

# Package ‘PAIRADISE’

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**Title** PAIRADISE: Paired analysis of differential isoform expression

**Version** 1.26.0

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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

**License** MIT + file LICENSE

**RoxygenNote** 7.1.1

**Encoding** UTF-8

**VignetteBuilder** knitr

**Suggests** testthat, knitr, rmarkdown, BiocStyle

**biocViews** RNASeq, DifferentialExpression, AlternativeSplicing, StatisticalMethod, ImmunoOncology

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

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## 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 | <i>PDseDataSet counts</i> |
|--------|---------------------------|

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**Description**

PDseDataSet counts

**Usage**

```
counts(object)
```

**Arguments**

object            A PDseDataSet object

**Value**

A counts matrix

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

---

**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. |

---

|                    |              |
|--------------------|--------------|
| <code>logit</code> | <i>logit</i> |
|--------------------|--------------|

---

**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)
```

---

|                            |                      |
|----------------------------|----------------------|
| <code>loglikelihood</code> | <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  $\text{logit}(\psi_1)$ ,  $\text{logit}(\psi_2)$ ,  $\alpha$

**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

*PAIRADISE Detecting allele-specific alternative splicing from population-scale RNA-seq data*

**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

*pairadise*


---

## 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 tol = 10 <sup>-2</sup> |
| pseudocount    | Positive number. Specifies a value for a pseudocount added to each count at the beginning of the analysis. Default is 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 | <i>PDseDataSet object and constructor</i> |
|-------------------|-------------------------------------------|

---

**Description**

‘PDseDataSet’ is a subclass of ‘SummarizedExperiment’. It can 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)
acount <- 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(acount, design, lens)
```

---

|                    |                                                    |
|--------------------|----------------------------------------------------|
| PDseDataSetFromMat | <i>PDseDataSet from rMATs/PAIRADISE Mat format</i> |
|--------------------|----------------------------------------------------|

---

### 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 pairadise analysis</i> |
|---------|-----------------------------------------------|

---

### Description

Extract results for pairadise analysis

### Usage

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

### Arguments

|           |                                              |
|-----------|----------------------------------------------|
| pdat      | A PDseDataSet object from pairadise 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 <- pairadise(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 | <i>sigmoid</i> |
|---------|----------------|

---

**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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