

# Package ‘qsea’

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**Description** qsea (quantitative sequencing enrichment analysis) was developed as the successor of the MEDIPS package for analyzing data derived from methylated DNA immunoprecipitation (MeDIP) experiments followed by sequencing (MeDIP-seq). However, qsea provides several functionalities for the analysis of other kinds of quantitative sequencing data (e.g. ChIP-seq, MBD-seq, CMS-seq and others) including calculation of differential enrichment between groups of samples.

**License** GPL-2

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qsea-package

*QSEA: Quantitative sequencing enrichment analysis and visualization*

---

### Description

QSEA (quantitative sequencing enrichment analysis) was developed as the successor of the MEDIPS package for analyzing data derived from methylated DNA immunoprecipitation (MeDIP) experiments followed by sequencing (MeDIP-seq). However, qsea provides functionality for the analysis of other kinds of quantitative sequencing data (e.g. ChIP-seq, MBD-seq, CMS-seq and others) including calculation of differential enrichment between groups of samples.

### Author(s)

Matthias Lienhard, Lukas Chavez and Ralf Herwig

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### References

Lienhard M, Grimm C, Morkel M, Herwig R, Chavez L., (Bioinformatics, 2014): MEDIPS: genome-wide differential coverage analysis of sequencing data derived from DNA enrichment experiments.

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addCNV *estimate CNV information and add to qseaSet object*

---

### Description

This function adds information on Copy Number Variation (CNV) to the qseaSet object, which is used for normalization. Sample wise CNV information can either be provided, or estimated from input or enrichment sequencing data, by incorporating functions of the HMMcopy package.

### Usage

```
addCNV(qs, file_name, window_size=1000000, paired=FALSE, fragment_length, cnv,
mu=log2(c(1/2, 2/3, 1, 3/2, 2, 3)), normal_idx, plot_dir, MeDIP=FALSE,
parallel=FALSE)
```

### Arguments

qs	the qseaSet object
cnv	pre-computed CNV information for each sample. If provided, the following parameters are ignored
file_name	column name of the sample table for the sequencing files, from which CNV information are computed
window_size	window size for CNV analysis
paired	are files in file_name column paired end
fragment_length	for single end sequencing, provide the average fragment length
mu	a priori CNV levels of different states, parameter passed to HMMcopy
normal_idx	index of samples which are assumed to be CNV free. The median of these samples serves as "normal" CNV reference level, and CNV are computed relative to this reference level. By default, QSEA looks for samples with "normal" or "control" in its name.
plot_dir	If provided, detail CNV plots for each chromosome and each sample are created in the provided directory
MeDIP	If set TRUE, QSEA assumes that provided files are methylation enriched sequencing data. In this case, only fragments without CpG dinucleotides are considered. This option allows QSEA to infer CNV information from MeDIP or MDB seq experiments directly
parallel	Switch for parallel computing, using BiocParallel

### Value

The qseaSet object, extended by the CNV information

### Author(s)

Mathias Lienhard

**See Also**

HMMsegment

**Examples**

```
library("BSgenome.Hsapiens.UCSC.hg19")

bam_hESCs_1 = system.file("extdata",
  "hESCs.MeDIP.Rep1.chr22.bam", package="MEDIPSData")
bam_hESCs_2 = system.file("extdata",
  "hESCs.MeDIP.Rep2.chr22.bam", package="MEDIPSData")
sample_table=data.frame(sample_name=paste0("hESCs_", 1:2),
  file_name=c(bam_hESCs_1,bam_hESCs_2),
  group=rep("hESC",2), stringsAsFactors=FALSE)
qseaSet=createQseaSet(sampleTable=sample_table,
  BSgenome="BSgenome.Hsapiens.UCSC.hg19",
  chr.select="chr22",
  window_size=500)

#this is an example for computing CNVs from MeDIP data. A very limited example
#however, since the samples do not contain CNVs.
qseaSet=addCNV(qseaSet, fragment_length=300, file_name="file_name", MeDIP=TRUE,
  window_size=1000000)
```

addContrast

*fit GLMs to reduced model and test for significance***Description**

This function fits negative binomial GLMs to reduced models defined either by the "contrast" parameter, or by one or several model coefficients (specified by "coef" parameter) set to zero. Subsequently, a likelihood ratio test is applied, to identify windows significantly dependent on the tested coefficient.

**Usage**

```
addContrast(qs,glm,contrast,coef,name,verbose=TRUE, nChunks = NULL,
  parallel = FALSE )
```

**Arguments**

qs	a qseaSet object
glm	a qseaGLM object
contrast	numeric vector specifying a contrast of the model coefficients. This contrast can for example be defined using <code>limma::makeContrasts()</code>
coef	alternatively defines the contrast by coefficient(s) of the model tested to be equal to zero.
name	short descriptive name for the contrast (as "TvsN"), used for examples in columns of result tables

verbose	more messages that document the process
nChunks	fit GLMs in multiple chunks
parallel	use multicore processing

**Value**

This function returns the qseaGLM object, extended by the fitted coefficients of the reduced GLMs, as well as the test statistics. Note that one qseaGLM object can contain several contrasts.

