Package 'UMI4Cats'

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Title UMI4Cats: Processing, analysis and visualization of UMI-4C chromatin contact data

Version 1.21.0

URL https://github.com/Pasquali-lab/UMI4Cats

Description UMI-4C is a technique that allows characterization of 3D chromatin interactions with a bait of interest, taking advantage of a sonication step to produce unique molecular identifiers (UMIs) that help remove duplication bias, thus allowing a better differential comparsion of chromatin interactions between conditions. This package allows processing of UMI-4C data, starting from FastQ files provided by the sequencing facility. It provides two statistical methods for detecting differential contacts and includes a visualization function to plot integrated information from a UMI-4C assay.

BugReports https://github.com/Pasquali-lab/UMI4Cats/issues

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`.getCache` *Get BiocFileCache object*

Description

Get BiocFileCache object

Usage

```
.getCache()
```

Value

Returns BFC object with the cache for the UMI4Cats package

.getSummaryBam *Summarize BAM file*

Description

Get summary of interesting bam statistics

Usage

```
.getSummaryBam(bam_file, mapped = TRUE, secondary = FALSE)
```

Arguments

bam_file	Path for the bam file.
mapped	Logical indicating whether to extract mapped reads.
secondary	Logical indicating whether to extract secondary aligned reads.

Value

Returns a numeric containing the number of reads in bam_file that has the specified mapped and secondary status.

.singleAlignmentUMI4C *Align split fastq file*

Description

Align split fastq file

Usage

```
.singleAlignmentUMI4C(
  split_file,
  align_dir,
  threads = 1,
  bowtie_index,
  pos_viewpoint,
  filter_bp = 1e+07
)
```

Arguments

split_file	Split fastq file to align.
align_dir	Directory where to save aligned files.
threads	Number of threads to use in the analysis. Default=1.
bowtie_index	Path and prefix of the bowtie index to use for the alignment.
pos_viewpoint	GRanges object containing the genomic position of the viewpoint.
filter_bp	Integer indicating the bp upstream and downstream of the viewpoint to select for further analysis. Default=10e6

Value

Creates a BAM file in wk_dir/align named "basename(fastq))_filtered.bam", containing the aligned filtered reads. A data.frame object with the statisitics is also returned.

.singleCounterUMI4C *Count UMIs for a given bam file.*

Description

Count UMIs for a given bam file.

Usage

```
.singleCounterUMI4C(
  filtered_bam_R1,
  filtered_bam_R2,
  digested_genome_gr,
  pos_viewpoint,
  res_enz,
  count_dir,
  filter_bp = 1e+07
)
```

Arguments

filtered_bam_R1	R1 bam file.
filtered_bam_R2	R2 bam file.
digested_genome_gr	GRanges object containing the coordinates for the digested genome.
pos_viewpoint	Vector consist of chromosome, start and end position of the viewpoint.
res_enz	Character containing the restriction enzyme sequence.
count_dir	Counter directory.
filter_bp	Integer indicating the bp upstream and downstream of the viewpoint to select for further analysis. Default=10e6

Value

Creates a tab-delimited file in wk_dir/count named "basename(fastq) _counts.tsv", containing the coordinates for the viewpoint fragment, contact fragment and the number of UMIs detected in the ligation.

`.singlePrepUMI4C` *Prepar fastq files at a given barcode.*

Description

Prepar fastq files at a given barcode.

Usage

```
.singlePrepUMI4C(
  fq_R1,
  fq_R2,
  bait_seq,
  bait_pad,
  res_enz,
  prep_dir,
  numb_reads = 1e+09
)
```

Arguments

fq_R1	Fastq file R1.
fq_R2	Fastq file R2.
bait_seq	Character containing the bait primer sequence.
bait_pad	Character containing the pad sequence (sequence between the bait primer and the restriction enzyme sequence).
res_enz	Character containing the restriction enzyme sequence.
prep_dir	Prep directory.
numb_reads	Number of lines from the FastQ file to load in each loop. If having memory size problems, change it to a smaller number. Default=1e9.

Value

Creates a compressed FASTQ file in wk_dir/prep named basename(Fastq)).fq.gz, containing the filtered reads with the UMI sequence in the header. A data.frame object with the statisitics is also returned.

.singleSplitUMI4C *Split fastq files at a given restriction site.*

Description

Split fastq files at a given restriction site.

Usage

```
.singleSplitUMI4C(
  fastq_file,
  res_enz,
  cut_pos,
  split_dir,
  min_flen = 20,
  numb_reads = 1e+09
)
```

Arguments

fastq_file	Fastq file path.
res_enz	Character containing the restriction enzyme sequence.
cut_pos	Numeric indicating the nucleotide position where restriction enzyme cuts (zero-based) (for example, for DpnII is 0).
split_dir	Directory where to save split files.
min_flen	Minimal fragment length to use for selecting the fragments. Default=20
numb_reads	Number of lines from the FastQ file to load in each loop. If having memory size problems, change it to a smaller number. Default=1e9.

Value

Creates a compressed FASTQ file in `wk_dir/split` named `basename(fastq)).fq.gz`, containing the split reads based on the restriction enzyme used.

.smoothMonotone *Monotone smoothing of the VST counts*

Description

Takes the variance stabilized count values and calculates a symmetric monotone fit for the distance dependency. The signal trend is fitted using the fda package.

Usage

```
.smoothMonotone(trafo_counts, alpha = 20, penalty = 0.1, frag_data)
```

Arguments

trafo_counts	Variance stabilized count values assay from DDS object.
alpha	Approximate number of fragments desired for every basis function of the B-spline basis. floor((max(number of fragments)) / alpha) is passed to create.bspline.basis as nbasis argument. 4 is the minimum allowed value. Default: 20.
penalty	Amount of smoothing to be applied to the estimated functional parameter. Default: 0.1.
frag_data	Data frame with all the information on restriction fragments and the interval around the viewpoint.

Details

This function computes the smoothing function for the VST values, based on fda package, and calculates a symmetric monotone fit counts for the distance dependency

Value

A dataframe with monotone smoothed fit counts.

---

addGrouping *Add grouping of UMI-4C samples*

Description

This function can be used to add specific groupings to UMI4C objects.

Usage

```
addGrouping(
  umi4c,
  grouping = "sampleID",
  scales = 5:150,
  normalized = TRUE,
  sd = 2
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C.
grouping	Name of the column in colData used to merge the samples or replicates. Set to NULL for skipping grouping. Default: "condition".
scales	Numeric vector containing the scales for calculating the domainogram.
normalized	Logical indicating whether UMI-4C profiles should be normalized to the ref_umi4c sample/group. Default: TRUE
sd	Stantard deviation for adaptative trend.

Value

Adds a new UMI4C object into the groupsUMI4C slot with samples grouped according to grouping variable.

Examples

```
data("ex_ciita_umi4c")

ex_ciita_umi4c <- addGrouping(ex_ciita_umi4c, grouping="condition")
```

---

addStepping *Add stepping for plotting genes*

Description

Given a GRanges-class dataset representing genes, will add an arbitrary value for them to be plotted in the Y axis without overlapping each other.

Usage

```
addStepping(genesDat, coordinates, mcol.name)
```

Arguments

genesDat	GRanges object containing gene information.
coordinates	GRanges object with coordinates you want to plot.
mcol.name	Integer containing the column number that contains the gene name.

Value

Calculates the stepping position to avoid overlap between genes.

---

alignmentUMI4C *UMI4C alignment*

Description

Align split UMI-4C reads to a reference genome using Bowtie2.

Usage

