Package ‘baySeq’

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Description This package identifies differential expression in high-throughput 'count' data, such as that derived from next-generation sequencing machines, calculating estimated posterior likelihoods of differential expression (or more complex hypotheses) via empirical Bayesian methods.

License GPL-3

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- **baySeq-package**

  Empirical Bayesian analysis of patterns of differential expression in count data.

### Description

This package is intended to identify differential expression in high-throughput 'count' data, such as that derived from next-generation sequencing machines. We achieve this by empirical bayesian methods, first bootstrapping to estimate prior parameters from the data and then assessing posterior likelihoods of the models proposed.

### Details
To use the package, construct a `countData` object and use the functions documented in `getPriors` to empirically determine priors on the data. Then use the functions documented in `getLikelihoods` to establish posterior likelihoods for the models proposed. A few convenience functions, `getTPs` and `topCounts` are also included.

The package (optionally) makes use of the 'snow' package for parallelisation of computationally intensive functions. This is highly recommended for large data sets.

See the vignette for more details.

Author(s)

Thomas J. Hardcastle
Maintainer: Thomas J. Hardcastle <tjh48@cam.ac.uk>

References


Examples

```r
# See vignette for more examples.

# load test data
data(simData)

# replicate structure of data

# define hypotheses on data
groups <- list(NDE = c(1,1,1,1,1,1,1,1), DE = c(1,1,1,1,2,2,2,2))

# construct 'countData' object
CD <- new("countData", data = simData, replicates = replicates, groups = groups)

# estimate library sizes for countData object
libsizes(CD) <- getLibsizes(CD)

# estimate prior distributions on 'countData' object using negative binomial
# method. Other methods are available - see getPriors
```
allModels <- getPrior.NB(CD, cl = NULL)

# estimate posterior likelihoods for each row of data belonging to each hypothesis
CDPost <- getLikelihoods(CDPost, cl = NULL)

# display the rows of data showing greatest association with the second
# hypothesis (differential expression)
topCounts(CDPost, group = "DE", number = 10)

# find true positive selection rate
getTPs(CDPost, group = "DE", TPs = 1:100)[1:100]

allModels

Function to generate all possible models for a countData object based
on the replicate data.

Description
This function populates the '@groups' slot of the supplied countData object with all possible models for equivalence/non-equivalence of expression between replicate groups.

Usage
allModels(CD)

Arguments
CD A countData object with a populated '@replicates' slot.

Details
Given a large number of different replicate groups, the total number of possible models listed in the '@groups' slot rises exponentially. This function will attempt to list them all. The use of consensus priors (see getPriors) is recommended if the number of models is high.

Value
A countData with populated '@groups' slot.

Author(s)
Thomas J. Hardcastle

References
See Also

getPriors

Examples

# load test data
data(simData)

# Create a {countData} object from test data, supposing that there are # multiple experimental groups present.

replicates <- c("simA", "simA", "simB", "simC", "simD", "simE", "simE", "simF", "simG")
CD <- new("countData", data = simData, replicates = replicates)
CD <- allModels(CD)

# The total number of models generated is high.
length(CD@groups)

Description

The countData class is used to define summaries of count data and establishing prior and posterior parameters on distributions defined upon the count data.

Slots

Objects of these class contain the following components:

data: Count data (matrix).
replicates: The replicate structure of the data. Stored as a factor, but can be given in any form.
groups: Group (model) structure to test on the data (list).
annotation: Annotation data for each count (data.frame).
priorType: Character string describing the type of prior information available in slot 'priors'.
priors: Prior parameter information. Calculated by the functions described in getPriors.
posterior: Estimated (log)-posterior likelihoods for each group (matrix). Calculated by the functions described in getLikelihoods.
estProps: Estimated proportion of tags belonging to each group (numeric). Calculated by the functions described in getLikelihoods.
nullPosts: If calculated, the posterior likelihoods for the data having no true expression of any kind.
seglengths: Lengths of segments containing the counts described in data. A matrix, but may be initialised with a vector, or ignored altogether.

Details

The seglengths slot describes, for each row of the data object, the length of the 'segment' that contains the number of counts described by that row. For example, if we are looking at the number of hits matching genes, the seglengths object would consist of transcript lengths. Exceptionally, we
may want to use different segment lengths for different samples and so the slot takes the form of a matrix. If the matrix has only one column, it is duplicated for all samples. Otherwise, it should have the same number of columns as the `@data` slot. If the slot is the empty matrix, then it is assumed that all segments have the same length.

**Methods**

The standard methods 'new', 'dim', '[', 'show', 'rbind' and 'c' have been defined for these classes. The methods 'groups', 'groups<-', 'replicates', 'replicates<-', 'libsizes' and 'libsizes<- ' have also been defined in order to access and modify these slots, and their use is recommended. The method 'flatten' can be used to produce a data.frame object containing much of the basic data in a member of this class.

