

Package ‘PAIRADISE’

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Title PAIRADISE: Paired analysis of differential isoform expression

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Description This package implements the PAIRADISE procedure for detecting differential isoform expression between matched replicates in paired RNA-Seq data.

Depends R (>= 3.6), nloptr

Imports SummarizedExperiment, S4Vectors, stats, methods, abind, BiocParallel

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| | |
|------------|-------------------|
| clean.data | <i>clean.data</i> |
|------------|-------------------|

Description

Removes missing data and invalid pairs from the matched pair data to be analyzed by PAIRADISE.

Usage

```
clean.data(my.data)
```

Arguments

| | |
|---------|--|
| my.data | Data frame containing grouped data to be analyzed. |
|---------|--|

Details

The data frame has 7 columns, arranged as follows: Column 1 contains the ID of the exons/events. Column 2 contains counts of isoform 1 corresponding to the first group. Column 3 contains counts of isoform 2 corresponding to the first group. Column 4 contains counts of isoform 1 corresponding to the second group. Column 5 contains counts of isoform 2 corresponding to the second group. Replicates in columns 2-5 should be separated by commas, e.g. 1623,432,6 for three replicates. Column 6 contains the effective length of isoform 1. Column 7 contains the effective length of isoform 2.

Value

The function clean.data returns a list containing the following entries:

| | |
|----------|--|
| I1 | Group 1 isoform 1 counts for each replicate. |
| S1 | Group 1 isoform 2 counts for each replicate. |
| I2 | Group 2 isoform 1 counts for each replicate. |
| S2 | Group 2 isoform 2 counts for each replicate. |
| length_I | Effective lengths of isoform 1. |

| | |
|----------|--|
| length_S | Effective lengths of isoform 2. |
| exonList | IDs of the exons/events. |
| nExon | Number of exons/events. |
| M | Vector containing the number of replicates per exon/event. |

counts *PDseDataSet counts*

Description

PDseDataSet counts

Usage

counts(object)

Arguments

object A PDseDataSet object

Value

A counts matrix

load.data *load.data*

Description

Loads the matched pair data to be analyzed by PAIRADISE.

Usage

load.data(my.data)

Arguments

my.data Data frame containing grouped data to be analyzed.

Details

The data frame has 7 columns, arranged as follows: Column 1 contains the ID of the exons/events. Column 2 contains counts of isoform 1 corresponding to the first group. Column 3 contains counts of isoform 2 corresponding to the first group. Column 4 contains counts of isoform 1 corresponding to the second group. Column 5 contains counts of isoform 2 corresponding to the second group. Replicates in columns 2-5 should be separated by commas, e.g. 1623,432,6 for three replicates. Column 6 contains the effective length of isoform 1. Column 7 contains the effective length of isoform 2.

Value

The function `load.data` returns a list containing the following entries:

| | |
|----------|--|
| I1 | Group 1 isoform 1 counts for each replicate. |
| S1 | Group 1 isoform 2 counts for each replicate. |
| I2 | Group 2 isoform 1 counts for each replicate. |
| S2 | Group 2 isoform 2 counts for each replicate. |
| length_I | Effective lengths of isoform 1. |
| length_S | Effective lengths of isoform 2. |
| exonList | IDs of the exons/events. |
| nExon | Number of exons/events. |
| M | Vector containing the number of replicates per exon/event. |

logit

logit

Description

Takes in a vector and applies the logit function elementwise to that vector

Usage

```
logit(x)
```

Arguments

`x` : numeric vector, whose entries should be strictly between 0 and 1

Value

logit(x)

| | |
|---------------|----------------------|
| loglikelihood | <i>loglikelihood</i> |
|---------------|----------------------|

Description

Used internally in PAIRADISE to compute the log-likelihood function

Usage

```
loglikelihood(
  M,
  I1,
  S1,
  I2,
  S2,
  l.iI,
  l.iS,
  logit.psi1,
  logit.psi2,
  alpha,
  s1,
  s2,
  s,
  mu,
  delta
)
```