```
alignmentUMI4C(
  wk_dir,
  pos_viewpoint,
  bowtie_index,
  threads = 1,
  filter_bp = 1e+07
)
```

Arguments

wk_dir	Working directory where to save the outputs generated by the UMI-4c analysis.
pos_viewpoint	GRanges object containing the genomic position of the viewpoint. It can be generated by getViewpointCoordinates function.
bowtie_index	Path and prefix of the bowtie index to use for the alignment.
threads	Number of threads to use in the analysis. Default=1.
filter_bp	Integer indicating the bp upstream and downstream of the viewpoint to select for further analysis. Default=10e6

Value

Creates a BAM file in wk_dir/align named "basename(fastq))_filtered.bam", containing the aligned filtered reads. The alignment log is also generated in wk_dir/logs named "umi4c_alignment_stats.txt".

Examples

```
if (interactive()){
path <- downloadUMI4CexampleData(reduced = TRUE)
alignmentUMI4C(
    wk_dir = file.path(path, "CIITA"),
    pos_viewpoint = GenomicRanges::GRanges("chr16:10972515-10972548"),
    bowtie_index = file.path(path, "ref_genome", "ucsc.hg19.chr16")
)
}
```

---

calculateAdaptativeTrend

Adaptative smoothing of normalized trend

Description

Will perform adaptative smoothing will scaling one profile to the reference UMI-4C profile.

Usage

```
calculateAdaptativeTrend(umi4c, sd = 2, normalized = TRUE)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C.
sd	Stantard deviation for adaptative trend.
normalized	Logical indicating whether UMI-4C profiles should be normalized to the ref_umi4c sample/group. Default: TRUE

Value

Calculates the adaptative trend considering the minimum number of molecules to use for merging different restriction fragments. It also calculates the geometric mean of the coordinates of the merged restriction fragments.

---

calculateDomainogram *Create Domainogram*

Description

Using as input the raw UMIs, this function creates a domainogram for the supplied scales.

Usage

```
calculateDomainogram(umi4c, scales = 5:150, normalized = TRUE)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C.
scales	Integer vector indicating the number of scales to use for the domainogram creation. Default: 5:150.
normalized	Logical whether the the resulting domainograms should be normalized or not. Default: TRUE.

Value

A matrix where the first column represents the fragment end coordinates (start) and the rest represent the number of UMIs found when using a specific scale.

---

callInteractions *Call significant interactions*

Description

Test a set of query_regions for significant interactions with the viewpoint.

Usage

```
callInteractions(
  umi4c,
  design = ~condition,
  query_regions,
  padj_method = "fdr",
  zscore_threshold = 2,
  padj_threshold = 0.1,
  alpha = 20,
  penalty = 0.1
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C or the UMI4C constructor.
design	A formula or matrix. The formula expresses how the counts for each fragment end depend on the variables in colData. See DESeqDataSet.
query_regions	GRanges object or data.frame containing the coordinates of the genomic regions you want to use to perform the analysis in specific genomic intervals. Default: NULL.
padj_method	The method to use for adjusting p-values, see p.adjust. Default: fdr.
zscore_threshold	Numeric indicating the z-score threshold to use to define significant differential contacts. Default: 2.
padj_threshold	Numeric indicating the adjusted p-value threshold to use to define significant differential contacts. Default: 0.1.
alpha	Approximate number of fragments desired for every basis function of the B-spline basis. floor((max(number of fragments)) / alpha) is passed to create.bspline.basis as nbasis argument. 4 is the minimum allowed value. Default: 20.
penalty	Amount of smoothing to be applied to the estimated functional parameter. Default: 0.1.

Value

GRangesList where each element is a UMI4C sample with the queried regions and their adjusted p-values and Z-scores.

Examples

```
data("ex_ciita_umi4c")
umi <- ex_ciita_umi4c
win_frags <- makeWindowFragments(umi, n_frags=8, sliding=1)

gr <- callInteractions(umi, ~condition, win_frags, padj_threshold = 0.01, zscore_threshold=2)
inter <- getSignInteractions(gr)
```

---

combineUMI4C *Combine UMI4C fragments*

Description

Combine the UMI4C fragments that overlap a given set of query_regions.

Usage

```
combineUMI4C(umi4c, query_regions)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C or the UMI4C constructor.
query_regions	GRanges object containing the coordinates of the genomic regions for combining restriction fragments.

Value

UMI4C object with rowRanges corresponding to query_regions and assay containing the sum of raw UMI counts at each specified query_region.

Examples

```
data("ex_ciita_umi4c")

wins <- makeWindowFragments(ex_ciita_umi4c)
umi_comb <- combineUMI4C(ex_ciita_umi4c, wins)
```

---

contactsUMI4C *UMI4C Contacts Processing*

Description

Using demultiplexed FastQ files as input, performs all necessary steps to end up with a tsv file summarizing the restriction enzyme fragments and the number of UMIs supporting that specific contact with the viewpoint (bait) of interest.

Usage

```
contactsUMI4C(
  fastq_dir,
  wk_dir,
  file_pattern = NULL,
  bait_seq,
  bait_pad,
  res_enz,
  cut_pos,
  digested_genome,
  bowtie_index,
  threads = 1,
  numb_reads = 1e+09,
  rm_tmp = TRUE,
  min_flen = 20,
  filter_bp = 1e+07,
  ref_gen,
  sel_seqname = NULL
)
```

Arguments

fastq_dir	Path of the directory containing the FastQ files (compressed or uncompressed).
wk_dir	Working directory where to save the outputs generated by the UMI-4c analysis.
file_pattern	Character that can be used to filter the files you want to analyze in the fastq_dir.
bait_seq	Character containing the bait primer sequence.
bait_pad	Character containing the pad sequence (sequence between the bait primer and the restriction enzyme sequence).
res_enz	Character containing the restriction enzyme sequence.
cut_pos	Numeric indicating the nucleotide position where restriction enzyme cuts (zero-based) (for example, for DpnII is 0).
digested_genome	Path for the digested genome file generated using the digestGenome function.
bowtie_index	Path and prefix of the bowtie index to use for the alignment.
threads	Number of threads to use in the analysis. Default=1.
numb_reads	Number of lines from the FastQ file to load in each loop. If having memory size problems, change it to a smaller number. Default=1e9.
rm_tmp	Logical indicating whether to remove temporary files (sam and intermediate bams). TRUE or FALSE. Default=TRUE.
min_flen	Minimal fragment length to use for selecting the fragments. Default=20
filter_bp	Integer indicating the bp upstream and downstream of the viewpoint to select for further analysis. Default=10e6
ref_gen	A BSgenome object of the reference genome.
sel_seqname	A character with the chromosome name to focus the search for the viewpoint sequence.

Value

This function is a combination of calls to other functions that perform the necessary steps for processing UMI-4C data.

Examples

```
if (interactive()) {
path <- downloadUMI4CexampleData()

hg19_dpnii <- digestGenome(
    cut_pos = 0,
    res_enz = "GATC",
    name_RE = "DpnII",
    ref_gen = BSgenome.Hsapiens.UCSC.hg19::BSgenome.Hsapiens.UCSC.hg19,
    out_path = file.path(path, "digested_genome")
)


raw_dir <- file.path(path, "CIITA", "fastq")
```

```
contactsUMI4C(
    fastq_dir = raw_dir,
    wk_dir = file.path(path, "CIITA"),
    bait_seq = "GGACAAGCTCCCTGCAACTCA",
    bait_pad = "GGACTTGCA",
    res_enz = "GATC",
    cut_pos = 0,
    digested_genome = hg19_dpnii,
    bowtie_index = file.path(path, "ref_genome", "ucsc.hg19.chr16"),
    threads = 1,
    numb_reads = 1e9,
    ref_gen = BSgenome.Hsapiens.UCSC.hg19::BSgenome.Hsapiens.UCSC.hg19,
    sel_seqname = "chr16"
)

unlink(path, recursive=TRUE)
}
```

`counterUMI4C` *UMI counting*

Description

Algorithm for counting and collapsing the number of UMIs supporting a specific ligation.

Usage

