLevels contains the predicted methylation level spanning a CpG-site using Hidden Markov model. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| methStates | The matrix methStates contains the state of methylation obtained from Hidden Markov model spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. The value of state is stored in metadata, named Beta. |
| methVars | The matrix methVars contains the variances of the corresponding methLevels obtained from MCMC. |

Value

A [BSDMCs-class](#) object

Slots

methReads An integer matrix
 totalReads An integer matrix
 methLevels A numeric matrix
 methStates An integer matrix
 methVars A double matrix

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
nr <- 500; nc <- 16
metht <- matrix(as.integer(runif(nr * nc, 0, nr)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
meths <- matrix(as.integer(runif(nr * nc, 0, 10)), nr)
methl <- methc/metht
methv <- matrix((runif(nr * nc, 0.1, 0.5)), nr)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'),each=nc/2),row.names=LETTERS[1:nc])
OBJ2 <- cBSDMCs(rowRanges=r1,methReads=methc,totalReads=metht,
methLevels=methl,methStates=meths,methVars=methv,colData=cd1)
OBJ2
```

cBSDData-method

cBSDData method

Description

Creates a [BSDData-class](#) object

Usage

```
cBSDData(
  methReads,
  totalReads,
  rowRanges,
  colData = DataFrame(row.names = colnames(methReads)),
  metadata = list(),
  ...
)

## S4 method for signature 'matrix,matrix,GRanges'
cBSDData(
  methReads,
```

```

    totalReads,
    rowRanges,
    colData = DataFrame(row.names = colnames(methReads)),
    metadata = list(),
    ...
  )

```

Arguments

| | |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| methReads | The matrix methReads contains the number of methylated reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| totalReads | The matrix totalReads contains the number of reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| rowRanges | A GRanges or GRangesList object describing the ranges of interest. Names, if present, become the row names of the SummarizedExperiment object. The length of the GRanges or GRangesList must equal the number of rows of the matrices in assays. If rowRanges is missing, a SummarizedExperiment instance is returned. |
| colData | Object of class "DataFrame" containing information on variable values of the samples |
| metadata | An optional list of arbitrary content describing the overall experiment |
| ... | other possible parameters |

Details

The rows of a BSData object represent ranges (in genomic coordinates) of interest. The ranges of interest are described by a [GRanges](#) or a [GRangesList](#) object, accessible using the `rowRanges` function. The [GRanges](#) and [GRangesList](#) classes contains sequence (e.g., chromosome) name, genomic coordinates, and strand information. Each range can be annotated with additional data; this data might be used to describe the range or to summarize results (e.g., statistics of differential abundance) relevant to the range. Rows may or may not have row names; they often will not.

Value

A [BSData-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```

nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')

```

```
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'), each=nc/2), row.names=LETTERS[1:nc])
OBJ1 <- cBSDData(rowRanges=r1, methReads=methc, totalReads=methT, colData=cd1)
OBJ1
```

cBSDMCs-method

cBSDMCs method

Description

Creates a [BSDMCs-class](#) object

Usage

```
cBSDMCs(
  methReads,
  totalReads,
  methLevels,
  methStates,
  methVars,
  rowRanges,
  colData = DataFrame(row.names = colnames(methReads)),
  metadata = list(),
  ...
)

## S4 method for signature 'matrix,matrix,matrix,matrix,matrix,GRanges'
cBSDMCs(
  methReads,
  totalReads,
  methLevels,
  methStates,
  methVars,
  rowRanges,
  colData = DataFrame(row.names = colnames(methReads)),
  metadata = list(),
  ...
)
```

Arguments

| | |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| methReads | The matrix methReads contains the number of methylated reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| totalReads | The matrix totalReads contains the number of reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |

| | |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| methLevels | The matrix <code>methLevels</code> contains the predicted methylation level spanning a CpG-site using Hidden Markov model. The rows represent the CpG sites in <code>rowRanges</code> and the columns represent the samples in <code>colData</code> . |
| methStates | The matrix <code>methStates</code> contains the state of methylation obtained from Hidden Markov model spanning a CpG-site. The rows represent the CpG sites in <code>rowRanges</code> and the columns represent the samples in <code>colData</code> . The value of state is stored in <code>metadata</code> , named <code>Beta</code> . |
| methVars | The matrix <code>methVars</code> contains the variances of the corresponding <code>methLevels</code> obtained from MCMC. |
| rowRanges | A <code>GRanges</code> or <code>GRangesList</code> object describing the ranges of interest. Names, if present, become the row names of the <code>SummarizedExperiment</code> object. The length of the <code>GRanges</code> or <code>GRangesList</code> must equal the number of rows of the matrices in assays. If <code>rowRanges</code> is missing, a <code>SummarizedExperiment</code> instance is returned. |
| colData | Object of class "DataFrame" containing information on variable values of the samples |
| metadata | An optional list of arbitrary content describing the overall experiment |
| ... | other possible parameters |