**Author(s)**

Mathias Lienhard

**See Also**

limma::makeContrasts(), fitNBglm(), isSignificant()

**Examples**

```
qs=getExampleQseaSet()
design=model.matrix(~group, getSampleTable(qs))
TvN_glm=fitNBglm(qs, design, norm_method="beta")
TvN_glm=addContrast(qs,TvN_glm, coef=2, name="TvN")
```

---

addCoverage	<i>Import sequencing data</i>
-------------	-------------------------------

---

**Description**

This function imports the alignment files (in sam/bam format) and counts the reads per genomic window or directly imports coverage files (in wiggle/bigwiggle format)

**Usage**

```
addCoverage(qs, fragment_length, uniquePos=TRUE, minMapQual=1, paired=FALSE,
parallel=FALSE)
```

**Arguments**

qs	qseaSet object, e.g. produced by the createQseaSet() function
fragment_length	For single end data, provide the expected fragment length
paired	If set to TRUE, data is considered to be paired end sequencing, and the actual fragments size is used.
uniquePos	If set to TRUE, fragments with same position and orientation are considered to be PCR duplicates and replaced by one representative.
minMapQual	The minimal mapping quality for reads to be considered. Note that the definition of mapping quality depends on the alignment tool.
parallel	Switch for parallel computing, using BiocParallel

## Details

The coverage is imported from the files specified in the `file_name` column of the sample table, provided for the `createQseaSet()` function. In case of alignment files, the reads are counted for the window at the center of the sequencing fragment. For single end data, Filetypes is detected automatically from the file suffix.

## Value

The function returns the `qseaSet` object, extended by the number of reads per window for all samples

## Author(s)

Mathias Lienhard

## See Also

`crateQseaSet`

## Examples

```
library("BSgenome.Hsapiens.UCSC.hg19")

bam_hESCs_1 = system.file("extdata",
  "hESCs.MeDIP.Rep1.chr22.bam", package="MEDIPSData")
bam_hESCs_2 = system.file("extdata",
  "hESCs.MeDIP.Rep2.chr22.bam", package="MEDIPSData")
sample_table=data.frame(sample_name=paste0("hESCs_", 1:2),
  file_name=c(bam_hESCs_1,bam_hESCs_2),
  group=rep("hESC",2), stringsAsFactors=FALSE)
qseaSet=createQseaSet(sampleTable=sample_table,
  BSgenome="BSgenome.Hsapiens.UCSC.hg19",
  chr.select="chr22",
  window_size=500)
qseaSet=addCoverage(qseaSet, fragment_length=300)
```

---

addEnrichmentParameters

*Enrichment analysis*

---

## Description

This function analyses the dependency of enrichment on a sequence pattern, based on a subset of windows for which the signal is known.

## Usage

```
addEnrichmentParameters(qs, enrichmentPattern, signal, windowIdx,
  min_wd=5, bins=seq(.5,40.5,1))
```

**Arguments**

qs	The qseaSet object
enrichmentPattern	The name of the pattern, on which the enrichment depends on (usually CpG for methylation analysis). This name must correspond to the name specified in addPatternDensity()
windowIdx	vector of window indices, for which "true" values are known (or can be estimated)
signal	Matrix containing the known (or estimated) values for all samples and all specified windows, as a numeric matrix. These values are expected to be between 0 and 1.
bins	For the enrichment analysis, windows are binned according to pattern density. This parameter specifies the bins.
min_wd	minimal number of windows per bin to be considered

**Value**

The function returns the qseaSet object, extended by the parameters of the enrichment profiles for all samples

**Author(s)**

Mathias Lienhard

**See Also**

plotEnrichmentProfile, addPatternDensity

**Examples**

```
qs=getExampleQseaSet(enrichmentAnalysis=FALSE)
#this procedure assumes that regions with low CpG density is 80% methylated
#on average, and regions within CpG islands are 25% methylated on average.
wd=which(getRegions(qs)$CpG_density>1 &
  getRegions(qs)$CpG_density<15)
signal=(15-getRegions(qs)$CpG_density[wd])*0.55/15+0.25
signal=matrix(signal,nrow=length(signal),ncol=length(getSampleNames(qs)))
qs=addEnrichmentParameters(qs, enrichmentPattern="CpG",
  windowIdx=wd, signal=signal)
```

---

addLibraryFactors      *Estimate effective library size*

---

**Description**

Normalization factors for effective library size are computed using the trimmed mean of m-values approach (TMM).

**Usage**

```
addLibraryFactors(qs, factors,...)
```

**Arguments**

qs	The qseaSet object
factors	In case normalization factors have been pre-computed by the user, they can be passed with this parameter. In this case QSEA adds this factors to the qseaSet object and does not compute normalization factors.
...	Further parameters used for the TMM normalization (see details)

**Details**

The user can specify the TMM normalization by setting the following additional parameters, which are passed to the internal functions. `\trimA` [default: `c(.5,.99)`] lower and upper quantiles for trimming of A values `\trimM` [default: `c(.1,.9)`] lower and upper quantiles for trimming of M values `\doWeighting` [default: `TRUE`] computes a weighted TMM `\ref` [default: `1`] the index of the reference sample `\plot` [default: `FALSE`] if set to `TRUE`, MvsA plots depicting the TMM normalization are created. `\nReg` [default: `500000`] Number of regions to be analyzed for normalization. Regions are drawn uniformly over the whole genome.

**Value**

This function returns the qseaSet object, containing effective library size normalization factors.

**Author(s)**

Mathias Lienhard

**See Also**

`edgeR::calcNormFactors`

**Examples**

```
qs=getExampleQseaSet(expSamplingDepth=500*10^(1:5), repl=5)
#in this case, the first sample has only view reads, so it is important to set
#the reference sample
qs=addLibraryFactors(qs, plot=TRUE, ref="Sim5N")
```

---

addNewSamples

*Extends an existing qseaSet by new samples*

---

**Description**

This function allows the qseaSet to be extended by new samples, provided in the sample table.

