Package: DAMEfinder (via r-universe)

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Type Package

Title Finds DAMEs - Differential Allelicly MEthylated regions

Version 1.25.0

Description 'DAMEfinder' offers functionality for taking methtuple or bismark outputs to calculate ASM scores and compute DAMEs. It also offers nice visualization of methyl-circle plots.

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`calc_asm` *Calculate ASM Score*

Description

This function takes in a list of samples resulting from the read_tuples function and returns a SummarizedExperiment of Allele-Specific Methylation (ASM) scores, where each row is a tuple and each column is a sample.

Usage

```
calc_asm(
  sampleList,
  beta = 0.5,
  a = 0.2,
  transform = modulus_sqrt,
  coverage = 5,
  verbose = TRUE
)
```

Arguments

sampleList	List of samples returned from read_tuples
beta	The beta parameter used to calculate the weight in the ASM score. link{calc_weight} uses this parameter to penalize fully methylated or unmethylated tuples. Default = 0.5.
a	The distance from 0.5 allowed, where 0.5 is a perfect MM:UU balance for a tuple. In the default mode this value is set to 0.2, and we account for the instances where the balance is between 0.3 and 0.7.
transform	Transform the calculated tuple ASM scores. We use the modulus square root function which outputs the square root, while preserving the original sign.
coverage	Remove tuples with total reads below coverage. Default = 5.
verbose	If the function should be verbose. Default = TRUE.

Details

Calculates ASM score for a list of samples in the output format of the result of read_tuples This functions uses the following other functions: process, calcScore, calcWeight.

Value

A SummarizedExperiment of ASM scores where the rows are all the tuples and the columns the sample names.

Examples

```
DATA_PATH_DIR <- system.file('extdata', '.', package = 'DAMEfinder')
get_data_path <- function(file_name) file.path(DATA_PATH_DIR, file_name)

tuple_files <- list.files(DATA_PATH_DIR, '.tsv.gz')
tuple_files <- get_data_path(tuple_files)
ASM <- read_tuples(tuple_files, c('CRC1', 'NORM1'))
ASMscore <- calc_asm(ASM)
```

---

calc_derivedasm *Calculate SNP-based ASM*

Description

Combines all the GRangeslist generated in extract_bams into a RangedSummarizedExperiment object, and calculates SNP-based allele-specific methylation.

Usage

```
calc_derivedasm(sampleList, cores = 1, verbose = TRUE)
```

Arguments

sampleList	List of samples returned from extract_bams.
cores	Number of cores to thread.
verbose	If the function should be verbose.

Value

RangedSummarizedExperiment containing in assays:

- der.ASM: matrix with SNP-based ASM
- snp.table: Matrix with SNP associated to the CpG site.
- ref.cov: Coverage of the 'reference' allele.
- alt.cov: Coevarage of the 'alternative' allele.
- ref.meth: Methylated reads from the 'reference' allele.
- alt.meth: Methylated reads from the 'alternative' allele.

Examples

```
data(extractbams_output)
derASM <- calc_derivedasm(extractbams_output[c(1,2)], cores = 1,
   verbose = FALSE)
```

---

calc_logodds *Calculate the log odds ratio*

Description

This function calculates the log odds ratio for a CpG tuple: (MM*UU)/(UM*MU), where 'M' stands for methylated and 'U' for unmethylated. 'MM' reflects the count for instances the CpG pair is methylated at both positions. The higher the MM and UU counts for that CpG pair, the higher the log odds ratio.

Usage

```
calc_logodds(s, eps = 1)
```

Arguments

s	A data frame that contains the MM,UU,UM, and MU counts for each CpG tuple for a particular sample. It is the resulting object of the read_tuples.
eps	Count added to each of the MM,UU,UM and MU counts to avoid dividing by zero for example. The default is set to 1.

Value

The same object is returned with an additional column for the log odds ratio.

`calc_score` *Calculate score*

Description

This function calculates the ASM score for every tuple in a given sample. The ASM score is a multiplication of the log odds ratio by a weight that reflects the extent of allele-specific methylation. This weight is obtained with the `calc_weight` function.

Usage

```
calc_score(df, beta = 0.5, a = 0.2)
```

Arguments

`df`	data frame of a sample containing all information per tuple (MM,UU,UM and MU counts, as well as the log odds ratio per tuple) needed for the ASM score.
`beta`	parameter for the `calc_weight` function. It's the alpha and beta values for the Beta function.
`a`	parameter for the calc_weight function. The weight will be the probability that the MM/(MM+UU) ratio lies between 0.5-a and 0.5+a.