Details

The rows of a `BSDMCs` object represent ranges (in genomic coordinates) of interest. The ranges of interest are described by a `GRanges` or a `GRangesList` object, accessible using the `rowRanges` function. The `GRanges` and `GRangesList` classes contains sequence (e.g., chromosome) name, genomic coordinates, and strand information. Each range can be annotated with additional data; this data might be used to describe the range or to summarize results (e.g., statistics of differential abundance) relevant to the range. Rows may or may not have row names; they often will not.

Value

A `BSDMCs-class`

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c=metht,prob = runif(nr*nc)),nr,nc)
meths <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methl <- methc/metht
methv <- matrix((runif(nr * nc, 0.1, 0.5)), nr)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'),each=nc/2),row.names=LETTERS[1:nc])
```

```
OBJ2 <- cBDMCs(rowRanges=r1, methReads=methc, totalReads=metht,
methLevels=methl, methStates=meths, methVars=methv, colData=cd1)
OBJ2
```

| | |
|----------------|-----------------------|
| combine-method | <i>combine method</i> |
|----------------|-----------------------|

Description

combine two [BSDData-class](#) or two [BDMCs-class](#)

Usage

```
combine(obj1, obj2)

## S4 method for signature 'BSDData, BSDData'
combine(obj1, obj2)

## S4 method for signature 'BDMCs, BDMCs'
combine(obj1, obj2)
```

Arguments

```
obj1      A BSDData-class or BDMCs-class
obj2      A BSDData-class or BDMCs-class
```

Value

A [BSDData-class](#) or [BDMCs-class](#)

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc*2, 0, nr)), nr)
methc <- matrix(rbinom(n=nr*nc, c(metht), prob = runif(nr*nc*2)), nr, nc*2)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep('G1', each=nc), row.names=LETTERS[1:nc])
OBJ1 <- cBSDData(rowRanges=r1, methReads=methc[, 1:nc], totalReads=metht[, 1:nc],
colData=cd1)
cd2 <- DataFrame(Group=rep('G2', each=nc), row.names=LETTERS[nc+1:nc])
OBJ2 <- cBSDData(rowRanges=r1, methReads=methc[, nc+1:nc], totalReads=
metht[, nc+1:nc], colData=cd2)
OBJ3 <- combine(OBJ1, OBJ2)
OBJ3
```

data

data

Description

A part of BS-Seq data for three cell type: WGBS data were derived from whole blood collected on a cohort of healthy individuals from Sweden. Cell lines were separated into T-cells (19 samples), monocytes (13 samples) and B-cells (8 samples). Sequencing was performed on the Illumina HiSeq2000/2500 system for each of the 40 samples, separately. For illustration only 3 samples each containing 30,440 CpG sites around BLK gene are provided here. The whole data are analyzed in the cited paper.

Format

BED files

Details

The data is part of whole blood from Sweden.

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

SourceGenomic Quebec

findDMCs-method

findDMCs method

Description

finds the DMCs after smoothing using HMM

Usage

```
findDMCs(  
  object,  
  formula,  
  FDRthreshold,  
  Methylthreshold,  
  mc.cores,  
  windowsize,  
  weightfunction  
)
```

```
## S4 method for signature 'BSDMCs'
findDMCs(
  object,
  formula,
  FDRthreshold,
  Methylthreshold,
  mc.cores,
  windowsize,
  weightfunction
)
```

Arguments

object A [BSDData-class](#) or [BSDMCs-class](#) object

formula A formula

FDRthreshold A numeric value

Methylthreshold
 A positive numeric value; the default is 0.001

mc.cores An integer greater than 0

windowsize An integer value for partitioning data into windows of size windowsize.

weightfunction A function to create weights using variance obtained from the MCMC algorithm