**Usage**

```
addNewSamples(qs, sampleTable, force=FALSE, parallel=FALSE)
```



**Arguments**

qs	The qseaSet object to be extended
sampleTable	data.frame, describing the samples. Must be in same format as getSampleTable(qs)
force	force adding of new samples, even if existing CNV or enrichment information requires recomputation
parallel	parallel processing of alignment files

**Value**

An object of class qseaSet, including the new samples.

**Author(s)**

Mathias Lienhard

**Examples**

```
library("BSgenome.Hsapiens.UCSC.hg19")
data(samplesNSCLC, package="MEDIPSData")
path=system.file("extdata", package="MEDIPSData")
samples_NSCLC$file_name=paste0(path,"/",samples_NSCLC$file_name )
originalQseaSet=createQseaSet(sampleTable=samples_NSCLC[1:4,],
  BSgenome="BSgenome.Hsapiens.UCSC.hg19", chr.select="chr22",
  window_size=500)
originalQseaSet=addCoverage(originalQseaSet, uniquePos=TRUE, paired=TRUE)
qseaSet=addNewSamples(originalQseaSet, samples_NSCLC)
```

---

addOffset

*Estimate background reads*

---

**Description**

This function sets the background reads offset parameters for the qseaSet object, either by estimating offset reads, or by setting user provided values.

**Usage**

```
addOffset(qs,enrichmentPattern , maxPatternDensity=0.01,offset)
```

**Arguments**

qs	the qseaSet object
enrichmentPattern	name of the enrichment pattern, as specified in addPatternDensity
maxPatternDensity	Maximum pattern density, at which the window is treated as pattern free.
offset	This parameter alternatively allows to specify the amount of background reads for each sample manually. In this case, please provide average background reads for CNV free windows in rpkm scale.

**Value**

The function returns the `qseaSet` object, extended by the estimated amount of background reads for all samples

**Author(s)**

Mathias Lienhard

**See Also**

`addPatternDensity`, `getOffset`

**Examples**

```
#simulate data with varying background fractions
qs=getExampleQseaSet(expSamplingDepth=5e4, repl=5,bgfraction=seq(0,.8,.2))
#estimate the background in simulated data
addOffset(qs, "CpG", maxPatternDensity=0.7)
#return the background on different scales
getOffset(qs, scale="fraction") #estimated fraction of total reads
getOffset(qs, scale="rpw") #average background reads per CNV free window
```

---

`addPatternDensity`      *Infer sequence pattern density values and add to qseaSet object*

---

**Description**

This function estimates the average occurrences of a sequence pattern (such as CpG dinucleotides) within the overlapping sequencing fragments for each genomic window

**Usage**

```
addPatternDensity(qs, pattern,name, fragment_length, fragment_sd,
patternDensity, fixed=TRUE, masks=c("AGAPS","AMB", "RM", "TRF")[1:2])
```

**Arguments**

<code>qs</code>	a <code>qseaSet</code> object
<code>pattern</code>	actual sequence of the pattern (e.g. "CG")
<code>,</code>	
<code>name</code>	a name for the sequence pattern(e.g. "CpG")
<code>,</code>	
<code>fragment_length</code>	the average fragment length to be assumed for pattern density estimation. If omitted, this parameter is taken from the <code>qseaSet</code> object.
<code>fragment_sd</code>	the standard deviation of fragment length to be assumed for pattern density estimation. If omitted, this parameter is taken from the <code>qseaSet</code> object.

patternDensity	this parameter alternatively allows to specify the pattern density manually. In this case, please provide a numerical vector, containing a value (greater than 0) for each genomic window.
fixed	if FALSE, an IUPAC ambiguity code in the pattern can match any letter in the reference genome that is associated with the code, and vice versa.
masks	names of the BSgenome masks to be active.

**Value**

The function returns the qseaSet object, extended by the pattern density for all genomic windows

**Author(s)**

Mathias Lienhard

**Examples**

```
library("BSgenome.Hsapiens.UCSC.hg19")
bam_hESCs_1 = system.file("extdata",
  "hESCs.MeDIP.Rep1.chr22.bam", package="MEDIPSData")
bam_hESCs_2 = system.file("extdata",
  "hESCs.MeDIP.Rep2.chr22.bam", package="MEDIPSData")
sample_table=data.frame(sample_name=paste0("hESCs_", 1:2),
  file_name=c(bam_hESCs_1,bam_hESCs_2),
  group=rep("hESC",2), stringsAsFactors=FALSE)
qseaSet=createQseaSet(sampleTable=sample_table,
  BSgenome="BSgenome.Hsapiens.UCSC.hg19",
  chr.select="chr22",
  window_size=500)
qseaSet=addPatternDensity(qseaSet, "CG", name="CpG", fragment_length=300)
```

---

addSeqPref

*Add sequence preference to qseaSet object*

---

**Description**

This function allows to add window specific sequencing preference, that can be used by the normalization procedure. This preference can be defined by the user, or estimated from sequencing of input libraries.