Details

This function returns an allele-specific methylation (ASM) score for every given tuple in a sample. The ASM score is a product of the log odds ratio and a weight reflecting a measure of allele-specificity using the MM and UU counts.

Value

The same object with an additional column for the ASM score.

`calc_weight` *Calculate Weight for ASM Score*

Description

This function calculates a weight which reflects MM to UU balance, where M stands for methylated and U for unmethylated. Given the MM and UU counts for a particular tuple, the weight is obtained using the `link{pbeta}` function.

Usage

```
calc_weight(MM, UU, beta = 0.5, a = 0.2)
```

Arguments

MM	The read counts for where pos1 and pos2 of the tuple were both methylated.
UU	The read counts for where pos1 and pos2 of the tuple were both unmethylated.
beta	parameter for the beta distribution. In B(alpha,beta), we set alpha=beta=0.5 by default.
a	parameter for how far from 0.5 we go as a measure of allele-specific methylation. The weight is the probability that the MM:(MM+UU) ratio is between 0.5-a and 0.5+a. The default is set to 0.2.

Details

For a given tuple with MM and UU counts, the weight that reflects allele-scpecificity is calculated as follows:

- Prior:

$$p(\theta|\alpha,\beta) \sim Beta(\alpha,\beta),$$

where $\theta = \frac{MM}{MM+UU}$ and $\alpha = \beta = 0.5$. $p(\theta|\alpha,\beta)$ represents our prior belief which is that tuples are either fully methylated or fully unmethylated, rather than allele-specifically methylated which is a much rarer event.

- Likelihood:

$$p(x|\alpha,\beta) \propto \theta^{MM}(1-\theta)^{UU},$$

where x is our observation (the MM and UU counts).

- Posterior:

$$p(\theta|x) \propto p(x|\theta) * p(\theta|\alpha,\beta)$$

$$p(\theta|x) \propto \theta^{MM-0.5}(1-\theta)^{UU-0.5},$$

where $\alpha = \beta = 0.5$. This posterior also follows a beta distribution $\sim Beta(\alpha' = MM + 0.5, \beta' = UU + 0.5)$

Value

A number that reflects allele-specificity given MM and UU counts for a CpG pair. This is used as a weight that is multiplied by the log odds ratio to give the final ASM score of that tuple.

#calc_weight(MM=50, UU=50) #0.9999716

#calc_weight(MM=20, UU=60) #0.1646916

dame_track *Plot score tracks*

Description

Plot score tracks

Usage

```
dame_track(
  dame,
  window = 0,
  positions = 0,
  derASM = NULL,
  ASM = NULL,
  colvec = NULL,
  plotSNP = FALSE
)
```

Arguments

dame	GRanges object containing a region of interest, or detected with find_dames
window	Number of CpG sites outside (up or down-stream) of the DAME should be plotted. Default = 0.
positions	Number of bp sites outside (up or down-stream) of the DAME should be plotted. Default = 0.
derASM	SummarizedExperiment object obtained from calc_derivedasm (Filtering should be done by the user)
ASM	SummarizedExperiment object obtained from calc_asm (Filtering should be done by the user)
colvec	Vector of colors (mainly useful for the SNP plot, because I add it with cowplot, so I don't export a ggplot, optional)
plotSNP	whether to add the SNP track, only if derASM is specified. Default = FALSE

Value

Plot

Examples

```
library(GenomicRanges)
DAME <- GRanges(19, IRanges(306443,310272))
data('readtuples_output')
ASM <- calc_asm(readtuples_output)
SummarizedExperiment::colData(ASM)$group <- c(rep('CRC',3),rep('NORM',2))
SummarizedExperiment::colData(ASM)$samples <- colnames(ASM)
```

```
dame_track(dame = DAME,
           ASM = ASM)
```

`dame_track_mean` *Plot means per group of score tracks.*

Description

Plot means per group of score tracks.