```
counterUMI4C(
  wk_dir,
  pos_viewpoint,
  res_enz,
  digested_genome,
  filter_bp = 1e+07
)
```

Arguments

`wk_dir`	Working directory where to save the outputs generated by the UMI-4c analysis.
`pos_viewpoint`	GRanges object containing the genomic position of the viewpoint.
`res_enz`	Character containing the restriction enzyme sequence.
`digested_genome`	Path for the digested genome file generated using the `digestGenome` function.
`filter_bp`	Integer indicating the bp upstream and downstream of the viewpoint to select for further analysis. Default=10e6.

Details

For collapsing different molecules into the same UMI, takes into account the ligation position and the number of UMI sequence mismatches.

Value

Creates a compressed tab-delimited file in `wk_dir/count` named "`basename(fastq)_counts.tsv.gz`", containing the coordinates for the viewpoint fragment, contact fragment and the number of UMIs detected in the ligation.

Examples

```
if (interactive()) {
path <- downloadUMI4CexampleData(reduced = TRUE)

hg19_dpnii <- digestGenome(
    cut_pos = 0,
    res_enz = "GATC",
    name_RE = "DpnII",
    sel_chr = "chr16", # digest only chr16 to make example faster
    ref_gen = BSgenome.Hsapiens.UCSC.hg19::BSgenome.Hsapiens.UCSC.hg19,
    out_path = file.path(path, "digested_genome")
)

viewpoint <- GenomicRanges::GRanges("chr16:10972515-10972548")

counterUMI4C(
    wk_dir = file.path(path, "CIITA"),
    pos_viewpoint = viewpoint,
    res_enz = "GATC",
    digested_genome = hg19_dpnii
)

}
```

---

createGeneAnnotation *Create gene annotation object*

Description

Create gene annotation object

Usage

```
createGeneAnnotation(
  window,
  TxDb = TxDb.Hsapiens.UCSC.hg19.knownGene::TxDb.Hsapiens.UCSC.hg19.knownGene,
  OrgDb = "org.Hs.eg.db",
  longest = TRUE
)
```

Arguments

window	GRanges-class object with coordinates to use for selecting the genes to plot.
TxDb	TxDb object to use for drawing the genomic annotation.
OrgDb	A character string for the name of an annotation element of an annotation data package.
longest	Logical indicating whether to plot only the longest transcripts for each gene in the gene annotation plot.

Value

GRanges object with the gene annotation in the window.

Examples

```
library(TxDb.Hsapiens.UCSC.hg19.knownGene)
window <- GRanges("chr16:11298262-11400036")
gene_anno <- createGeneAnnotation(
    window = window,
    TxDb = TxDb.Hsapiens.UCSC.hg19.knownGene,
    OrgDb = "org.Hs.eg"
)
```

---

createStatsTable *Create stats table*

Description

Create a statistical summary of the UMI-4C experiments analyzed with contactsUMI4C.

Usage

```
createStatsTable(wk_dir)
```

Arguments

wk_dir	Working directory where to save the outputs generated by the UMI-4c analysis.

Value

Returns a data.frame summarizing all the different statistics for each sample analyzed in wk_dir.

darken *Darken colors*

Description

Darken colors

Usage

```
darken(color, factor = 1.4)
```

Arguments

color	Character containing the name or hex value of a color.
factor	Numeric representing a factor by which darken the specified color.

Value

Darkens the provided color by the provided factor.

Examples

```
darken("blue", factor = 1.4)
```

dds2UMI4C *DDS object to UMI4Cats object.*

Description

Transforms an DDS object to a UMI4C object after applying `nbinomWaldTestUMI4C`.

Usage

```
dds2UMI4C(
  umi4c,
  dds,
  normalized = TRUE,
  padj_method = "fdr",
  padj_threshold = 0.05
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C or the UMI4C constructor.
dds	DDS object as generated by nbinomWaldTestUMI4C with the DESeq2 Wald Test results
normalized	Logical indicating if the function should return normalized or raw UMI counts. Default: TRUE.
padj_method	The method to use for adjusting p-values, see p.adjust. Default: fdr.
padj_threshold	Numeric indicating the adjusted p-value threshold to use to define significant differential contacts. Default: 0.05.

Value

UMI4C object with the DESeq2 Wald Test results.

---

demultiplexFastq *Demultiplex FASTQ files using fastq-multx*

Description

Demultiplex FASTQ files containng different bait information

Usage

```
demultiplexFastq(barcodes, fastq, out_path = "raw_fastq", numb_reads = 1e+11)
```

Arguments

barcodes	Dataframe with "name of sample" and "barcode" for every sample to demultiplex.
fastq	Fastq to demultiplex containing mate 1s. Different pairs should be named as "_R1" or "_R2". Allowed formats: _R1.fastq.gz, _R1.fq.gz, _R1.fastq or _R1.fq.
out_path	Path where to save the demultiplex output. Defaults to a path named raw_fastq in your working directory.
numb_reads	Number of lines from the FastQ file to load in each loop. If having memory size problems, change it to a smaller number. Default=10e10.

Value

Paired-end FastQ files demultiplexed in a compressed format. A log file with the statistics is also generated in out_path named barcode_umi4cats_demultiplexFastq_stats.txt.

Examples

```
## Not run:
path <- downloadUMI4CexampleData(use_sample = TRUE)
fastq <- file.path(path, "CIITA", "fastq", "sub_ctrl_hi19_CIITA_R1.fastq.gz")
barcodes <- data.frame(
    sample = c("CIITA"),
    barcode = c("GGACAAGCTCCCTGCAACTCA")
)

demultiplexFastq(
    barcodes = barcodes,
    fastq = fastq,
    out_path = path
)

## End(Not run)
```

---

dgram *UMI4C class methods*

Description

This page contains a summary of the different methods used to access the information contained inside the UMI4C-class object. See the details section for more information on the different accessors.

Usage

```
dgram(object)

dgram(object) <- value

groupsUMI4C(object, value)

groupsUMI4C(object) <- value

bait(object)

trend(object)

resultsUMI4C(object, format = "GRanges", counts = TRUE, ordered = FALSE)

## S4 method for signature 'UMI4C'
dgram(object)

## S4 replacement method for signature 'UMI4C'
dgram(object) <- value
```

```
## S4 method for signature 'UMI4C'
groupsUMI4C(object)

## S4 replacement method for signature 'UMI4C'
groupsUMI4C(object) <- value

## S4 method for signature 'UMI4C'
bait(object)

## S4 method for signature 'UMI4C'
trend(object)

## S4 method for signature 'UMI4C'
resultsUMI4C(object, format = "GRanges", counts = FALSE, ordered = FALSE)
```

Arguments

object	a UMI4C-class object.
value	Alternative list of dgrams to replace the current slot.
format	Either "GRanges" (default) or "data.frame", indicating the format output of the results.
counts	Logical indicating whether counts for the different region should be provided. Default: FALSE.
ordered	Logical indicating whether to sort output by significance (adjusted p-value). Default: FALSE.

Value

There are several accessors to easily retrive information from a UMI4C-class object:

- dgram: Returns a named list with the output domainograms for each sample.
- bait: Returns a GRanges-class object with the position of the bait.
- trend: Returns a data.frame in long format with the values of the adapative smoothen trend.
- resultsUMI4C: Returns a GRanges-class or data.frame with the results of the differential analysis.