Arguments

| | |
|------------|--|
| M | Number of replicates for the current exon. Positive integer. |
| I1 | Exon inclusion counts for group 1. Positive integers. |
| S1 | Exon skipping counts for group 1. Positive integers. |
| I2 | Exon inclusion counts for group 2. Positive integers. |
| S2 | Exon skipping counts for group 2. Positive integers. |
| l.iI | Effective length of inclusion isoform. Positive integer. |
| l.iS | Effective length of skipping isoform. Positive integer. |
| logit.psi1 | Numeric vector with values of logit psi1. |
| logit.psi2 | Numeric vector with values of logit psi2. |
| alpha | Numeric vector with values of alpha. |
| s1 | Group 1 standard deviation. Positive number. |
| s2 | Group 2 standard deviation. Positive number. |
| s | Overall standard deviation. Positive number. |
| mu | Parameter mu. |
| delta | Parameter delta. |

Value

log likelihood value at input.

optimize1

optimize1

Description

Used internally in PAIRADISE to compute the MLEs of delta, mu, sigma1, sigma2, sigma

Usage

```
optimize1(
  x,
  M,
  I1,
  S1,
  I2,
  S2,
  l.iI,
  l.iS,
  logit.psi1,
  logit.psi2,
  alpha,
  equal.variance = FALSE
)
```

Arguments

| | |
|----------------|--|
| x | Numeric vector such that $x = (\text{sigma1}, \text{sigma2}, \text{sigma}, \text{mu}, \text{delta})$ if <code>equal.variance = FALSE</code> , and $x = (\text{sigma1}, \text{sigma}, \text{mu}, \text{delta})$ if <code>equal.variance = TRUE</code> . <code>sigma1</code> , <code>sigma2</code> , <code>sigma</code> must be positive |
| M | Number of replicates for the current exon. |
| I1 | Exon inclusion counts for group 1. Positive integers. |
| S1 | Exon skipping counts for group 1. Positive integers. |
| I2 | Exon inclusion counts for group 2. Positive integers. |
| S2 | Exon skipping counts for group 2. Positive integers. |
| l.iI | Effective length of inclusion isoform. Positive integer. |
| l.iS | Effective length of skipping isoform. Positive integer. |
| logit.psi1 | Numeric vector with values of logit psi1. |
| logit.psi2 | Numeric vector with values of logit psi2. |
| alpha | Numeric vector with values of alpha. |
| equal.variance | Are the group variances assumed equal? Default value is FALSE. |

Value

The MLEs.

optimize2

optimize2

Description

Used internally in PAIRADISE to compute the MLEs of $\text{logit}(\psi_1)$, $\text{logit}(\psi_2)$, α

Usage

optimize2(x, k, I1, S1, I2, S2, l.iI, l.iS, delta, mu, s1, s2, s)

Arguments

| | |
|-------|---|
| x | Numeric vector such that $x = (\text{logit}(\psi_1), \text{logit}(\psi_2), \alpha)$ |
| k | Index representing current replicate number. |
| I1 | Exon inclusion counts for group 1. Positive integers. |
| S1 | Exon skipping counts for group 1. Positive integers. |
| I2 | Exon inclusion counts for group 2. Positive integers. |
| S2 | Exon skipping counts for group 2. Positive integers. |
| l.iI | Effective length of inclusion isoform. Positive integer. |
| l.iS | Effective length of skipping isoform. Positive integer. |
| delta | Parameter delta. |
| mu | Parameter mu. |
| s1 | Group 1 standard deviation. Positive number. |
| s2 | Group 2 standard deviation. Positive number. |
| s | Overall standard deviation. Positive number. |

Value

The MLEs.

| | |
|-----------|--|
| PAIRADISE | <i>PAIRADISE Detecting allele-specific alternative splicing from population-scale RNA-seq data</i> |
|-----------|--|