Usage

```
dame_track_mean(
  dame,
  window = 0,
  positions = 0,
  derASM = NULL,
  ASM = NULL,
  colvec = NULL
)
```

Arguments

`dame`	GRanges object containing a region of interest, or detected with find_dames
`window`	Number of CpG sites outside (up or down-stream) of the DAME should be plotted. Default = 0.
`positions`	Number of bp sites outside (up or down-stream) of the DAME should be plotted. Default = 0.
`derASM`	SummarizedExperiment object obtained from calc_derivedasm (Filtering should be done by the user)
`ASM`	SummarizedExperiment object obtained from calc_asm (Filtering should be done by the user)
`colvec`	Vector of colors (mainly useful for the SNP plot, because I add it with cowplot, so I don't export a ggplot, optional)

Value

Plot

Examples

```
library(GenomicRanges)
DAME <- GRanges(19, IRanges(306443,310272))
data('readtuples_output')
ASM <- calc_asm(readtuples_output)
SummarizedExperiment::colData(ASM)$group <- c(rep('CRC',3),rep('NORM',2))
SummarizedExperiment::colData(ASM)$samples <- colnames(ASM)
dame_track_mean(dame = DAME,
                ASM = ASM)
```

`DAMEfinder` *DAMEfinder: Method to detect allele-specific methylation (ASM), and differential ASM from Bisulfite sequencing data in R.*

Description

The package allows the user to extract an ASM score in two ways: either from a `bismark` bam file(s) and VCF file(s), or from the output from `methtuple`. Either way the final output is a list of regions with diferential allele-specific methylated between groups of samples of interest. The package also provides functions to visualize ASM at the read level or the score level

DAMEfinder functions

`calc_asm` extracts ASM for pairs of CpG sites from a methtuple file, `calc_derivedasm` extracts ASM at each CpG site linked to a SNP from the VCF file. Both functions generate a `RangedSummarizedExperiment`, which is the input for the main function `find_dames`, that generates a `data.frame` with regions exhibiting differential ASM between a number of samples.

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`extract_bams` *Detect allele-specific methylation from a bam file*

Description

The function takes a bam (from bismark) and vcf file for each sample. For each SNP contained in the vcfile it calculates the proportion of methylated reads for each CpG site at each allele. At the end it returns (saves to working directory) a GRanges list, where each GRanges contains all the CpG sites overlapping the reads containing a specific SNP.

Usage

```
extract_bams(
  bamFiles,
  vcfFiles,
  sampleNames,
  referenceFile,
  coverage = 4,
  cores = 1,
  verbose = TRUE
)
```

Arguments

bamFiles	List of bam files.
vcfFiles	List of vcf files.
sampleNames	Names of files in the list.
referenceFile	fasta file used to generate the bam files. Or DNAStringSet with DNA sequence.
coverage	Minimum number of reads covering a CpG site on each allele. Default = 2.
cores	Number of cores to use. See package parallel for description of core. Default = 1.
verbose	Default = TRUE

Value

A list of GRanges for each sample. Each list is saved in a separate .rds file.

Examples

```
DATA_PATH_DIR <- system.file('extdata', '.', package = 'DAMEfinder')
get_data_path <- function(file_name) file.path(DATA_PATH_DIR, file_name)
bamFiles <- get_data_path('NORM1_chr19_trim.bam')
vcfFiles <- get_data_path('NORM1.chr19.trim.vcf')
sampleNames <- 'NORM1'

#referenceFile
suppressPackageStartupMessages({library(BSgenome.Hsapiens.UCSC.hg19)})
genome <- BSgenome.Hsapiens.UCSC.hg19
seqnames(genome) <- gsub("chr","",seqnames(genome))
dna <- DNAStringSet(genome[[19]], use.names = TRUE)
names(dna) <- 19

GRanges_list <- extract_bams(bamFiles, vcfFiles, sampleNames, dna)
```

extractbams_output *extract_bams() output.*

Description

4 Patients from a previous study (Parker et al, 2018.) with colorectal cancer were sequenced and the normal and cancerous tissue of each patient was obtained. The data includes a subset of chromosome 19.

Usage

```
extractbams_output
```

Format

A large list with 8 elements. Each element is a list of `GRanges` for each sample. Each GRanges in the list includes the location of the CpG sites contained in the reads for each SNP. The GRanges metadata table contains:

`cov.ref` Number of reads of "reference" allele in that SNP

`cov.alt` Number of reads of "alternative" allele in that SNP

`meth.ref` Number of methylated reads of "reference" allele in that SNP

`cov.ref` Number of methylated reads of "alternative" allele in that SNP

`snp` The SNP containing the reads

For further details, see https://www.ebi.ac.uk/arrayexpress/experiments/E-MTAB-6949/ sample names in in ArrayExpress do not necessarily match names given here!

find_dames *Find DAMEs*

Description

This function finds Differential Allele-specific MEthylated regions (DAMEs). It uses the `regionFinder` function from `bumphunter`, and asigns p-values either empirically or using the Simes method.