**Usage**

```
addSeqPref(qs, seqPref,file_name, fragment_length, paired=FALSE,
  uniquePos=TRUE, alpha=0.05, pseudocount=5, cut=3)
```

**Arguments**

qs	a qseaSet object
seqPref	A vector with predefined sequencing preference for each window. Values are interpreted as log <sub>2</sub> ratios relative to normal/average sequencing preference.
file_name	alternatively, the sequencing preference can be estimated from input sequencing. In this case, provide the column of the sample table that contains the file names for input sequencing alignment or coverage files.
fragment_length	for single end data, provide the expected fragment length
paired	if set to TRUE, data is considered to be paired end sequencing, and the actual fragments size is used.
uniquePos	if set to TRUE, fragments with same position and orientation are considered to be PCR duplicates and replaced by one representative.
alpha	currently ignored
pseudocount	this value is added to the coverage of each window, to smooth the estimates.
cut	absolute log <sub>2</sub> value threshold for windows to be excluded from later analysis due to extreme preference values.

**Value**

the function returns the qseaSet object, extended by the sequencing preference for all genomic windows.

**Author(s)**

Mathias Lienhard

---

createQseaSet	<i>Prepares a qseaSet Object</i>
---------------	----------------------------------

---

**Description**

This method prepares the qseaSet object, and prepares genome wide bins. Coverage and normalization parameters are added in succeeding functions.

**Usage**

```
createQseaSet(sampleTable,BSgenome, chr.select,Regions, window_size=250 )
```

**Arguments**

BSgenome	name of BSgenome package
Regions	GRanges object. If specified, only selected regions are processed
chr.select	If specified, only selected chromosomes are processed

sampleTable	data.frame, containing at least 3 columns: the sample names (sample_name), paths to alignment or coverage file in sam/bam/wiggle/bigwig format (file_name), and one or more test condition(s) (group). Optionally it may contain a column with alignment or coverage files for CNV analysis, and further information in the samples that are of interest for the analysis.
window_size	size for the genome wide bins in base pairs

**Value**

An object of class qseaSet, containing the sample and genome information.

**Author(s)**

Mathias Lienhard

**Examples**

```
library("BSgenome.Hsapiens.UCSC.hg19")
bam_hESCs_1 = system.file("extdata", "hESCs.MeDIP.Rep1.chr22.bam",
  package="MEDIPSData")
bam_hESCs_2 = system.file("extdata", "hESCs.MeDIP.Rep2.chr22.bam",
  package="MEDIPSData")
samplesTable=data.frame(sample_name=paste0("hESCs_", 1:2),
  file_name=c(bam_hESCs_1,bam_hESCs_2),
  group=rep("hESC",2),stringsAsFactors=FALSE)
qs=createQseaSet(samplesTable, BSgenome="BSgenome.Hsapiens.UCSC.hg19",
  chr.select="chr22", window_size=500)
```

---

fitNBglm

*Fit GLM for each window*


---

**Description**

This function fits a negative binomial GLM for each genomic window, according to the design matrix.

**Usage**

```
fitNBglm(qs,design,link="log",keep, disp_method="region_wise",
  norm_method="rpkm",init_disp=0.5 ,verbose=TRUE, minRowSum=10, pseudocount=1,
  disp_iter = 3, nChunks = NULL, parallel = FALSE)
```

**Arguments**

qs	a qseaSet object
design	the design matrix for the GLMs
link	name of the link function. Currently, only the canonical dQuotelog link function is implemented.
keep	indices of windows to be included in the analysis.

disp_method	method to estimate dispersion parameters. Allowed values are dQuote"region_wise" for independent window wise estimates, dQuote"common" for a single estimate for all windows, dQuote"cutAtQuantiles" for window wise estimates trimmed at the 25% and 75% quantiles, or dQuote"initial" for using the dispersion parameters provided with the init_disp parameter.
norm_method	normalization method, as defined by normMethod() function
init_disp	initial estimate for dispersion parameter. Either a single parameter for all regions, or a vector with window wise parameters.
verbose	more messages that document the process
minRowSum	filter out windows with less than minRowSum reads over all samples
pseudocount	this value is added to the read counts
disp_iter	number of iterations for dispersion estimation
nChunks	fit GLMs in multiple chunks
parallel	use multicore processing

**Value**

This function returns a qseaGLM object, containing the fitted coefficients of the GLMs.

**Author(s)**

Mathias Lienhard

**See Also**

addContrast()

**Examples**

```
#tbd
qs=getExampleQseaSet()
design=model.matrix(~group, getSampleTable(qs))
TvN_glm=fitNBglm(qs, design, norm_method="beta")
```

---

getExampleQseaSet      *Simulation of MeDIP seq QSEA set*

---

**Description**

Creates a example qseaSet object by sampling reads for simulated Tumor and Normal samples. Number of replicates, sequencing depth and fraction of background reads can be specified.

**Usage**

```
getExampleQseaSet(CpG=TRUE, CNV=TRUE, repl=2,
  doSampling=TRUE, enrichmentAnalysis=TRUE, expSamplingDepth=50000,
  bgfraction=.1)
```

**Arguments**

CpG	if TRUE CpG density is added to the object
CNV	if TRUE CNV are emulated for the tumor samples
repl	number of replicates for tumor and normal samples
doSampling	if TRUE, read counts are sampled and added to the object
enrichmentAnalysis	if TRUE, parameters for enrichment profiles are added
expSamplingDepth	expected value of sequencing depth
bgfraction	fraction of background reads

**Details**

The function creates an example and test qseaSet object for an toy example genome (one chromosome, 50kb) with 500 bases windows.