See Also

UMI4C, UMI4C-class

Examples

```
# Access the different information inside the UMI4C object
data("ex_ciita_umi4c")
ex_ciita_umi4c <- addGrouping(ex_ciita_umi4c, grouping="condition")

dgram(ex_ciita_umi4c)
```

```
bait(ex_ciita_umi4c)
head(trend(ex_ciita_umi4c))

# Perform differential test
enh <- GRanges(c("chr16:10925006-10928900", "chr16:11102721-11103700"))
umi_dif <- fisherUMI4C(ex_ciita_umi4c, query_regions = enh,
                       filter_low = 20, resize = 5e3)
resultsUMI4C(umi_dif)
```

`differentialNbinomWaldTestUMI4C` *Differential UMI4C contacts using DESeq2 Wald Test*

Description

Using a `UMI4C` object, infers the differences between conditions specified in `design` of the smooth monotone fitted values using a Wald Test from `DESeq2` package.

Usage

```
differentialNbinomWaldTestUMI4C(
  umi4c,
  design = ~condition,
  normalized = TRUE,
  padj_method = "fdr",
  query_regions = NULL,
  padj_threshold = 0.05,
  penalty = 0.1,
  alpha = 20
)
```

Arguments

`umi4c`	UMI4C object as generated by `makeUMI4C` or the `UMI4C` constructor.
`design`	A `formula` or `matrix`. The formula expresses how the counts for each fragment end depend on the variables in `colData`. See `DESeqDataSet`.
`normalized`	Logical indicating if the function should return normalized or raw UMI counts. Default: TRUE.
`padj_method`	The method to use for adjusting p-values, see `p.adjust`. Default: fdr.
`query_regions`	`GRanges` object or `data.frame` containing the coordinates of the genomic regions you want to use to perform the analysis in specific genomic intervals. Default: NULL.
`padj_threshold`	Numeric indicating the adjusted p-value threshold to use to define significant differential contacts. Default: 0.05.
`penalty`	Amount of smoothing to be applied to the estimated functional parameter. Default: 0.1.

alpha — Approximate number of fragments desired for every basis function of the B-spline basis. `floor((max(number of fragments)) / alpha)` is passed to `create.bspline.basis` as nbasis argument. 4 is the minimum allowed value. Default: 20.

Details

This function fits the signal trend of a variance stabilized count values using a symmetric monotone fit for the distance dependency. Then scales the raw counts across the samples to obtain normalized factors. Finally, it detects differences between conditions applying the DESeq2 Wald Test.

Value

`UMI4C` object with the DESeq2 Wald Test results.

Examples

```
## Not run:
 files <- list.files(system.file("extdata", "CIITA", "count", package="UMI4Cats"),
                     pattern = "*_counts.tsv.gz",
                     full.names = TRUE
 )
# Create colData including all relevant information
colData <- data.frame(
  sampleID = gsub("_counts.tsv.gz", "", basename(files)),
  file = files,
  stringsAsFactors = FALSE
)

library(tidyr)
colData <- colData |>
  separate(sampleID,
           into = c("condition", "replicate", "viewpoint"),
           remove = FALSE
  )

# Make UMI-4C object including grouping by condition
umi <- makeUMI4C(
  colData = colData,
  viewpoint_name = "CIITA",
  grouping = NULL,
  bait_expansion = 2e6
)

umi_wald <- differentialNbinomWaldTestUMI4C(umi4c=umi,
                                            design=~condition,
                                            alpha = 100)

## End(Not run)
```

digestGenome *Digest reference genome*

Description

Performs an *in silico* digestion of a given reference genome using a given restriction enzyme sequence.

Usage

```
digestGenome(
  res_enz,
  cut_pos,
  name_RE,
  ref_gen,
  sel_chr = paste0("chr", c(seq_len(22), "X", "Y")),
  out_path = "digested_genome/"
)
```

Arguments

res_enz	Character containing the restriction enzyme sequence.
cut_pos	Numeric indicating the nucleotide position where restriction enzyme cuts (zero-based) (for example, for DpnII is 0).
name_RE	Restriction enzyme name.
ref_gen	A BSgenome object of the reference genome.
sel_chr	Character vector indicating which chromosomes to select for the digestion. Default: chr1-22, chrX, chrY.
out_path	Output path where to save the genomic track. The default is a directory named `digested_genome/` created in your working directory. The rda objects are saved in folder named by the `ref_gene_name_RE` in the `out_path` folder.

Value

Creates a rda file for every chromosome defined in `sel_chr`.

Examples

```
library(BSgenome.Hsapiens.UCSC.hg19)
ref_gen <- BSgenome.Hsapiens.UCSC.hg19

hg19_dpnii <- digestGenome(
    res_enz = "GATC",
    cut_pos = 0,
    name_RE = "dpnII",
    sel_chr = "chr16", # Only in chr16 to reduce example running time
```

```
    ref_gen = ref_gen,
    out_path = file.path(tempdir(), "digested_genome/")
)
```

`downloadUMI4CexampleData` *Download UMI4Cats example datasets*

Description

Downloads the required UMI4Cats example datasets.

Usage

```
downloadUMI4CexampleData(out_dir = tempdir(), verbose = TRUE, reduced = FALSE)
```

Arguments

`out_dir`	Output directory for the datasets, defaults to tempdir().
`verbose`	Whether to print verbose messages or not. Default: TRUE.
`reduced`	Whether to use a reduced dataset to make test functions run faster.

Value

It creates the `output_dir` with the example UMI-4C files used by the vignette and examples. Takes advantage of the BiocFileCache package to make sure that the file has not been previously downloaded by the user.

Examples

```
if (interactive()) {
 # Using reduced data data to make example faster.
# Remove reduced=TRUE or set to FALSE to
# download the full dataset.

path <- downloadUMI4CexampleData(reduced = TRUE)
}
```

ex_ciita_umi4c *Contacts with CIITA promoter*

Description

An example UMI4C object showing the contacts with a viewpoint located at the CIITA gene promoter.

Usage

```
data("ex_ciita_umi4c")
```

Format

A UMI4C object from this package.

Source

See inst/script/CIITA_process_example.R to see the code use for generating the UMI4C object.

fisherUMI4C *Differential UMI4C contacts using Fisher's Exact test*

Description

Using the UMIs inside `query_regions` performs Fisher's Exact test to calculate significant differences between contact intensities.

Usage

```
fisherUMI4C(
  umi4c,
  grouping = "condition",
  query_regions,
  resize = NULL,
  window_size = 5000,
  filter_low = 50,
  padj_method = "fdr",
  padj_threshold = 0.05
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C or the UMI4C constructor.
grouping	Name of the column in colData used to merge the samples or replicates. If none available or want to add new groupings, run addGrouping. Default: "condition".
query_regions	GenomicRanges object or data.frame containing the region coordinates used to perform the differential analysis.
resize	Width in base pairs for resizing the query_regions. Default: no resizing.
window_size	If query_regions are not defined, wil bin region in window_size bp and perform the analysis using this windows.
filter_low	Either the minimum median UMIs requiered to perform Fisher's Exact test or FALSE for performing the test in all windows.
padj_method	Method for adjusting p-values. See p.adjust for the different methods.
padj_threshold	Numeric indicating the adjusted p-value threshold to use to define significant differential contacts.

Details

This function calculates the overlap of fragment ends with either the provided query_regions or the binned region using window_size. The resulting number of UMIs in each query_region will be the *sum* of UMIs in all overlapping fragment ends. As a default, will filter out those regions whose median UMIs are lower than filter_low.

Finally, a contingency table for each query_reegions or window that passed the filter_low filter is created as follows:

	query_region	*region*
Reference	n1	N1-n1
Condition	n2	N2-n2

and the Fisher's Exact test is performed. Obtained p-values are then converted to adjusted p-values using padj_method and the results list is added to the UMI4C object.

Value

Calculates statistical differences between UMI-4C experiments.

Examples