**Author(s)**

Thomas J. Hardcastle

**Examples**

```r
#load test data
data(simData)

# Create a 'countData' object from test data.
groups <- list(NDE = c(1,1,1,1,1,1,1,1,1,1), DE = c(1,1,1,1,1,2,2,2,2,2))
CD <- new("countData", data = simData, replicates = replicates, groups = groups)

#estimate library sizes for countData object
libsizes(CD) <- getLibsizes(CD)

CD[1:10,]
dim(CD)
```

---

### bimodalSeparator

A function that, given a numeric vector, finds the value which splits the data into two sets of minimal total variance using Otsu’s method.

**Description**

This function takes a numeric vector and finds the value which splits the data into two sets of minimal total variance, weighted by the size of subsets (Otsu’s method). It is principally intended to be a quick and easy way of separating bimodally distributed data.

**Usage**

```r
bimodalSeparator(x, weights = NULL, minperc = 0.1, elbow = NULL)
```
Arguments

- **x**: A numeric vector containing the data to be split.
- **weights**: Possible weightings on the values in x for calculating the variance.
- **minperc**: The required minimum size of each of the two subsets, expressed as a percentage of the total size. See Details.
- **elbow**: If set, finds the ‘left’ or ‘right’ elbow of variance, instead of the minimum; defaults to NULL. See Details.

Details

This function is intended to give a quick and easy way of splitting bimodally distributed data. Where there are large outliers in the data, it may be that the value which minimises the variance does not split the bimodal data but isolates the outliers. The 'minperc' parameter can be used to ensure that each subset of the split data will be of some minimum size, avoiding the outlier problem.

If 'elbow = NULL' (the default) then the split occurs at the value that minimises the variance, x0. If 'elbow = left' then we attempt to find the elbow point to the left of the value that minimises the variance, if 'elbow = right' then we find the elbow point to the right of the value that minimises the variance. Elbow points are found by drawing a line from the first point (for the left elbow) or the last point (for the right elbow) to x0, and finding the location on the curve of summed variances which maximises the distance to that line.

Value

Numeric value which splits the data.

Author(s)

Thomas J. Hardcastle

Examples

bimodalSeparator(c(rnorm(200, mean = c(5,7), sd = 1)))

**CDPost**

`'countData' object derived from data file 'simData' with estimated likelihoods of differential expression.`

Description

This `countData` object is derived from the data set `simData` and contains the estimated likelihoods of differential expression. This data set is intended to be used to speed the processing of the examples.

Usage

data(CDPost)
Format

A ‘countData’ object.

Source

Simulation.

References


CDPriors
‘countData’ object derived from data file ‘simData’ with estimated priors.

Description

This ‘countData’ object is derived from the data set ‘simData’ and contains the estimated priors. This data set is intended to be used to speed the processing of the examples.

Usage

data(CDPriors)

Format

A ‘countData’ object.

Source

Simulation.

References

densityFunction-class

Class "densityFunction"

Description

This function fills the '@densityFunction' slot of a 'countData' object. It defines the distribution used to estimate posterior likelihoods, and associated values used in these calculations.

Objects from the Class

Objects can be created by calls of the form new("densityFunction", ...).

Slots

description: A description of the distribution defined.
density: A "function", defining the likelihood of a data array given observed data and hyperparameters.
initiatingValues: A "list" of functions (may be supplied as numerics) that define initial values of numeric prior discovery.
equalOverReplicates: A "logical", describing which of the hyperparameters are equally marginally distributed over all groups, and which are not.
lower: A "function", required to define the lower limit of optimisation in the case where only one hyperparameter is *not* equally marginally distributed over all groups.
upper: A "function", required to define the upper limit of optimisation, as for 'lower', above.
stratifyFunction: An optional "function", used to stratify the data for more accurate prior estimation.
stratifyBreaks: An optional "numeric", used to define the number of strata in a stratification.
nullFunction: An optional "function" on the hyperparameters, used to generate a one-dimensional distribution which can be partitioned to identify 'null' data.
orderingFunction: An optional "function" for ordering the data between groups of a model.
modifyNullPriors: An optional "function" for modifying the priors for the 'null' data.

Methods

No methods defined with class "densityFunction" in the signature.

Author(s)

Thomas J. Hardcastle

Examples

showClass("densityFunction")
**densityFunctions**

Lists all currently available densityFunctions.

**Description**

The densityFunction objects define the distribution and various other parameters used to analyse the data stored in a countData object.

**Usage**

densityFunctions()

**Value**

Character string giving names of available densityFunction objects.

**Author(s)**

Thomas J. Hardcastle

**References**


**See Also**

densityFunction

---

**getLibsizes**

Estimates library scaling factors (library sizes) for count data.

**Description**

This function estimates the library scaling factors that should be used for either a ‘countData’, or a matrix of counts and replicate information.