**Value**

The qseaSet object

**Author(s)**

Mathias Lienhard

**See Also**

createQseaSet()

**Examples**

```
qs=getExampleQseaSet()
```

---

getPCA

*Principle Component Analysis (PCA) in QSea*

---

**Description**

The getPCA() function performs a Principle Component Analysis (PCA) of the coverage profiles from a qsea object for exploratory data analysis.

**Usage**

```
getPCA(qs, chr= getChrNames(qs),ROIs, minRowSum=20, keep ,  
norm_method=normMethod(logRPM =  
c("log", "library_size", "cnv", "preference", "psC10")), topVar=1000,  
samples=getSampleNames(qs), minEnrichment = 0)
```

**Arguments**

qs	DIPSset (mandatory)
chr	chromosomes to consider
ROIs	If specified, only windows overlapping ROIs are considered.
minRowSum	minimal number of total read counts per window over all samples
keep	windows to consider
norm_method	name of predefined normalization (e.g. "beta"), or user defined normalization by calling normMethod() function
topVar	only the top variable windows are considered
samples	names of samples to be considered
minEnrichment	for transformation to absolute methylation level, you can specify the minimal number of expected reads for a fully methylated window. This avoids inaccurate estimates, due to low enrichment.

**Details**

The principle component analysis is calculated using the singular value decomposition (svd).

**Value**

getPCA() returns a list object, containing the svd and information on the selected windows.

**Author(s)**

Mathias Lienhard

**See Also**

plotPCA

**Examples**

```
qs=getExampleQseaSet( repl=5)
pca=getPCA(qs, norm_method="beta")
colors=c(rep("red", 5), rep("green", 5))
plotPCA(pca, bgColor=colors)
#plotPCAFactors is more interesting, if ROIs have been specified in getPCA
plotPCAFactors(pca)
```

---

isSignificant

*Finds Significant Regions*

---

**Description**

This function looks for regions, where the test statistic is below the defined thresholds

**Usage**

```
isSignificant(glm, contrast = NULL, fdr_th = NULL, pval_th = NULL,
              absLogFC_th = NULL, direction = "both")
```



**Arguments**

glm	A qseaGLM object (mandatory)
contrast	name of contrast to be used
fdr_th	a threshold for the false discovery rate
pval_th	a p value threshold
absLogFC_th	the threshold for the absolute value of logFC
direction	direction of change: either "both", "loss", or "gain"

**Details**

If a threshold is NULL, it is ignored.

For the direction parameter, the following synonyms are valid:

"loss" == "less" == "hypo"

"gain" == "more" == "hyper"

**Value**

A vector with indices of significant windows, which can be passed to keep parameter of makeTable() function

**Author(s)**

Mathias Lienhard

**See Also**

makeTable

**Examples**

```
qs=getExampleQseaSet()
design=model.matrix(~group, getSampleTable(qs))
TvN_glm=fitNBglm(qs, design, norm_method="beta")
TvN_glm=addContrast(qs,TvN_glm, coef=2, name="TvN")
sig=isSignificant(TvN_glm, fdr_th=0.01)
```

---

makeTable

*Create a Results Table*

---

**Description**

This function creates a table from the qsea objects qseaSet and qseaTvN\_glm

**Usage**

```
makeTable(qs,glm,norm_methods="counts",samples,groupMeans, keep, ROIs,
annotation, minPvalSummarize, CNV=FALSE, verbose=TRUE, minEnrichment=3,
chunksize=1e5)
```

**Arguments**

qs	a qseaSet object (mandatory)
glm	a list of one or more qseaGLM objects (optional)
norm_methods	either a character vector of pre-defined normalization combinations, or a list defining normalization combinations. This affects both individual and mean values.
samples	The indices of the samples for which individual values are to be written out in the specified order
groupMeans	a named list of indices vectors, defining groups for which mean values are to be written out
keep	a vector of indices of the windows that are considered (as created by isSignificant)
ROIs	A GRanges object, containing regions of interest (ROIs). Only windows overlapping ROIs are considered.
annotation	a named list of GRRange objects, containing annotations (e.g. genes, CpG islands, ...) that are added to the table.
minPvalSummarize	If ROIs are given, you can specify a QseaTvN_glm object. For each ROI the window with the most significant differential coverage is written out
CNV	If set TRUE, the CNV logFC for the samples specified by samples are written out.
verbose	verbosity level
minEnrichment	for transformation to absolute methylation level, you can specify the minimal number of expected reads for a fully methylated window. This avoids inaccurate estimates, due to low enrichment.
chunksize	For efficient memory usage, the table is built up in chunks. With this parameter, the maximum number of windows processed in one chunk is specified.

**Details**

Note that, if overlapping ROIs are specified, windows might emerge in the table several times.

**Value**

A result table containing the specified normalized values for the selected windows and samples/groups

**Author(s)**

Mathias Lienhard

**See Also**

isSignificant

**Examples**

```

#create example set
qs=getExampleQseaSet()
design=model.matrix(~group, getSampleTable(qs))
TvN_glm=fitNBglm(qs, design, norm_method="beta")
TvN_glm=addContrast(qs,TvN_glm, coef=2, name="TvN")
sig=isSignificant(TvN_glm, fdr_th=0.01)

##Table containing all significant windows
tab1=makeTable(qs=qs, glm=TvN_glm,
  keep=sig, samples=getSampleNames(qs))
##additional CNV logFC for the selected samples
tab2=makeTable(qs=qs, glm=TvN_glm,
  keep=sig, samples=getSampleNames(qs), CNV=TRUE)
##explicit selection of normalization:
##counts (i.e. no normalization, only counts)
tab3=makeTable(qs=qs, glm=TvN_glm, keep=sig,
  samples=getSampleNames(qs), norm_method="counts")

##counts AND %methylation values for individual samples and group means
tab4=makeTable(qs=qs, glm=TvN_glm, keep=sig,
  samples=getSampleNames(qs), groupMeans=getSampleGroups(qs),
  norm_method=c("counts", "beta"))

```

normMethod

*Definition of normalization procedure***Description**

This function allows to define normalization methods by specifying components.