```
data("ex_ciita_umi4c")
ex_ciita_umi4c <- addGrouping(ex_ciita_umi4c, grouping="condition")

# Perform differential test
enh <- GRanges(c("chr16:10925006-10928900", "chr16:11102721-11103700"))
umi_dif <- fisherUMI4C(ex_ciita_umi4c, query_regions = enh,
                       filter_low = 20, resize = 5e3)
resultsUMI4C(umi_dif)
```

formatPlotsUMI4C *Format plots for UMI4C*

Description

Format plots for UMI4C

Usage

```
formatPlotsUMI4C(plot_list, font_size)
```

Arguments

plot_list	List of plots generated by plotUMI4C
font_size	Base font size to use for the UMI4C plot. Default: 14.

Value

Given a named plot_list and considering the number and type of included plots, formats their axes accordingly to show the final UMI4C plot.

geoMeanCoordinates *Get geometric mean of given coordinates*

Description

Get geometric mean of given coordinates

Usage

```
geoMeanCoordinates(coords, scale, bait_start)
```

Arguments

coords	Vector of integers representing the coordinates from which to obtain the geometric mean.
scale	Vector of scales indicating how many fragment where merged.
bait_start	Integer indicating the coordinates for the bait start.

Value

Calculates geometric mean of the provided coordinates, taking into account the distance to the viewpoint and how many restriction fragments are being merged.

getColors *Get default colors*

Description

Get default colors

Usage

```
getColors(factors)
```

Arguments

factors	Name of the factors that will be used for grouping variables.

Value

Depending on the number of factors it creates different color palettes.

getFactors *Get factors fro plotting*

Description

Get factors fro plotting

Usage

```
getFactors(umi4c, grouping = NULL)
```

Arguments

umi4c	UMI4C object
grouping	Grouping used for the different samples. If none available or want to add new groupings, run addGrouping.

Value

Factor vector where the first element is the reference factor.

getNormalizationMatrix *Get normalization matrix*

Description

Will return a normalization matrix.

Usage

```
getNormalizationMatrix(
  umi4c,
  norm_bins = 10^(3:6),
  post_smooth_win = 50,
  r_expand = 1.2
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C.
norm_bins	Numeric vector with the genomic bins to use for normalization. Default: 1K, 10K, 100K, 1Mb.
post_smooth_win	Numeric indicating the smoothing window to use. Default: 50.
r_expand	Numeric indicanting the expansion value for normalization. Default: 1.2.

Value

Creates a matrix of normalization factors using as a reference the profile specified in the UMI4C object.

getSignInteractions *Get significant interactions from a GRangesList*

Description

Retrieves all significant interactions from the output of callInteractions.

Usage

```
getSignInteractions(gr_interactions)
```

Arguments

gr_interactions	GRangesList outputed by callInteractions.

Value

GRanges object with a list of significantly interacting regions.

Examples

```
data("ex_ciita_umi4c")
umi <- ex_ciita_umi4c
win_frags <- makeWindowFragments(umi, n_frags=8, sliding=1)

gr <- callInteractions(umi, ~condition, win_frags, padj_threshold = 0.01, zscore_threshold=2)
inter <- getSignInteractions(gr)
```

---

getViewpointCoordinates

Get viewpoint coordinates

Description

Finds the viewpoint coordinates for a given reference genome and sequence.

Usage

```
getViewpointCoordinates(
  bait_seq,
  bait_pad,
  res_enz,
  ref_gen,
  sel_seqname = NULL
)
```

Arguments

bait_seq	Character containing the bait primer sequence.
bait_pad	Character containing the pad sequence (sequence between the bait primer and the restriction enzyme sequence).
res_enz	Character containing the restriction enzyme sequence.
ref_gen	A BSgenome object of the reference genome.
sel_seqname	A character with the chromosome name to focus the search for the viewpoint sequence.

Value

Creates a GRanges object containing the genomic position of the viewpoint.

Examples

```
getViewpointCoordinates(
    bait_seq = "GGACAAGCTCCCTGCAACTCA",
    bait_pad = "GGACTTGCA",
    res_enz = "GATC",
    ref_gen = BSgenome.Hsapiens.UCSC.hg19::BSgenome.Hsapiens.UCSC.hg19,
    sel_seqname = "chr16" # Look only in chr16
)
```

`groupSamplesUMI4C` *Group UMI4C samples*

Description

Combines UMI4C samples by adding UMIs from `assay(umi4c)` to represent the levels in `grouping`.

Usage

```
groupSamplesUMI4C(umi4c, grouping = "condition")
```

Arguments

`umi4c`	UMI4C object as generated by `makeUMI4C`.
`grouping`	Name of the column in colData used to merge the samples or replicates. Set to NULL for skipping grouping. Default: "condition".

Value

A grouped `UMI4C` object.

`makeWindowFragments` *Make windows merging restriction fragments*

Description

Use a set of continuous restriction fragments to generate windows containing a fixed number of fragments (n_frags).

Usage

```
makeWindowFragments(input, n_frags = 8, sliding = 1)
```

Arguments

input	Input object containing the restriction fragments. Should be class UMI4C (rowRanges will be extracted) or class GRanges.
n_frags	Number of fragments to use for generating the windows. This should include restriction fragments with 0 counts (Default: 8).
sliding	Numeric indicating the factor for generating sliding windows. If set to 1 (default) will use fixed windows. If set to > 0 and < 1 will use n_frags * sliding fragments to generate sliding windows.

Value

A GRanges object containing the windows of merged restriction fragments.

Examples

```
data("ex_ciita_umi4c")

# Without sliding windows
win_frags <- makeWindowFragments(ex_ciita_umi4c, n_frags=30, sliding=1)
win_frags

# With sliding windows (n_frags*sliding)
win_frags <- makeWindowFragments(ex_ciita_umi4c, n_frags=30, sliding=0.5)
win_frags
```

---

nbinomWaldTestUMI4C *Differential UMI4C contacts using DESeq2 Wald Test*

Description

Takes the smooth monotone fit count values and infers the differential UMI4C contacts using DESeq2 Wald Test from DESeq2 package.

Usage

```
nbinomWaldTestUMI4C(dds, query_regions = NULL)
```

Arguments

dds	DDS object as generated by smoothMonotoneUMI4C with the smooth monotone fit counts
query_regions	GRanges object or data.frame containing the coordinates of the genomic regions you want to use to perform the analysis in specific genomic intervals. Default: NULL.

Details

This function back-transform fitted values to the scale of raw counts and scale them across the samples to obtain normalized factors using `normalizationFactors` from `DESeq2` package. To detect differences between conditions, the DESeq2

Value

DDS object with the DESeq2 Wald Test results, with results columns accessible with the `results` function.

`plotDifferential` *Plot differential contacts*

Description

Plot differential contacts

Usage

```
plotDifferential(umi4c, grouping = NULL, colors = NULL, xlim = NULL)
```

Arguments

`umi4c`	UMI4C object as generated by `makeUMI4C`.
`grouping`	Grouping used for the different samples. If none available or want to add new groupings, run `addGrouping`.
`colors`	Named vector of colors to use for plotting for each group.
`xlim`	Limits for the plot x axis (genomic coordinates).

Value

Produces a plot of the fold changes at the differential regions analyzed ghat are contained in the UMI4C object.