Usage

```
find_dames(
  sa,
  design,
  coef = 2,
  contrast = NULL,
  smooth = TRUE,
  Q = 0.5,
```

```
  pvalAssign = "simes",
  maxGap = 20,
  verbose = TRUE,
  maxPerms = 10,
  method = "ls",
  trend = FALSE,
  ...
)
```

Arguments

sa	A SummarizedExperiment containing ASM values where each row correspond to a tuple/site and a column to sample/replicate.
design	A design matrix created with model.matrix.
coef	Column in design specifying the parameter to estimate. Default = 2.
contrast	a contrast matrix, generated with makeContrasts.
smooth	Whether smoothing should be applied to the t-Statistics. Default = TRUE.
Q	The percentile set to get a cutoff value K. K is the value on the Qth quantile of the absolute values of the given (smoothed) t-statistics. Only necessary if pvalAssign = 'empirical'. Default = 0.5.
pvalAssign	Choose method to assign pvalues, either 'simes' (default) or 'empirical'. This second one performs maxPerms number of permutations to calculate null statistics, and runs regionFinder.
maxGap	Maximum gap between CpGs in a cluster (in bp). NOTE: Regions can be as small as 1 bp. Default = 20.
verbose	If the function should be verbose. Default = TRUE.
maxPerms	Maximum possible permutations generated. Only necessary if pvalAssign = 'empirical'. Default = 10.
method	The method to be used in limma's lmFit. The default is set to 'ls' but can also be set to 'robust', which is recommended on a real data set.
trend	Passed to eBayes. Should an intensity-trend be allowed for the prior variance? Default is that the prior variance is constant, e.g. FALSE.
...	Arguments passed to get_tstats.

Details

The simes method has higher power to detect DAMEs, but the consistency in signal across a region is better controlled with the empirical method, since it uses regionFinder and getSegments to find regions with t-statistics above a cuttof (controled with parameter Q), whereas with the 'simes' option, we initially detects clusters of CpG sites/tuples, and then test if at least 1 differential site/tuple is present in the cluster.

We recommend trying out different maxGap and Q parameters, since the size and the effect-size of obtained DAMEs change with these parameters.

Value

A data frame of detected DAMEs ordered by the p-value. Each row is a DAME and the following information is provided in the columns (some column names change depending on the `pvalAssign` choice):

- chr: on which chromosome the DAME is found.
- start: The start position of the DAME.
- end: The end position of the DAME.
- pvalSimes: p-value calculated with the Simes method.
- pvalEmp: Empirical p-value obtained from permuting covariate of interest.
- sumTstat: Sum of t-stats per segment/cluster.
- meanTstat: Mean of t-stats per segment/cluster.
- segmentL: Size of segmented cluster (from `getSegments`).
- clusterL: Size of original cluster (from `clusterMaker`).
- FDR: Adjusted p-value using the method of Benjamini, Hochberg. (from `p.adjust`).
- numup: Number of sites with ASM increase in cluster (only for Simes).
- numdown: Number of sites with ASM decrease in cluster (only for Simes).

Examples

```
data(readtuples_output)
ASM <- calc_asm(readtuples_output)
grp <- factor(c(rep('CRC',3),rep('NORM',2)), levels = c('NORM', 'CRC'))
mod <- model.matrix(~grp)
dames <- find_dames(ASM, mod, verbose = FALSE)
```

`get_tstats` *Get t-Statistics*

Description

This function calculates a moderated t-Statistic per site or tuple using `limma`'s `lmFit` and `eBayes` functions. It then smoothes the obtained t-Statistics using `bumphunter`'s `smoother` function.

Usage

```
get_tstats(
  sa,
  design,
  contrast = NULL,
  method = "ls",
  trend = FALSE,
  smooth = FALSE,
```

```
  maxGap = 20,
  coef = 2,
  verbose = TRUE,
  filter = TRUE,
  ...
)
```

Arguments

sa	A SummarizedExperiment containing ASM values where each row and column correspond to a tuple/site and sample respectively.
design	a design matrix created with model.matrix.
contrast	a contrast matrix, generated with makeContrasts.
method	The method to be used in limma's lmFit. The default is set to 'ls' but can also be set to 'robust', which is recommended on a real data set.
trend	Passed to eBayes. Should an intensity-trend be allowed for the prior variance? Default is that the prior variance is constant, e.g. FALSE.
smooth	Whether smoothing should be applied to the t-Statistics. Default = FALSE. If TRUE, wherever smoothing is not possible, the un-smoothed t-stat is used instead.
maxGap	The maximum allowed gap between genomic positions for clustering of genomic regions to be used in smoothing. Default = 20.
coef	Column in model.matrix specifying the parameter to estimate. Default = 2. If contrast specified, column with contrast of interest.
verbose	Set verbose. Default = TRUE.
filter	Remove empty tstats. Default = TRUE.
...	Arguments passed to loessByCluster. Only used if smooth = TRUE.