Value

[BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'), each=nc/2), row.names=LETTERS[1:nc])
OBJ1 <- cBSDData(rowRanges=r1, methReads=methc, totalReads=metht, colData=cd1)
OBJ2 <- methHMEM(OBJ1, MaxK=2, mc.cores=2)
OBJ3 <- methHMMCMC(OBJ2, mc.cores=2)
OBJ4 <- findDMCs(OBJ3, mc.cores=2)
head(metadata(OBJ4)$DMCHMM)
```

manhattanDMCs-method *manhattanDMCs method*

Description

Creates a Manhattan plot based on the p-values obtained from [findDMCs](#) method

Usage

```
manhattanDMCs(  
  object,  
  col,  
  chrlabs,  
  suggestiveline,  
  genomewideline,  
  highlight,  
  logp,  
  annotatePval,  
  annotateTop,  
  ...  
)  
  
## S4 method for signature 'BSDMCs'  
manhattanDMCs(  
  object,  
  col,  
  chrlabs,  
  suggestiveline,  
  genomewideline,  
  highlight,  
  logp,  
  annotatePval,  
  annotateTop,  
  ...  
)
```

Arguments

| | |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------|
| object | A BSDData-class or BSDMCs-class object |
| col | A character vector indicating which colors to alternate. |
| chrlabs | A character vector equal to the number of chromosomes specifying the chromosome labels (e.g., <code>c(1:22, "X", "Y", "MT")</code>). |
| suggestiveline | Where to draw a "suggestive" line. Default $-\log_{10}(1e-5)$. Set to FALSE to disable. |
| genomewideline | Where to draw a "genome-wide significant" line. Default $-\log_{10}(5e-8)$. Set to FALSE to disable. |

| | |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| highlight | A character vector of SNPs in your dataset to highlight. These SNPs should all be in your dataset. |
| logp | If TRUE, the $-\log_{10}$ of the p-value is plotted. It isn't very useful to plot raw p-values, but plotting the raw value could be useful for other genome-wide plots, for example, peak heights, bayes factors, test statistics, other "scores," etc. |
| annotatePval | If set, SNPs below this p-value will be annotated on the plot. |
| annotateTop | If TRUE, only annotates the top hit on each chromosome that is below the annotatePval threshold. |
| ... | other possible parameters |

Value

A Manhattan plot

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'), each=nc/2), row.names=LETTERS[1:nc])
OBJ1 <- cBSData(rowRanges=r1,methReads=methc,totalReads=metht,colData=cd1)
OBJ2 <- methHMEM(OBJ1, MaxK=2, mc.cores=2)
OBJ3 <- methHMMCMC(OBJ2, mc.cores=2)
OBJ4 <- findDMCs(OBJ3, mc.cores=2)
manhattanDMCs(OBJ4)
```

methHMEM-method

methHMEM method

Description

Estimates the HMM methylation paths and the HMM order for each sample using the EM algorithm

Usage

```
methHMEM(object, MaxK, MaxEmitter, epsEM, useweight, mc.cores)
```

```
## S4 method for signature 'BSData'
```

```
methHMEM(object, MaxK, MaxEmitter, epsEM, useweight, mc.cores)
```

Arguments

| | |
|------------|------------------------------------------------------------------------|
| object | A BSDData-class or BSDMCs-class object |
| MaxK | An integer value |
| MaxEmitter | An integer value |
| epsEM | A positive numeric value |
| useweight | A logical value |
| mc.cores | An integer greater than 0 |

Value

[BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c=metht,prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'), each=nc/2), row.names=LETTERS[1:nc])
OBJ1 <- cBSDData(rowRanges=r1, methReads=methc, totalReads=metht, colData=cd1)
OBJ2 <- methHMEM(OBJ1, MaxK=2, mc.cores=2)
OBJ2
```

methHMMCMC-method

methHMMCMC method

Description

Estimates the HMM methylation paths and the HMM order for each sample using the MCMC algorithm

Usage

```
methHMMCMC(object, useweight, nburn, nthin, nsamp, mc.cores)
```

```
## S4 method for signature 'BSDMCs'
```

```
methHMMCMC(object, useweight, nburn, nthin, nsamp, mc.cores)
```

Arguments

| | |
|-----------|------------------------------------------------------------------------|
| object | A BSDData-class or BSDMCs-class object |
| useweight | A logical value |
| nburn | An integer value |
| nthin | An integer value |
| nsamp | An integer value |
| mc.cores | An integer greater than 0 |

Value

[BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'),each=nc/2),row.names=LETTERS[1:nc])
OBJ1 <- cBSDData(rowRanges=r1,methReads=methc,totalReads=metht,colData=cd1)
OBJ2 <- methHMEM(OBJ1, MaxK=2, mc.cores=2)
OBJ3 <- methHMMC(OBJ2, mc.cores=2)
OBJ3
```

methLevels-method *methLevels method*

Description

Returns methLevels stored in [BSDMCs-class](#)