Examples

```
data("ex_ciita_umi4c")
ex_ciita_umi4c <- addGrouping(ex_ciita_umi4c, grouping="condition")

enh <- GRanges(c("chr16:10925006-10928900", "chr16:11102721-11103700"))
umi_dif <- fisherUMI4C(ex_ciita_umi4c, query_regions = enh,
                       filter_low = 20, resize = 5e3)
plotDifferential(umi_dif)
```

plotDomainogram *Plot domainogram*

Description

Plot domainogram

Usage

```
plotDomainogram(
  umi4c,
  dgram_function = "quotient",
  grouping = NULL,
  colors = NULL,
  xlim = NULL
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C.
dgram_function	Function used for calculating the fold-change in the domainogram plot, either "difference" or "quotient". Default: "quotient".
grouping	Grouping used for the different samples. If none available or want to add new groupings, run addGrouping.
colors	Named vector of colors to use for plotting for each group.
xlim	Limits for the plot x axis (genomic coordinates).

Value

Produces the domainogram plot, summarizing the merged number of UMIs at the different scales analyzed (y axis).

Examples

```
data("ex_ciita_umi4c")
ex_ciita_umi4c <- addGrouping(ex_ciita_umi4c, grouping="condition")

plotDomainogram(ex_ciita_umi4c, grouping = "condition")
```

plotGenes *Plot genes*

Description

Plot genes in a window of interest.

Usage

```
plotGenes(
  window,
  TxDb = TxDb.Hsapiens.UCSC.hg19.knownGene::TxDb.Hsapiens.UCSC.hg19.knownGene,
  OrgDb = "org.Hs.eg.db",
  longest = TRUE,
  xlim = NULL,
  font_size = 14
)
```

Arguments

window	GRanges-class object with coordinates to use for selecting the genes to plot.
TxDb	TxDb object to use for drawing the genomic annotation.
OrgDb	A character string for the name of an annotation element of an annotation data package.
longest	Logical indicating whether to plot only the longest transcripts for each gene in the gene annotation plot.
xlim	Limits for the plot x axis (genomic coordinates).
font_size	Base font size to use for the UMI4C plot. Default: 14.

Value

Produces a plot with the genes found in the provided window.

Examples

```
window <- GRanges("chr16:11348649-11349648")
plotGenes(
    window = window,
    TxDb = TxDb.Hsapiens.UCSC.hg19.knownGene::TxDb.Hsapiens.UCSC.hg19.knownGene
)
```

plotInteractions *Plot interactions*

Description

Plot the results of callInteractions.

Usage

```
plotInteractions(gr_interactions, xlim = NULL, significant = TRUE)
```

Arguments

gr_interactions	GRangesList outputed by callInteractions.
xlim	Limits for the plot x axis (genomic coordinates).
significant	Logical indicating whether to plot only significant interactions (default: TRUE).

Value

Produces a ggplot2 plot showing the queried interactions at each analysed sample.

plotInteractionsUMI4C *Plot Interactions UMI4C*

Description

Plot the results of callInteractions together with the gene annotation and the trend.

Usage

```
plotInteractionsUMI4C(
  umi4c,
  gr_interactions,
  grouping = "condition",
  significant = TRUE,
  colors = NULL,
  xlim = NULL,
  ylim = NULL,
  TxDb = TxDb.Hsapiens.UCSC.hg19.knownGene::TxDb.Hsapiens.UCSC.hg19.knownGene,
  longest = TRUE,
  rel_heights = c(0.25, 0.5, 0.25),
  font_size = 14
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C.
gr_interactions	GRangesList outputed by callInteractions.
grouping	Grouping used for the different samples. If none available or want to add new groupings, run addGrouping.
significant	Logical indicating whether to plot only significant interactions (default: TRUE).
colors	Named vector of colors to use for plotting for each group.
xlim	Limits for the plot x axis (genomic coordinates).
ylim	Limits of the trend y axis.
TxDb	TxDb object to use for drawing the genomic annotation.
longest	Logical indicating whether to plot only the longest transcripts for each gene in the gene annotation plot.
rel_heights	Numeric vector of length 3 or 4 (if differential plot) indicating the relative heights of each part of the UMI4C plot.
font_size	Base font size to use for the UMI4C plot. Default: 14.

Value

Combined plot with gene annotation, trend and interaction plot.

---

plotTrend *Plot adaptative smoothen trend*

Description

Plot adaptative smoothen trend

Usage

```
plotTrend(umi4c, grouping = NULL, colors = NULL, xlim = NULL, ylim = NULL)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C.
grouping	Grouping used for the different samples. If none available or want to add new groupings, run addGrouping.
colors	Named vector of colors to use for plotting for each group.
xlim	Limits for the plot x axis (genomic coordinates).
ylim	Limits of the trend y axis.

Value

Produces the adaptative trend plot, showing average UMIs at each position taking into account the minimum number of molecules used to merge restriction fragments.

Examples

```
data("ex_ciita_umi4c")

plotTrend(ex_ciita_umi4c)
```

`plotUMI4C` *Plot UMI4C data*

Description

Produce a UMI-4C data plot containing the genes in the region, the adaptative smoothen trend and the domainogram.

Usage

```
plotUMI4C(
  umi4c,
  grouping = "condition",
  dgram_function = "quotient",
  dgram_plot = TRUE,
  colors = NULL,
  xlim = NULL,
  ylim = NULL,
  TxDb = TxDb.Hsapiens.UCSC.hg19.knownGene::TxDb.Hsapiens.UCSC.hg19.knownGene,
  OrgDb = "org.Hs.eg.db",
  longest = TRUE,
  rel_heights = c(0.25, 0.4, 0.12, 0.23),
  font_size = 14
)
```

Arguments

`umi4c`	UMI4C object as generated by `makeUMI4C`.
`grouping`	Grouping used for the different samples. If none available or want to add new groupings, run `addGrouping`.
`dgram_function`	Function used for calculating the fold-change in the domainogram plot, either "difference" or "quotient". Default: "quotient".
`dgram_plot`	Logical indicating whether to plot the domainogram. If the UMI4C object only contains one sample will be automatically set to FALSE. Default: TRUE.
`colors`	Named vector of colors to use for plotting for each group.
`xlim`	Limits for the plot x axis (genomic coordinates).

ylim	Limits of the trend y axis.
TxDb	TxDb object to use for drawing the genomic annotation.
OrgDb	A character string for the name of an annotation element of an annotation data package.
longest	Logical indicating whether to plot only the longest transcripts for each gene in the gene annotation plot.
rel_heights	Numeric vector of length 3 or 4 (if differential plot) indicating the relative heights of each part of the UMI4C plot.
font_size	Base font size to use for the UMI4C plot. Default: 14.

Value

Produces a summary plot with all the information contained in the UMI4C opject.

Examples

```
data("ex_ciita_umi4c")
ex_ciita_umi4c <- addGrouping(ex_ciita_umi4c, grouping="condition")

plotUMI4C(ex_ciita_umi4c,
    dgram_plot = FALSE,
    TxDb = TxDb.Hsapiens.UCSC.hg19.knownGene::TxDb.Hsapiens.UCSC.hg19.knownGene,
    OrgDb = "org.Hs.eg.db"
)
```

---

prepUMI4C *Prepare UMI4C data*

Description

Prepare the FastQ files for the further analysis by selecting reads with bait and adding the respective UMI identifier for each read in its header.

Usage

```
prepUMI4C(
  fastq_dir,
  wk_dir,
  file_pattern = NULL,
  bait_seq,
  bait_pad,
  res_enz,
  numb_reads = 1e+09
)
```

Arguments

fastq_dir	Path of the directory containing the FastQ files (compressed or uncompressed).
wk_dir	Working directory where to save the outputs generated by the UMI-4c analysis.
file_pattern	Character that can be used to filter the files you want to analyze in the fastq_dir.
bait_seq	Character containing the bait primer sequence.
bait_pad	Character containing the pad sequence (sequence between the bait primer and the restriction enzyme sequence).
res_enz	Character containing the restriction enzyme sequence.
numb_reads	Number of lines from the FastQ file to load in each loop. If having memory size problems, change it to a smaller number. Default=1e9.

Value

Creates a compressed FASTQ file in wk_dir/prep named basename(fastq)).fq.gz, containing the filtered reads with the UMI sequence in the header. A log file with the statistics is also generated in wk_dir/logs named umi4c_stats.txt.

See Also

contactsUMI4C.

Examples