**Usage**

```
normMethod(methods, ...)
```

**Arguments**

methods	names of predefined normalization methods ( for a list of predefined methods, see details)
...	sets of normalization components, that can be combined to user defined normalization methods

**Details**

Predefined normalization methods:

“counts”: no normalization, simply raw count values

“reads”: same as counts

“rpm”: reads per million mappable reads

“nrpm”: CNV normalized reads per million mappable reads

“beta”: transformation to % methylation, posterior mean point estimator

“logitbeta”: logit transformed beta values

“betaLB”: 2.5 lower bound for the point estimator

“betaUB”: 97.5 upper bound for the point estimator

Allowd components for user defined normalization methods:

“library\_size”: scale by effective library size

“region\_length”: scale by window size

“preference”: scale by positional sequencing preference

“cnv”: scale by CNV ratio

“enrichment”: use enrichment profiles for transformation to absolute methylation level

“qXY”: quantile estimator for transformation to absolute methylation level. XY must be replaced by the quantile (see example with self defined lower and upper bound)

“offset”: consider background reads

WARNING: not all combinations are allowed (eg qXY requires enrichment) and not all allowed combinations are meaningful. Inexperienced users should stick to predefined normalization methods.

## Value

a list object, containing the components for the specified normalization procedure

## Author(s)

Mathias Lienhard

## See Also

makeTable

## Examples

```
#simply raw counts
nm=normMethod("counts")
#beta-values (% methylation) including lower and upper bounds
nm=normMethod(c("beta", "betaLB", "betaUB"))
#self defined lower and upper bound: 10% and 90% quantile
nm=normMethod("beta",
betaLB_10=c("enrichment", "cnv", "library_size",
"region_length", "preference", "q10", "offset"),
betaUB_90=c("enrichment", "cnv", "library_size",
"region_length", "preference", "q90", "offset")
)
```

**Description**

This function plots the Copy Number Variations (CNVs) of the samples in a heatmap like representation. Amplified regions are depicted in red, whereas deletions are depicted green, and CNV free regions blue. The samples are ordered by an hierarchical clustering.

**Usage**

```
plotCNV(qs, dist = c("euclid", "cor")[1], clust_method = "complete",  
        chr = getChrNames(qs), samples =getSampleNames(qs),  
        cex = 1, labels = c(TRUE, TRUE,TRUE, TRUE), naColor = "darkgrey",  
        indicateLogFC = TRUE )
```

**Arguments**

qs	a qseaSet object (mandatory)
dist	distance measure for clustering. dQuoteeuclidian or dQuotecorrelation based (1-cor)
clust_method	method to be passed to hclust
chr	vector of chromosomes to be depicted
samples	samples for which CNVs are depicted
cex	font size of labels
labels	Boolean vector of length four (bottom, left, top, right), specifying the sides of the map to be labeled
naColor	Color for regions without CNV information
indicateLogFC	indicate the CNV logFC values in the legend

**Value**

This function returns the pairwise distances of the CNV profiles, on which the clustering is based on.

**Author(s)**

Mathias Lienhard

**Examples**

```
qs=getExampleQseaSet()  
plotCNV(qs, labels=c(FALSE, TRUE, TRUE, FALSE))
```

---

plotCoverage

*Plots a genome-browser-like image of a region*


---

### Description

This function plots the normalized coverage of specified samples in a specified region, together with annotations, in a genome-browser-like fashion

### Usage

```
plotCoverage(qs,test_results, chr, start, end, samples,samples2,
norm_method="nrpkm", yoffset, xlab="Position",
ylab="MeDIP seq", col="black", main, reorder="non", indicate_reorder=TRUE,
distfun=dist, clustmethod="complete", scale=TRUE, steps=TRUE, space=0.05,
baselines=TRUE, scale_val, scale_unit=NULL, logFC_pc=.1, cex=1, smooth_width,
smooth_function=mean, regions, regions_lwd=1, regions_col,
regions_offset, regions_names, regions_dash=0.1)
```

### Arguments

qs	a qseaSet object
chr	the chromosome of the region to be depicted
start	the start position of the region to be depicted
end	the end position of the region to be depicted
samples	the indices of the samples to be depicted
samples2	if specified, used to calculated logFC (samples/samples2) profiles, must be of same length as samples
logFC_pc	if samples2 is specified and logFC are calculated, this parameter specifies the pseudocount to avoid division by zero
norm_method	a vector of normalization methods to be combined
yoffset	horizontal offset, used to adjust the space between the profiles
xlab	title for the x axis
ylab	title for the y axis
main	an overall title for the plot
col	color vector for the samples (is recycled)
reorder	indicate whether, and if yes how, the samples are reordered. Valid values are "non", "clust", "max", "minP", or a genomic position within the range that is depicted
test_results	a qseaGLM object, used to find the region with minimal p value (only if reorder="minP")
indicate_reorder	indicate the window that has been used for reordering by an arrow.
distfun	if reorder="clust": for hierarchical clustering for reordering
clustmethod	if reorder="clust": for hierarchical clustering for reordering
scale	if set TRUE, print a bar scale