Assigns methLevels to [BSDMCs-class](#)

Usage

```
methLevels(object)
```

```
methLevels(object) <- value
```

```
## S4 method for signature 'BSDMCs'
methLevels(object)
```

```
## S4 replacement method for signature 'BSDMCs,matrix'
methLevels(object) <- value
```

Arguments

object A [BSDData-class](#) or [BSDMCs-class](#) object
value An integer matrix

Value

A matrix
A [BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
meths <- matrix(as.integer(runif(nr * nc, 0, 10)), nr)
methl <- methc/metht
methv <- matrix((runif(nr * nc, 0.1, 0.5)), nr)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'),each=nc/2),row.names=LETTERS[1:nc])
OBJ2 <- cBSDMCs(rowRanges=r1,methReads=methc,totalReads=metht,
methLevels=methl,methStates=meths,methVars=methv,colData=cd1)
methLevels(OBJ2)
methLevels(OBJ2) <- methl
```

methReads-method *methReads method*

Description

Returns methReads stored in [BSDData-class](#)
Assigns methReads to [BSDData-class](#)
Returns methReads stored in [BSDMCs-class](#)
Assigns methReads to [BSDMCs-class](#)

Usage

```
methReads(object)

methReads(object) <- value

methReads(object)

methReads(object) <- value

## S4 method for signature 'BSDData'
methReads(object)

## S4 replacement method for signature 'BSDData,matrix'
methReads(object) <- value

## S4 method for signature 'BSDMCs'
methReads(object)

## S4 replacement method for signature 'BSDMCs,matrix'
methReads(object) <- value
```

Arguments

| | |
|--------|------------------------------------------------------------------------|
| object | A BSDData-class or BSDMCs-class object |
| value | An integer matrix |

Value

A matrix
A [BSDData-class](#) object
A matrix
A [BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1','G2'),each=nc/2),row.names=LETTERS[1:nc])
OBJ1 <- cBSDData(rowRanges=r1,methReads=methc,totalReads=metht,colData=cd1)
methReads(OBJ1)
methReads(OBJ1) <- methc
```

methStates-method *methStates method*

Description

Returns methStates stored in [BSDMCs-class](#)

Assigns methStates to [BSDMCs-class](#)

Usage

```
methStates(object)
```

```
methStates(object) <- value
```

```
## S4 method for signature 'BSDMCs'
```

```
methStates(object)
```

```
## S4 replacement method for signature 'BSDMCs,matrix'
```

```
methStates(object) <- value
```

Arguments

object A [BSDData-class](#) or [BSDMCs-class](#) object

value An integer matrix

Value

A matrix

A [BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
meths <- matrix(as.integer(runif(nr * nc, 0, 10)), nr)
methl <- methc/metht
methv <- matrix((runif(nr * nc, 0.1, 0.5)), nr)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'),each=nc/2),row.names=LETTERS[1:nc])
OBJ2 <- cBSDMCs(rowRanges=r1,methReads=methc,totalReads=metht,
methLevels=methl,methStates=meths,methVars=methv,colData=cd1)
```

```
methStates(OBJ2)
methStates(OBJ2)<- meths
```

```
methVars-method      methVars method
```

Description

Returns methVars stored in [BSDMCs-class](#)

Assigns methVars to [BSDMCs-class](#)

Usage