```
if (interactive()) {
path <- downloadUMI4CexampleData(reduced = TRUE)
raw_dir <- file.path(path, "CIITA", "fastq")

prepUMI4C(
    fastq_dir = raw_dir,
    wk_dir = file.path(path, "CIITA"),
    bait_seq = "GGACAAGCTCCCTGCAACTCA",
    bait_pad = "GGACTTGCA",
    res_enz = "GATC"
)
}
```

---

smoothMonotoneUMI4C *Monotone smoothing of the DDS object VST counts*

Description

Takes the variance stabilized count values and calculates a symmetric monotone fit for the distance dependency. The signal trend is fitted using the fda package. The position information about the viewpoint have to be stored in the metadata as metadata(dds)[['bait']].

Usage

```
smoothMonotoneUMI4C(dds, alpha = 20, penalty = 0.1)
```

Arguments

dds	DDS object as generated by vstUMI4C with the variance stabilized count values.
alpha	Approximate number of fragments desired for every basis function of the B-spline basis. floor((max(number of fragments)) / alpha) is passed to create.bspline.basis as nbasis argument. 4 is the minimum allowed value. Default: 20.
penalty	Amount of smoothing to be applied to the estimated functional parameter. Default: 0.1.

Details

This function computes the smoothing function for the VST values, based on fda package, and calculates a symmetric monotone fit counts for the distance dependency

Value

DDS object with monotone smoothed fit counts.

---

splitUMI4C *Split UMI4C reads*

Description

Split the prepared reads using the restrition enzyme information.

Usage

```
splitUMI4C(wk_dir, res_enz, cut_pos, numb_reads = 1e+09, min_flen = 20)
```

Arguments

wk_dir	Working directory where to save the outputs generated by the UMI-4c analysis.
res_enz	Character containing the restriction enzyme sequence.
cut_pos	Numeric indicating the nucleotide position where restriction enzyme cuts (zero-based) (for example, for DpnII is 0).
numb_reads	Number of lines from the FastQ file to load in each loop. If having memory size problems, change it to a smaller number. Default=1e9.
min_flen	Minimal fragment length to use for selecting the fragments. Default=20

Value

Creates a compressed FASTQ file in wk_dir/split named basename(fastq)).fq.gz, containing the split reads based on the restriction enzyme used.

Examples

```
if (interactive()) {
path <- downloadUMI4CexampleData(reduced = TRUE)

splitUMI4C(
    wk_dir = file.path(path, "CIITA"),
    res_enz = "GATC",
    cut_pos = 0
)
}
```

`statsUMI4C` *Statistics UMI4C*

Description

Creates a stats summary file and generates a summary plot describing statistics for processed UMI-4C samples.

Usage

```
statsUMI4C(wk_dir)
```

Arguments

`wk_dir`	Working directory where to save the outputs generated by the UMI-4c analysis.

Value

Returns a plot summarizing the main statistics of the processed UMI-4C experiments found in `wk_dir`. Also, writes a file named `stats_summary.txt` in `wk_dir/logs` that summarizes all the values represented in the plot.

Examples

```
statsUMI4C(wk_dir = system.file("extdata", "CIITA",
    package = "UMI4Cats"
))
stats <- read.delim(system.file("extdata", "CIITA", "logs", "stats_summary.txt",
    package = "UMI4Cats"
))
head(stats)
```

theme *Theme*

Description

Theme

Usage

```
theme(...)
```

Arguments

...	Additional arguments to pass to the theme call from ggplot2.

Value

ggplot2 theme.

Examples

```
library(ggplot2)

ggplot(
    iris,
    aes(Sepal.Length, Sepal.Width)
) +
    geom_point() +
    theme()
```

themeXblank *Theme X blank*

Description

Theme X blank

Usage

```
themeXblank(...)
```

Arguments

...	Additional arguments to pass to the theme call from ggplot2.

Value

ggplot2 theme with a blank X axis.

Examples

```
library(ggplot2)

ggplot(
    iris,
    aes(Sepal.Length, Sepal.Width)
) +
    geom_point() +
    themeXblank()
```

`themeXYblank` *Theme Y blank*

Description

Theme Y blank

Usage

```
themeXYblank(...)
```

Arguments

`...`	Additional arguments to pass to the theme call from ggplot2.

Value

ggplot2 theme with a blank X and Y axis.

Examples

```
library(ggplot2)

ggplot(
    iris,
    aes(Sepal.Length, Sepal.Width)
) +
    geom_point() +
    themeXYblank()
```

themeYblank *Theme Y blank*

Description

Theme Y blank

Usage

```
themeYblank(...)
```

Arguments

...	Additional arguments to pass to the theme call from ggplot2.

Value

ggplot2 theme with a blank Y axis.

Examples

```
library(ggplot2)

ggplot(
    iris,
    aes(Sepal.Length, Sepal.Width)
) +
    geom_point() +
    themeYblank()
```

UMI4C *UMI4C-class*

Description

The UMI4C constructor is the function makeUMI4C. By using the arguments listed below, performs the necessary steps to analyze UMI-4C data and summarize it in an object of class UMI4C.

Usage

```
makeUMI4C(
  colData,
  viewpoint_name = "Unknown",
  grouping = "condition",
  normalized = TRUE,
  ref_umi4c = NULL,
  bait_exclusion = 3000,
```

```
  bait_expansion = 1e+06,
  scales = 5:150,
  min_win_factor = 0.02,
  sd = 2
)
```

Arguments

colData	Data.frame containing the information for constructing the UMI4C experiment object. Needs to contain the following columns: • sampleID. Unique identifier for the sample. • condition. Condition for performing differential analysis. Can be control and treatment, two different cell types, etc. • replicate. Number for identifying replicates. • file. File as outputed by `umi4CatsContacts` function.
viewpoint_name	Character indicating the name for the used viewpoint.
grouping	Name of the column in colData used to merge the samples or replicates. Set to NULL for skipping grouping. Default: "condition".
normalized	Logical indicating whether UMI-4C profiles should be normalized to the `ref_umi4c` sample/group. Default: TRUE
ref_umi4c	Name of the sample or group to use as reference for normalization. By default is NULL, which means it will use the sample with less UMIs in the analyzed region. It should be a named vector, where the name corresponds to the grouping column from `colData` and the value represents the level to use as reference.
bait_exclusion	Region around the bait (in bp) to be excluded from the analysis. Default: 3000bp.
bait_expansion	Number of bp upstream and downstream of the bait to use for the analysis (region centered in bait). Default: 1Mb.
scales	Numeric vector containing the scales for calculating the domainogram.
min_win_factor	Proportion of UMIs that need to be found in a specific window for adaptative trend calculation
sd	Stantard deviation for adaptative trend.

Value

It returns an object of the class UMI4C.

Slots

`colData` Data.frame containing the information for constructing the UMI4C experiment object. Needs to contain the following columns:

- `sampleID`: Unique identifier for the sample.
- `condition`: Condition for performing differential analysis. Can be control and treatment, two different cell types, etc.
- `replicate`: Number or ID for identifying different replicates.
- `file`: Path to the files outputed by `contactsUMI4C`.

`rowRanges` GRanges-class object with the coordinates for the restriction fragment ends, their IDs and other additional annotation columns.

`metadata` List containing the following elements:

1. `bait`: GRanges-class object representing the position of the bait used for the analysis.
2. `scales`: Numeric vector containing the scales used for calculating the domainogram.
3. `min_win_factor`: Factor for calculating the minimum molecules requiered in a window for not merging it with the next one when calculating the adaptative smoothing trend.
4. `grouping`: Columns in `colData` used for the different sample groupings, accessible through `groupsUMI4C`.
5. `normalized`: Logical indicating whether samples/groups are normalized or not.
6. `region`: GRanges-class with the coordinates of the genomic window used for analyzing UMI4C data.
7. `ref_umi4c`: Name of the sample or group used as reference for normalization.

`assays` Matrix where each row represents a restriction fragment site and columns represent each sample or group defined in `grouping`. After running the `makeUMI4C` function, it will contain the following data:

1. `umis`: Raw number of UMIs detected by `contactsUMI4C`.
2. `norm_mat`: Normalization factors for each sample/group and fragment end.
3. `trend`: Adaptative smoothing trend of UMIs.
4. `geo_coords`: Geometric coordinates obtained when performing the adaptative smoothing.
5. `scale`: Scale selected for the adaptative smoothing.
6. `sd`: Stantard deviation for the adaptative smoothing trend.

`dgram` List containing the domainograms for each sample. A domainogram is matrix where columns are different scales selected for merging UMI counts and rows are the restriction fragments.

`groupsUMI4C` List of `UMI4C` objects with the specific groupings.

`results` List containing the results for the differential analysis ran using `fisherUMI4C`.

Note

The `UMI4C` class extends the SummarizedExperiment class.

See Also

UMI4C-methods

Examples