scale_val	length of the bar scale
scale_unit	unit of the bar scale
steps	plot the coverage as step function (steps=TRUE), or as lines
space	fraction of the plot set aside for sample names etc.
baselines	depict the baselines (zero) of the coverage profiles
cex	font size
smooth_width	number of windows to be considered for sliding window smoothing
smooth_function	function to be applied on the sliding windows for smoothing
regions	named list of GenomicRanges objects, containing annotation (eg exons) to be depicted below the coverage profiles
regions_lwd	vector of line width for the
regions_col	vector of colors for the regions
regions_offset	offset value, defining the space between the regions
regions_names	vector of column names, that store the names of the regions
regions_dash	vector, specifying the length of the end dashes of the regions

**Value**

list containing a table containing the plotted coverage values, the position that has been used for ordering, and the image coordinates

**Author(s)**

Mathias Lienhard

**Examples**

```
qs=getExampleQseaSet(repl=5)
colors=c(rep("red", 5), rep("green", 5))
plot(1)
plotCoverage(qs,samples=getSampleNames(qs),
  chr="chr1", start=1960001, end=1970001,col=colors,
  norm_method="beta", yoffset=1,space=.2, reorder=1964500)
plotCoverage(qs,samples=getSampleNames(qs),
  chr="chr1", start=1960001, end=1970001,col=colors,
  norm_method="beta", yoffset=1,space=.2, reorder="clust")
```

---

plotEnrichmentProfile *Plotting functions for enrichment profiles*

---

**Description**

Plots the estimated sequence pattern dependent enrichment profile for one or several samples as a matrix of plots

**Usage**

```
plotEnrichmentProfile(qs, sample, sPoints=seq(0,30,1),
  fitPar=list(lty=2, col="green"), cfPar=list(lty=1), densityPar, meanPar, ... )
plotEPmatrix(qs, sa=getSampleNames(qs), nrow=ceiling(sqrt(length(sa))),
  ncol=ceiling(length(sa)/nrow), ...)
```

**Arguments**

qs	The qseaSet object
sample	The index of the sample for which the enrichment profile should be depicted
sPoints	The values at which the enrichment profile function is evaluated
fitPar	List of parameters for depiction of the fitted enrichment profile function (see details)
cfPar	List of parameters for depiction of the empirical enrichment profile (see details)
densityPar	List of parameters for depiction high density scatterplot of coverage and pattern density (see details)
meanPar	List of parameters for depiction of the mean coverage per pattern density bin (see details)
sa	vector of samples to be depicted in matrix plot
nrow	number of rows in matrix plot
ncol	number of columns in matrix plot
...	Further graphical parameters may also be supplied

**Details**

Parameter lists for lines in the plot (e.g. fitPar, cfPar and meanPar) are passed to graphics::lines(), densityPar are passed to graphics::smoothScatter() function.

**Value**

plotEnrichmentProfile returns the coordinates of the enrichment profile. plotEPmatrix returns enrichment profile coordinates for all depicted samples.

**Author(s)**

Mathias Lienhard

**See Also**

addEnrichmentParameters

**Examples**

```
#create example object with different sequencing depth
qs=getExampleQseaSet(expSamplingDepth=50*10^(1:4), repl=4)
#enrichment profile for one sample
plotEnrichmentProfile(qs, "Sim4T")
#enrichment profile for all samples
plotEPmatrix(qs)
```



**Description**

The principle components can be depicted using the plotting methods `plotPCA` and `plotPCAfactors`

**Usage**

```
## S4 method for signature 'qseaPCA'
plotPCA(object,plotComponents=c(1,2), fgColor="black",
        bgColor = "white", legend, plotLabels=TRUE, radius=5, labelOffset=.5,
        labelPos=1, labelAdj, labelColor="black", cex=1, ...)

## S4 method for signature 'qseaPCA'
plotPCAfactors(object,plotComponents=c(1,2),
               fgColor="black",bgColor = "white", plotTopLabels=100, labelsOfInterest,
               radius=1, labelOffset=.5,labelPos=1,labelColor="black", cex=1, ...)
```

**Arguments**

<code>object</code>	the <code>qseaPCA</code> object, resulting from the <code>getPCA</code> function
<code>plotComponents</code>	vector of the two components of the PCA
<code>fgColor</code>	vector of foreground colors for the circles
<code>bgColor</code>	vector of background colors for the circles
<code>legend</code>	add a legend to the plot
<code>plotLabels</code>	if set <code>TRUE</code> , the labels of the samples are written in the plot
<code>radius</code>	defines the size of the plotted circles
<code>labelOffset</code>	defines the offset of the labels to the circles
<code>labelPos</code>	specify position of the labels in the plot (see <code>graphics::text</code> )
<code>labelAdj</code>	alternative way to specify position of the labls in the plot (see <code>graphics::text</code> )
<code>labelColor</code>	a vector of colors for the labels
<code>cex</code>	font size of the labels
<code>plotTopLabels</code>	labels of factors with strongest contribution to plotted components are shown
<code>labelsOfInterest</code>	vector of factor names that are highlighted and labeled in the plot
<code>...</code>	further graphical parameters

**Value**

The functions return a list with the coordinates of the depicted components

**Author(s)**

Mathias Lienhard

**See Also**

plotPCA

**Examples**

```
qs=getExampleQseaSet( repl=5)
pca=getPCA(qs, norm_method="beta")
colors=c(rep("red", 5), rep("green", 5))

plotPCA(pca, bgColor=colors)
#plotPCAfactors is more interesting, if ROIs have been specified in getPCA
plotPCAfactors(pca)
```

---

qseaGLM-class

*qseaGLM class and its methods*

---

**Description**

The qseaGLM class is used in qsea to store fitted coefficients of the GLM.