```
methVars(object)

methVars(object) <- value

## S4 method for signature 'BSDMCs'
methVars(object)

## S4 replacement method for signature 'BSDMCs,matrix'
methVars(object) <- value
```

Arguments

| | |
|--------|------------------------------------------------------------------------|
| object | A BSDData-class or BSDMCs-class object |
| value | An integer matrix |

Value

A matrix
 A [BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
meths <- matrix(as.integer(runif(nr * nc, 0, 10)), nr)
methl <- methc/metht
methv <- matrix((runif(nr * nc, 0.1, 0.5)), nr)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
```

```
cd1 <- DataFrame(Group=rep(c('G1', 'G2'), each=nc/2), row.names=LETTERS[1:nc])
OBJ2 <- cBSDMCs(rowRanges=r1, methReads=methc, totalReads=metht,
methLevels=methl, methStates=meths, methVars=methv, colData=cd1)
methVars(OBJ2)
methVars(OBJ2)<- meths
```

 params

params

Description

parameters name and their descriptions

Arguments

| | |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| methReads | The matrix methReads contains the number of methylated reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| totalReads | The matrix totalReads contains the number of reads spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| methLevels | The matrix methLevels contains the predicted methylation level spanning a CpG-site using Hidden Markov model. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. |
| methVars | The matrix methVars contains the variances of the corresponding methLevels obtained from MCMC. |
| methStates | The matrix methStates contains the state of methylation obtained from Hidden Markov model spanning a CpG-site. The rows represent the CpG sites in rowRanges and the columns represent the samples in colData. The value of state is stored in metadata, named Beta. |
| rowRanges | A GRanges or GRangesList object describing the ranges of interest. Names, if present, become the row names of the SummarizedExperiment object. The length of the GRanges or GRangesList must equal the number of rows of the matrices in assays. If rowRanges is missing, a SummarizedExperiment instance is returned. |
| colData | Object of class "DataFrame" containing information on variable values of the samples |
| metadata | An optional list of arbitrary content describing the overall experiment |
| object | A BSDData-class or BSDMCs-class object |
| value | An integer matrix |
| obj1 | A BSDData-class or BSDMCs-class |
| obj2 | A BSDData-class or BSDMCs-class |
| files | A character list |

| | |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| file | A character |
| name | A character list |
| MaxK | An integer value |
| MaxEmitter | An integer value |
| epsEM | A positive numeric value |
| useweight | A logical value |
| mc.cores | An integer greater than 0 |
| nburn | An integer value |
| nthin | An integer value |
| nsamp | An integer value |
| formula | A formula |
| FDRthreshold | A numeric value |
| Methylthreshold | A positive numeric value; the default is 0.001 |
| weightfunction | A function to create weights using variance obtained from the MCMC algorithm |
| ... | other possible parameters |
| col | A character vector indicating which colors to alternate. |
| chrlabs | A character vector equal to the number of chromosomes specifying the chromosome labels (e.g., c(1:22, "X", "Y", "MT")). |
| suggestiveline | Where to draw a "suggestive" line. Default $-\log_{10}(1e-5)$. Set to FALSE to disable. |
| genomewideline | Where to draw a "genome-wide significant" line. Default $-\log_{10}(5e-8)$. Set to FALSE to disable. |
| highlight | A character vector of SNPs in your dataset to highlight. These SNPs should all be in your dataset. |
| logp | If TRUE, the $-\log_{10}$ of the p-value is plotted. It isn't very useful to plot raw p-values, but plotting the raw value could be useful for other genome-wide plots, for example, peak heights, bayes factors, test statistics, other "scores," etc. |
| annotatePval | If set, SNPs below this p-value will be annotated on the plot. |
| annotateTop | If TRUE, only annotates the top hit on each chromosome that is below the annotatePval threshold. |
| windowSize | An integer value for partitioning data into windows of size windowSize. |

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

`qqDMCs-method`*qqDMCs method*

Description

Creates a Q-Q plot based on the p-values obtained from `findDMCs` method

Usage

```
qqDMCs(object, ...)
```

```
## S4 method for signature 'BSDMCs'  
qqDMCs(object, ...)
```

Arguments

```
object      A BSDData-class or BSDMCs-class object  
...        other possible parameters
```

Value

A QQ plot

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
set.seed(1980)  
nr <- 150; nc <- 8  
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)  
methc <- matrix(rbinom(n=nr*nc,c=metht,prob = runif(nr*nc)),nr,nc)  
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')  
names(r1) <- 1:nr  
cd1 <- DataFrame(Group=rep(c('G1', 'G2'),each=nc/2),row.names=LETTERS[1:nc])  
OBJ1 <- cBSDData(rowRanges=r1,methReads=methc,totalReads=metht,colData=cd1)  
OBJ2 <- methHMEM(OBJ1, MaxK=2, mc.cores=2)  
OBJ3 <- methHMMCMC(OBJ2, mc.cores=2)  
OBJ4 <- findDMCs(OBJ3, mc.cores=2)  
qqDMCs(OBJ4)
```

readBismark-method *readBismark method*

Description

reads BS-Seq data

Usage