```
# Load sample processed file paths
files <- list.files(system.file("extdata", "CIITA", "count",
    package = "UMI4Cats"
),
pattern = "*_counts.tsv",
full.names = TRUE
)
```

```
# Create colData including all relevant information
colData <- data.frame(
    sampleID = gsub("_counts.tsv.gz", "", basename(files)),
    file = files,
    stringsAsFactors = FALSE
)

library(tidyr)
colData <- colData |>
    separate(sampleID,
        into = c("condition", "replicate", "viewpoint"),
        remove = FALSE
    )

# Load UMI-4C data and generate UMI4C object
umi <- makeUMI4C(
    colData = colData,
    viewpoint_name = "CIITA",
    grouping = "condition"
)
```

`UMI4C2dds` *UMI4Cats object to DDS object.*

Description

Transforms an UMI4C object to a DDS object

Usage

```
UMI4C2dds(umi4c, design = ~condition)
```

Arguments

`umi4c`	UMI4C object as generated by `makeUMI4C` or the `UMI4C` constructor.
`design`	A `formula` or `matrix`. The formula expresses how the counts for each fragment end depend on the variables in `colData`. See `DESeqDataSet`.

Value

DDS object.

UMI4Cats *UMI4Cats: A package for analyzing UMI-4C chromatin contact data*

Description

The UMI4Cats package provides functions for the pre-processing, analysis and visualization of UMI-4C chromatin contact data.

File preparation

There are two different functions that can be used to prepare the files for analyzing them with UMI4Cats:

1. `demultiplexFastq`. Demultiplex reads belonging to different viewpoints from a paired-end FastQ file.
2. `digestGenome`. Digest the reference genome of choice using a given restriction sequence.

Processing

The pre-processing functions are wrapped in the `contactsUMI4C` main function. This function will sequentially run the following steps:

1. `prepUMI4C`. Filter specific and high quality reads.
2. `splitUMI4C`. Split reads by the restriction sequence.
3. `alignmentUMI4C`. Align reads to the reference genome.
4. `counterUMI4C`. Apply UMI counting algorithm to quantify the interactions with the viewpoint.

The statistics from the samples analyzed with the `contactsUMI4C` function can be extracted and visualized with the function `statsUMI4C`.

Analysis

The analysis of UMI-4C data is wrapped in the construction of an object of UMI4C class by the creator function `makeUMI4C`. This function will group your samples according to the variable you provided in the `grouping` argument (default: "condition") and then normalize it to `ref_umi4c`.

Significant interactions with the viewpoint can be called when several replicates are available, using the `callInteractions` function. A set of `query_regions`, such as enhancers or open chromatin regions needs to be provided. When no candidate regions are available, one can use the function `makeWindowFragments` to join a fixed number of restriction fragments into windows. The results of this analysis can be visualized using `plotInteractionsUMI4C` and the list of significant interactions can be retrieved using `getSignInteractions`.

The differential analysis can be performed with `fisherUMI4C` or `waldUMI4C` functions and can be focused in a set of regions of interest by providing the `query_regions` argument. Both will return a UMI4C object containing the results of the differential test. You can access these results with the method `resultsUMI4C`.

Visualization

An integrative plot showing the results stored inside the UMI4C object can be generated with the function `plotUMI4C`.

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See Also

Useful links:

- https://github.com/Pasquali-lab/UMI4Cats
- Report bugs at https://github.com/Pasquali-lab/UMI4Cats/issues

---

vstUMI4C *Variance stabilizing transformation*

Description

Using a DDS object performs a variance stabilizing transformation from DESeq2 package to the UMI4C counts

Usage

```
vstUMI4C(dds)
```

Arguments

dds	DDS object generated by `UMI4C2dds`

Details

This function estimate the size factors and dispersions of the counts base on `DESeq` for infering the VST distribution and transform raw UMI4C counts.

Value

DDS object with variance stabilizing transformation counts

waldUMI4C *DESeq2 Wald test for differential contacts*

Description

Using a UMI4C object, infers the differences between conditions specified in design using a Wald Test from DESeq2 package.

Usage

```
waldUMI4C(
  umi4c,
  query_regions = NULL,
  subset = "sum",
  design = ~condition,
  normalized = TRUE,
  padj_method = "fdr",
  padj_threshold = 0.05
)
```

Arguments

umi4c	UMI4C object as generated by makeUMI4C or the UMI4C constructor.
query_regions	GRanges object containing the coordinates of the genomic regions you want to use to perform the analysis in specific genomic intervals. Default: NULL.
subset	If query_regions are provided, how to subset the UMI4C object: "sum" for summing raw UMIs in fragments overlapping query_regions (default) or "overlap" for selecting overlapping fragments.
design	A formula or matrix. The formula expresses how the counts for each fragment end depend on the variables in colData. See DESeqDataSet.
normalized	Logical indicating if the function should return normalized or raw UMI counts. Default: TRUE.
padj_method	The method to use for adjusting p-values, see p.adjust. Default: fdr.
padj_threshold	Numeric indicating the adjusted p-value threshold to use to define significant differential contacts. Default: 0.05.

Value

UMI4C object with the DESeq2 Wald Test results, which can be accessed using resultsUMI4C.

Examples

```
data("ex_ciita_umi4c")

umi_dif <- waldUMI4C(ex_ciita_umi4c)
```

zscoreUMI4C *Z-score calculation using residuals of trend and fit UMI4C counts*

Description

Calculates the z-score and then they are converted into one-sided P-values and adjusted for multiple testing using the method of Benjamini and Hochberg

Usage

```
zscoreUMI4C(
  dds,
  padj_method = "fdr",
  zscore_threshold = 2,
  padj_threshold = 0.1
)
```

Arguments

dds	DDS object as generated by smoothMonotoneUMI4C with the smooth monotone fit counts
padj_method	The method to use for adjusting p-values, see p.adjust. Default: fdr.
zscore_threshold	Numeric indicating the z-score threshold to use to define significant differential contacts. Default: 2.
padj_threshold	Numeric indicating the adjusted p-value threshold to use to define significant differential contacts. Default: 0.1.

Details

This function calculates the z-score for each fragment over all samples from the residuals of the symmetric monotone fit and the median absolute deviation (mad). Z-scores are then converted into one-sided P-values using the standard Normal cumulative distribution function, and these are adjusted for multiple testing using the method of Benjamini and Hochberg

Value

DDS object with zscore,pvalue and padjusted assays

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