**Slots**

fullModelDesign: design matrix of full model  
 fullModel : list containing parameters and fitted coefficients of full model  
 parameters: list of parameters used to create the object  
 contrast: list of lists containing parameters and the fitted model coefficients of the reduced models  
 windows: vector of window indices, for which GLMs have been fitted

**Author(s)**

Matthias Lienhard

**Examples**

```
showClass("qseaGLM")
```

---

qseaPCA-class

*qseaPCA class and its methods*

---

**Description**

The qseaPCA class is used in qsea to store results of the principle component analysis.

**Slots**

svd: singular value decomposition  
 sample\_names : names of the samples  
 factor\_names: names of the genomic windows involved

**Author(s)**

Matthias Lienhard

**Examples**

```
showClass("qseaPCA")
```

---

qseaSet-class

*qseaSet class and its methods*


---

**Description**

The qseaSet class is used in qsea to store information about the coverage, the dependent organism, the chromosomes included in the input file, the length of the included chromosomes (automatically loaded), the number of regions, and optionally CNV information.

**Slots**

**sampleTable:** Object of class "data.frame": the sample table

**count\_matrix:** Object of class "matrix": matrix containing the coverage for all samples

**zygosity:** Object of class "matrix": matrix containing the zygosity for all chromosomes and all samples

**regions:** Object of class "GenomicRanges": the genomic regions for the coverage matrix

**parameters:** Object of class "list": the parameter list used to create this object

**cnv:** Object of class "GenomicRanges": CNV ranges and logFCs

**enrichment :** Object of class "list": parameters of the sequence pattern enrichment analysis

**libraries :** Object of class "matrix": parameters of the sequencing libraries

**Methods**

**getSampleTable** signature(object = "qseaSet"): extracts the sample table of a qsea set

**getSampleNames** signature(object = "qseaSet"): extracts the sample names of a qsea set

**getSampleGroups** signature(object = "qseaSet"): extracts the sample groups of a qsea set

**getChrNames** signature(object = "qseaSet"): returns the analysed chromosomes

**getCounts** signature(object = "qseaSet"): extracts the count matrix a qsea set

**getRegions** signature(object = "qseaSet"): extracts the regions object of a qsea set

**getParameters** signature(object = "qseaSet"): extracts the parameter list of a qsea set

**getLibSize** signature(object = "qseaSet"): extracts the library size (eg the total number of read counts per sample)

**getNormFactors** signature(object = "qseaSet"): extracts the list with the different normalization factors

**hasCNV** signature(object = "qseaSet"): TRUE if CNV information is present, FALSE otherwise

**getCNV** signature(object = "qseaSet"): extracts the CNV regions and logFCs

**getOffset** signature(object = "qseaSet"): extracts offset of rpkm scaled background reads

**getWindowSize** signature(object = "qseaSet"): returns the window size of the object

**getZyosity** signature(object = "qseaSet"): returns the zygosity matrix of the object

**setZyosity** signature(object = "qseaSet", zygosityMatrix): sets the zygosity matrix, and resets CNV

**Author(s)**

Matthias Lienhard

**Examples**

```
showClass("qseaSet")
```

---

regionStats

*Counts the Windows in Regions of Interest*

---

**Description**

This function takes a list of window indices and a list of ROIs and counts the number of overlapping windows

**Usage**

```
regionStats(qs, subsets = list(covered = which(rowSums(getCounts(qs)) >= 20)),
  ROIs = list(), minoverlap = 0, maxgap = -1)
```

**Arguments**

qs	A qsea Set object
subsets	A list of window indices
ROIs	A list of Regions of Interest
minoverlap	Passed to findOverlaps
maxgap	Passed to findOverlaps

**Value**

a matrix, containing the total number of windows overlapping the ROIs and the numbers of windows from the subset list overlapping ROIs

**Author(s)**

Mathias Lienhard

**See Also**

findOverlaps

**Examples**

```
qs=getExampleQseaSet()
#as an example, we analyze the fraction of reads covered by at least 10
#or at least 20 reads, for bins of CpG density
ROIs=list()
regs=getRegions(qs)
cpg=getRegions(qs)$CpG_density
bins=seq(0,30,5)
for(i in 1:(length(bins)-1)){
```

```
n=paste0(bins[i],"-",bins[i+1]," CpGs")
ROIs[[n]]=regs[which(cpg>=bins[i] & cpg < bins[i+1])]
}
subsets = list(
  ">10" = which(rowSums(getCounts(qs)) >= 10),
  ">20" = which(rowSums(getCounts(qs)) >= 20))
coverage_stats=regionStats(qs, subsets, ROIs)
coverage_stats_rel=coverage_stats[,-1]/coverage_stats[,1]
x=barplot(t(coverage_stats_rel)*100,ylab="fraction of windows[%]",
  beside=TRUE, legend=TRUE, las=2, args.legend=list(x="topleft"),
  main="Covered Windows")
```

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