Details

The smoothing is done on genomic clusters consisting of CpGs that are close to each other. In the case of tuples, the midpoint of the two genomic positions in each tuple is used as the genomic position of that tuple, to perform the smoothing.The function takes a RangedSummarizedExperiment generated by calc_derivedasm or calc_asm containing ASM across samples, and the index of control and treatment samples.

Value

A vector of t-Statistics within the RangedSummarizedExperiment.

Examples

```
data(readtuples_output)
ASM <- calc_asm(readtuples_output)
grp <- factor(c(rep('CRC',3),rep('NORM',2)), levels = c('NORM', 'CRC'))
mod <- model.matrix(~grp)
tstats <- get_tstats(ASM, mod)
```

`methyl_circle_plot` *Draw methylation circle plot*

Description

Draws CpG site methylation status as points, in reads containing a specific SNP. Generates one plot per bam file.

Usage

```
methyl_circle_plot(
  snp,
  vcfFile,
  bamFile,
  refFile,
  build = "hg19",
  dame = NULL,
  letterSize = 2.5,
  pointSize = 3,
  sampleName = "sample1",
  cpgsite = NULL,
  sampleReads = FALSE,
  numReads = 20
)
```

Arguments

`snp`	GRanges object containing SNP location.
`vcfFile`	vcf file.
`bamFile`	bismark bam file path.
`refFile`	fasta reference file path. Or `DNAStringSet` with DNA sequence.
`build`	genome build used. default = "hg19"
`dame`	(optional) GRanges object containing a region to plot.
`letterSize`	Size of alleles drawn in plot. Default = 2.5.
`pointSize`	Size of methylation circles. Default = 3.
`sampleName`	FIX?: this is to save the vcf file to not generate it every time you run the function.
`cpgsite`	(optional) GRanges object containing a single CpG site location of interest.
`sampleReads`	Whether a subset of reads should be plotted. Default = FALSE.
`numReads`	Number of reads to plot per allele, if sampleReads is TRUE. Default = 20

Value

Plot

Examples

```
DATA_PATH_DIR <- system.file('extdata', '.', package = 'DAMEfinder')

get_data_path <- function(file_name) file.path(DATA_PATH_DIR, file_name)
bam_files <- get_data_path('NORM1_chr19_trim.bam')
vcf_files <- get_data_path('NORM1.chr19.trim.vcf')
sample_names <- 'NORM1'
#reference_file
suppressPackageStartupMessages({library(BSgenome.Hsapiens.UCSC.hg19)})
genome <- BSgenome.Hsapiens.UCSC.hg19
seqnames(genome) <- gsub("chr","",seqnames(genome))
dna <- DNAStringSet(genome[[19]], use.names = TRUE)
names(dna) <- 19

snp <- GenomicRanges::GRanges(19, IRanges::IRanges(292082, width = 1))
methyl_circle_plot(snp = snp,
 vcfFile = vcf_files,
 bamFile = bam_files,
 refFile = dna,
 sampleName = sample_names)
```

---

methyl_circle_plotCpG *Draw methylation circle plot without SNP*

Description

Draws CpG site methylation status as points, in reads containing a specific CpG site. Generates one plot per bam file.