Description

We introduce PAIRADISE (PAIred Replicate analysis of Allelic Differential Splicing Events), a method for detecting allele-specific alternative splicing (ASAS) from RNA-seq data. PAIRADISE uses a statistical model that aggregates ASAS signals across multiple individuals in a population. It formulates ASAS detection as a statistical problem for identifying differential alternative splicing from RNA-seq data with paired replicates. The PAIRADISE statistical model is applicable to many forms of allele-specific isoform variation (e.g. RNA editing), and can be used as a generic statistical model for RNA-seq studies involving paired replicates.

See Also

[pairadise](#)

| | |
|-----------|------------------|
| pairadise | <i>pairadise</i> |
|-----------|------------------|

Description

Primary function of the PAIRADISE package. Analyzes matched pairs for differences in isoform expression. Uses parallel processing to speed up computation.

Usage

```
pairadise(
  pdat,
  nIter = 100,
  tol = 10(-2),
  pseudocount = 0,
  seed = 12321,
  equal.variance = FALSE,
  numCluster = 2,
  BPPARAM = MulticoreParam(numCluster)
)
```

Arguments

| | |
|-------|--|
| pdat | A PDseDataSet object |
| nIter | Positive integer. Specifies the maximum number of iterations of the optimization algorithm allowed. Default is nIter = 100 |

| | |
|----------------|---|
| tol | Positive number. Specifies the tolerance level for terminating the optimization algorithm, defined as the difference in log-likelihood ratios between iterations. Default is $\text{tol} = 10^{-2}$ |
| pseudocount | Positive number. Specifies a value for a pseudocount added to each count at the beginning of the analysis. Default is $\text{pseudocount} = 0$ |
| seed | An integer to set seed. |
| equal.variance | Are the group variances assumed equal? Default value is FALSE. |
| numCluster | Number of clusters to use for parallel computing. |
| BPPARAM | parallel parameters from package BiocParallel. |

Details

This is the primary function of the PAIRADISE package that implements the PAIRADISE algorithm.

Value

A PDseDataSet object contains outputs from PAIRADISE algorithm.

Examples

```
#####
## Example: Simulated data ##
#####

set.seed(12345)
data("sample_dataset")
pdat <- PDseDataSetFromMat(sample_dataset)
pdat <- pairadise(pdat, numCluster = 4)
results(pdat)
```

PDseDataSet-class *PDseDataSet object and constructor*

Description

'PDseDataSet' is a subclass of 'SummarizedExperiment'. It can be used to store inclusion and skipping splicing counts for pair designed samples.

Usage

```
PDseDataSet(counts, design, lengths)
```

Arguments

| | |
|---------|---|
| counts | The counts of splicing events, including inclusion and skipping counts in 3 dimensions for each sample. |
| design | The paired design data.frame, including sample column for sample ids and group column for design factors. |
| lengths | Two columns iLen and sLen for the effective lengths of inclusion and skipping isoforms. |

Value

A PDseDataSet object

Examples

```
icount <- matrix(1:4, 1)
scount <- matrix(5:8, 1)
account <- abind::abind(icount, scount, along = 3)
design <- data.frame(sample = rep(c("s1", "s2"), 2),
  group = rep(c("T", "N"), each = 2))
lens <- data.frame(sLen=1L, iLen=2L)
PDseDataSet(account, design, lens)
```

PDseDataSetFromMat

PDseDataSet from rMATs/PAIRADISE Mat format

Description

The Mat format should have 7 columns, arranged as follows: Column 1 contains the ID of the alternative splicing events. Column 2 contains counts of isoform 1 corresponding to the first group. Column 3 contains counts of isoform 2 corresponding to the first group. Column 4 contains counts of isoform 1 corresponding to the second group. Column 5 contains counts of isoform 2 corresponding to the second group. Column 6 contains the effective length of isoform 1. Column 7 contains the effective length of isoform 2. Replicates in columns 2-5 should be separated by commas, e.g. "1623,432,6" for three replicates and the replicate order should be consistent for each column to ensure pairs are matched correctly.