```
readBismark(files, colData, mc.cores)

## S4 method for signature 'character,DataFrame,numeric'
readBismark(files, colData, mc.cores)

## S4 method for signature 'character,data.frame,numeric'
readBismark(files, colData, mc.cores)

## S4 method for signature 'character,character,numeric'
readBismark(files, colData, mc.cores)
```

Arguments

| | |
|----------|--------------------------------------------------------------------------------------|
| files | A character list |
| colData | Object of class "DataFrame" containing information on variable values of the samples |
| mc.cores | An integer greater than 0 |

Value

A [BSData-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
fn <- list.files(system.file('extdata',package = 'DMCHMM'))
fn.f <- list.files(system.file('extdata',package='DMCHMM'), full.names=TRUE)
OBJ <- readBismark(fn.f, fn, mc.cores=2)
cdOBJ <- DataFrame(Cell = factor(c('BC', 'TC', 'Mono'),
labels = c('BC', 'TC', 'Mono')), row.names = c('BCU1568', 'BCU173', 'BCU551'))
colData(OBJ) <- cdOBJ
OBJ
```

| | |
|-------------------|--------------------------|
| totalReads-method | <i>totalReads method</i> |
|-------------------|--------------------------|

Description

Returns totalReads stored in [BSDData-class](#)

Assigns totalReads to [BSDData-class](#)

Returns totalReads stored in [BSDMCs-class](#)

Assigns totalReads to [BSDMCs-class](#)

Usage

```
totalReads(object)
```

```
totalReads(object) <- value
```

```
totalReads(object)
```

```
totalReads(object) <- value
```

```
## S4 method for signature 'BSDData'
totalReads(object)
```

```
## S4 replacement method for signature 'BSDData,matrix'
totalReads(object) <- value
```

```
## S4 method for signature 'BSDMCs'
totalReads(object)
```

```
## S4 replacement method for signature 'BSDMCs,matrix'
totalReads(object) <- value
```

Arguments

object A [BSDData-class](#) or [BSDMCs-class](#) object

value An integer matrix

Value

A matrix

A [BSDData-class](#) object

A matrix

A [BSDMCs-class](#) object

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Examples

```
nr <- 150; nc <- 8
metht <- matrix(as.integer(runif(nr * nc, 0, 100)), nr)
methc <- matrix(rbinom(n=nr*nc,c(metht),prob = runif(nr*nc)),nr,nc)
r1 <- GRanges(rep('chr1', nr), IRanges(1:nr, width=1), strand='*')
names(r1) <- 1:nr
cd1 <- DataFrame(Group=rep(c('G1', 'G2'),each=nc/2),row.names=LETTERS[1:nc])
OBJ1 <- cBSDData(rowRanges=r1,methReads=methc,totalReads=metht,colData=cd1)
totalReads(OBJ1)
totalReads(OBJ1) <- metht
```

writeBED-method

writeBED method

Description

write BS-Seq data to BED files

Usage

```
writeBED(object, name, file)

## S4 method for signature 'BSDData,character,character'
writeBED(object, name, file)

## S4 method for signature 'BSDData,character,missing'
writeBED(object, name)

## S4 method for signature 'BSDData,missing,character'
writeBED(object, file)

## S4 method for signature 'BSDData,missing,missing'
writeBED(object)

## S4 method for signature 'BSDMCs,character,character'
writeBED(object, name, file)

## S4 method for signature 'BSDMCs,character,missing'
writeBED(object, name)

## S4 method for signature 'BSDMCs,missing,character'
writeBED(object, file)

## S4 method for signature 'BSDMCs,missing,missing'
writeBED(object)
```

Arguments

| | |
|--------|------------------------------------------------------------------------|
| object | A BSDData-class or BSDMCs-class object |
| name | A character list |
| file | A character |

Value

BED files

Author(s)