Usage

```
methyl_circle_plotCpG(
  cpgsite = cpgsite,
  bamFile = bamFile,
  pointSize = 3,
  refFile = refFile,
  dame = NULL,
  order = FALSE,
  sampleName = NULL,
  sampleReads = FALSE,
  numReads = 20
)
```

Arguments

cpgsite	GRanges object containing a single CpG site location of interest
bamFile	bismark bam file path

pointSize	Size of methylation circles. Default = 3.
refFile	fasta reference file path
dame	(optional) GRanges object containing a region to plot
order	Whether reads should be sorted by methylation status. Default= False.
sampleName	Plot title.
sampleReads	Whether a subset of reads should be plotted. Default = FALSE.
numReads	Number of reads to plot, if sampleReads is TRUE. Default = 20

Value

Plot

Examples

```
DATA_PATH_DIR <- system.file('extdata', '.', package = 'DAMEfinder')
get_data_path <- function(file_name) file.path(DATA_PATH_DIR, file_name)
bam_files <- get_data_path('NORM1_chr19_trim.bam')
sample_names <- 'NORM1'
#reference_file
suppressPackageStartupMessages({library(BSgenome.Hsapiens.UCSC.hg19)})
genome <- BSgenome.Hsapiens.UCSC.hg19
seqnames(genome) <- gsub("chr","",seqnames(genome))
dna <- DNAStringSet(genome[[19]], use.names = TRUE)
names(dna) <- 19

cpg <- GenomicRanges::GRanges(19, IRanges::IRanges(292082, width = 1))
methyl_circle_plotCpG(cpgsite = cpg,
 bamFile = bam_files,
 refFile = dna)
```

---

methyl_MDS_plot *Multidimensional scaling plot of distances between methylation proportions (beta values)*

Description

Same as plotMDS, except for an arc-sine transformation of the methylation proportions.

Usage

```
methyl_MDS_plot(x, group, top = 1000, coverage = 5, adj = 0.02, pointSize = 4)
```

Arguments

x	RangedSummarizedExperiment, output from calc_derivedasm or calc_asm.
group	Vector of group or any other labels, same length as number of samples.
top	Number of top CpG sites used to calculate pairwise distances.
coverage	Minimum number of reads covering a CpG site on each allele. Default = 5.
adj	Text adjustment in y-axis. Default = 0.2.
pointSize	Default = 4.

Value

Two-dimensional MDS plot.

Examples

```
data(readtuples_output)
ASM <- calc_asm(readtuples_output)
grp <- factor(c(rep('CRC',3),rep('NORM',2)), levels = c('NORM', 'CRC'))
methyl_MDS_plot(ASM, grp)
```

---

modulus_sqrt *Get Modulus Square Root*

Description

Function to calculate signed square root (aka modulus square root).

Usage

```
modulus_sqrt(values)
```

Arguments

values	Vector or matrix of ASM scores where each column is a sample. These values are transformed with a square root transformation that (doesn't) preserve the sign.

Value

Vector or matrix of transformed scores.

read_tuples *Read in list of methtuple files*

Description

This function reads in a list of files obtained from the methtuple tool. It filters out tuples based on the set minimum coverage (min_cov) and the maximum allowed distance (maxGap) between two genomic positions in a tuple.

Usage

```
read_tuples(files, sampleNames, minCoverage = 2, maxGap = 20, verbose = TRUE)
```

Arguments

files	List of methtuple files.
sampleNames	Names of files in the list.
minCoverage	The minimum coverage per tuple. Tuples with a coverage < minCoverage are filtered out. Default = 2.
maxGap	The maximum allowed distance between two positions in a tuple. Only distances that are <= maxGap are kept. Default = 150 base pairs.
verbose	If the function should be verbose.

Value

A list of data frames, where each data frame corresponds to one file.

Examples

```
DATA_PATH_DIR <- system.file('extdata', '.', package = 'DAMEfinder')
get_data_path <- function(file_name) file.path(DATA_PATH_DIR, file_name)

tuple_files <- list.files(DATA_PATH_DIR, '.tsv.gz')
tuple_files <- get_data_path(tuple_files)
ASM <- read_tuples(tuple_files, c('CRC1', 'NORM1'))
```

`readtuples_output` *read_tuples() output.*

Description

3 Patients from a previous study (Parker et al, 2018.) with colorectal cancer were sequenced and the normal and cancerous tissue of each patient was obtained. The data includes a subset of chromosome 19. Here one normal sample is not included.

Usage

```
readtuples_output
```

Format

A large list with 5 elements. Each element is a `tibble` with the coordinates of the pairs of CpG sites (tuples). Rest of the tibble contains:

`MM` Number of reads with both CpG sites methylated

`MU` Number of reads with first CpG site methylated

`UM` Number of reads with second CpG site methylated

`UU` Number of reads with both CpG sites unmethylated

`cov` Coverage, total reads at tuple

`inter_dist` Distance in bp between CpG sites

For further details, see https://www.ebi.ac.uk/arrayexpress/experiments/E-MTAB-6949/ sample names in in ArrayExpress do not necessarily match names given here!

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