Usage

```
PDseDataSetFromMat(dat)
```

Arguments

| | |
|-----|---------------------------|
| dat | The Mat format dataframe. |
|-----|---------------------------|

Value

A PDseDataSet object

Examples

```
data("sample_dataset")
pdat <- PDseDataSetFromMat(sample_dataset)
```

| | |
|---------|--|
| results | <i>Extract results for paradise analysis</i> |
|---------|--|

Description

Extract results for paradise analysis

Usage

```
results(pdat, p.adj = "BH", sig.level = 0.01, details = FALSE)
```

Arguments

| | |
|-----------|---|
| pdat | A PDseDataSet object from paradise analysis |
| p.adj | The p adjustment method. |
| sig.level | The cutoff of significant results |
| details | Whether to list detailed results. |

Value

The function return a results DataFrame.

| | |
|-----------|--|
| testStats | Vector of test statistics for paired analysis. |
| p.value | Vector of pvalues for each exon/event. |
| p.adj | The adjusted p values |

If details is TRUE, more detailed parameter estimates for constrained and unconstrained model will return.

Examples

```
data("sample_dataset")
pdat <- PDseDataSetFromMat(sample_dataset)
pdat <- paradise(pdat)
results(pdat)
```

| | |
|----------------|-----------------------|
| sample_dataset | <i>sample_dataset</i> |
|----------------|-----------------------|

Description

The CEU dataset was generated by analyzing the allele-specific alternative splicing events in the GEUVADIS CEU data. Allele-specific reads were mapped onto alternative splicing events using rPGA (version 2.0.0). Then the allele-specific bam files mapped onto the two haplotypes are merged together to detect alternative splicing events using rMATS (version 3.2.5)¹⁶.

The LUSC dataset was generated by analyzing the tumor versus adjacent control samples from TCGA LUSC RNA-seq data.

Usage

```
data(sample_dataset)
```

```
data(sample_dataset_CEU)
```

```
data(sample_dataset_LUSC)
```

Format

The dataset has 7 columns, arranged as follows:

ExonID Column 1 contains the ID of the alternative splicing events.

I1 Column 2 contains counts of isoform 1 corresponding to the first group.

S1 Column 3 contains counts of isoform 2 corresponding to the first group.

I2 Column 4 contains counts of isoform 1 corresponding to the second group.

S2 Column 5 contains counts of isoform 2 corresponding to the second group.

I_len Column 6 contains the effective length of isoform 1.

S_len Column 7 contains the effective length of isoform 2.

The dataset has 7 columns, arranged as follows:

ExonID Column 1 contains the ID of the alternative splicing events.

I1 Column 2 contains counts of isoform 1 corresponding to the first group.

S1 Column 3 contains counts of isoform 2 corresponding to the first group.

I2 Column 4 contains counts of isoform 1 corresponding to the second group.

S2 Column 5 contains counts of isoform 2 corresponding to the second group.

I_len Column 6 contains the effective length of isoform 1.

S_len Column 7 contains the effective length of isoform 2.

The dataset has 7 columns, arranged as follows:

ExonID Column 1 contains the ID of the alternative splicing events.

- I1** Column 2 contains counts of isoform 1 corresponding to the first group.
- S1** Column 3 contains counts of isoform 2 corresponding to the first group.
- I2** Column 4 contains counts of isoform 1 corresponding to the second group.
- S2** Column 5 contains counts of isoform 2 corresponding to the second group.
- I_len** Column 6 contains the effective length of isoform 1.
- S_len** Column 7 contains the effective length of isoform 2.

sigmoid

sigmoid

Description

Takes in a vector and applies the sigmoid function elementwise to that vector

Usage

sigmoid(x)

Arguments

x : numeric vector

Value

sigmoid(x)

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