Farhad Shokoohi <shokoohi@icloud.com>

Index

- * **manhattan**
 - manhattanDMCs-method, 12
- * **object**
 - BSDData-class, 3
 - BSDMCs-class, 4
- * **visualization**
 - manhattanDMCs-method, 12
- BSDData (BSDData-class), 3
- BSDData-class, 3
- BSDMCs (BSDMCs-class), 4
- BSDMCs-class, 4
- cBSDData, 3
- cBSDData (cBSDData-method), 5
- cBSDData, matrix, matrix, GRanges-method
 - (cBSDData-method), 5
- cBSDData-method, 5
- cBSDMCs, 3
- cBSDMCs (cBSDMCs-method), 7
- cBSDMCs, matrix, matrix, matrix, matrix, matrix, GRanges-method
 - (cBSDMCs-method), 7
- cBSDMCs-method, 7
- combine (combine-method), 9
- combine, BSDData, BSDData-method
 - (combine-method), 9
- combine, BSDMCs, BSDMCs-method
 - (combine-method), 9
- combine-method, 9
- data, 10
- DMCHMM (DMCHMM-package), 3
- DMCHMM-package, 3
- findDMCs, 3, 12, 22
- findDMCs (findDMCs-method), 10
- findDMCs, BSDMCs-method
 - (findDMCs-method), 10
- findDMCs-method, 10
- GRanges, 6, 8, 20
- GRangesList, 6, 8, 20
- manhattanDMCs, 3
- manhattanDMCs (manhattanDMCs-method), 12
- manhattanDMCs, BSDMCs-method
 - (manhattanDMCs-method), 12
- manhattanDMCs-method, 12
- methHMEM, 3
- methHMEM (methHMEM-method), 13
- methHMEM, BSDData-method
 - (methHMEM-method), 13
- methHMEM-method, 13
- methHMMCMC, 3
- methHMMCMC (methHMMCMC-method), 14
- methHMMCMC, BSDMCs-method
 - (methHMMCMC-method), 14
- methHMMCMC-method, 14
- methLevels (methLevels-method), 15
- methLevels, BSDMCs-method
 - (methLevels-method), 15
- methLevels-method, 15
- methLevels<- (methLevels-method), 15
- methLevels<-, BSDMCs, matrix-method
 - (methLevels-method), 15
- methReads (methReads-method), 16
- methReads, BSDData-method
 - (methReads-method), 16
- methReads, BSDMCs-method
 - (methReads-method), 16
- methReads-method, 16
- methReads<- (methReads-method), 16
- methReads<-, BSDData, matrix-method
 - (methReads-method), 16
- methReads<-, BSDMCs, matrix-method
 - (methReads-method), 16
- methStates (methStates-method), 18
- methStates, BSDMCs-method
 - (methStates-method), 18
- methStates-method, 18
- methStates<- (methStates-method), 18

- methStates<- ,BSDMCs,matrix-method
(methStates-method), 18
- methVars (methVars-method), 19
- methVars,BSDMCs-method
(methVars-method), 19
- methVars-method, 19
- methVars<- (methVars-method), 19
- methVars<- ,BSDMCs,matrix-method
(methVars-method), 19

- params, 20

- qqDMCs, 3
- qqDMCs (qqDMCs-method), 22
- qqDMCs,BSDMCs-method (qqDMCs-method), 22
- qqDMCs-method, 22

- readBismark, 3
- readBismark (readBismark-method), 23
- readBismark,character,character,numeric-method
(readBismark-method), 23
- readBismark,character,data.frame,numeric-method
(readBismark-method), 23
- readBismark,character,DataFrame,numeric-method
(readBismark-method), 23
- readBismark-method, 23

- SummarizedExperiment, 4, 6, 8, 20

- totalReads (totalReads-method), 24
- totalReads,BSDData-method
(totalReads-method), 24
- totalReads,BSDMCs-method
(totalReads-method), 24
- totalReads-method, 24
- totalReads<- (totalReads-method), 24
- totalReads<- ,BSDData,matrix-method
(totalReads-method), 24
- totalReads<- ,BSDMCs,matrix-method
(totalReads-method), 24

- writeBED, 3
- writeBED (writeBED-method), 25
- writeBED,BSDData,character,character-method
(writeBED-method), 25
- writeBED,BSDData,character,missing-method
(writeBED-method), 25
- writeBED,BSDData,missing,character-method
(writeBED-method), 25
- writeBED,BSDData,missing,missing-method
(writeBED-method), 25
- writeBED,BSDMCs,character,character-method
(writeBED-method), 25
- writeBED,BSDMCs,character,missing-method
(writeBED-method), 25
- writeBED,BSDMCs,missing,character-method
(writeBED-method), 25
- writeBED,BSDMCs,missing,missing-method
(writeBED-method), 25
- writeBED-method, 25