**Usage**

getLibsizes(cD, data, replicates, subset = NULL, estimationType = c("quantile", "total", "edgeR"), quant...
Arguments

- **cD**: A `countData` object.
- **data**: A matrix of count values. Ignored if 'cD' is given.
- **replicates**: A replicate structure for the data given in 'data'. Ignored if 'cD' is given.
- **subset**: A numerical vector indicating the rows of the 'countData' object that should be used to estimate library scaling factors.
- **estimationType**: One of 'quantile', 'total', or 'edgeR'. Partial matching is allowed. See Details.
- **quantile**: A value between 0 and 1 indicating the level of trimming that should take place. See Details.
- **...**: Additional parameters to be passed to the 'edgeR' `calcNormFactors` function.

Details

This function estimates the library scaling factors (surrogates for library size) in one of several ways, depending on the 'estimationType' argument. 'total' will give the library sizes by summing all counts in each sample. 'quantile' will give a library scaling factor by the method of Bullard et al (Bioinformatics 2010), summing all counts in each sample whose value below the qth quantile of non-zero counts for that sample. 'edgeR' uses the Trimmed Mean of M-values (TMM) method of Robinson and Oshlack (Genome Biology, 2010) via the 'edgeR' `calcNormFactors` function; other options are available through this function.

If a `countData` object 'cD' is given, the library sizes will be inferred from this. Alternatively, a matrix of count values (columns are libraries) and a replicate structure (a vector defining which samples belong to which replicate group) can be given.

Value

If a `countData` object is given, an identical object will be returned with updated library sizes. If only the data and replicate structure are given, a numerical vector of library sizes (scaling factors) for each library in the data will be returned.

Author(s)

Thomas J. Hardcastle

See Also

- `countData`

Examples

```r
data(simData)
replicates <- c(1,1,1,1,1,2,2,2,2,2)
groups <- list(c(1,1,1,1,1,1,1,1,1,1), c(1,1,1,1,1,2,2,2,2,2))
CD <- new("countData", data = simData, replicates = replicates, groups = groups)

libsizes(CD) <- getLibsizes(CD)
```
getLikelihoods

Finds posterior likelihoods for each count or paired count as belonging to some model.

Description

These functions calculate posterior probabilities for each of the rows in a `countData` object belonging to each of the models specified in the ‘groups’ slot.

Usage

getLikelihoods.NB(cD, prs, pET = "BIC", marginalise = FALSE, subset = NULL, priorSubset = NULL, bootStraps = 1, conv = 1e-4, nullData = FALSE, returnAll = FALSE, returnPD = FALSE, verbose = TRUE, discardSampling = FALSE, cl, ...)
getLikelihoods.BB(cD, prs, pET = "BIC", marginalise = FALSE, subset = NULL, priorSubset = NULL, bootStraps = 1, conv = 1e-04, nullData = FALSE, returnAll = FALSE, returnPD = FALSE, verbose = TRUE, discardSampling = FALSE, cl, ...)
getLikelihoods(cD, prs, pET = "BIC", marginalise = FALSE, subset = NULL, priorSubset = NULL, bootStraps = 1, bsNullOnly = TRUE, conv = 1e-4, nullData = FALSE, weightByLocLikelihoods = TRUE, modelPriorSets = list(), modelPriorValues = list(), returnAll = FALSE, returnPD = FALSE, verbose = TRUE, discardSampling = FALSE, modelLikes = TRUE, cl = NULL, tempFile = NULL, largeness = 1e+08)

Arguments

cD
An object of type `countData`, or descending from this class.

prs
(Initial) prior probabilities for each of the groups in the ‘cD’ object. Should sum to 1, unless nullData is TRUE, in which case it should sum to less than 1.

pET
What type of prior re-estimation should be attempted? Defaults to "BIC"; "none" and "iteratively" are also available.

marginalise
Should an attempt be made to numerically marginalise over a prior distribution iteratively estimated from the posterior distribution? Defaults to FALSE, as in general offers little performance gain and increases computational cost considerably.

subset
Numeric vector giving the subset of counts for which posterior likelihoods should be estimated.

priorSubset
Numeric vector giving the subset of counts which may be used to estimate prior probabilities on each of the groups. See Details.

bootStraps
How many iterations of bootstrapping should be used in the (re)estimation of priors in the negative binomial method.

bsNullOnly
If TRUE (default, bootstrap hyper-parameters based on the likelihood of the null model and its inverse only; otherwise, on the likelihood of all models.
getLikelihoods

conv If not null, bootstrapping iterations will cease if the mean squared difference between posterior likelihoods of consecutive bootstraps drops below this value.

nullData If TRUE, looks for segments or counts with no true expression. See Details.

weightByLocLikelihoods If a locLikelihoods slot is present in the ‘cD’ object, and nullData = TRUE, then the initial weighting on nulls will be determined from the locLikelihoods slot. Defaults to TRUE.

modelPriorSets If given, a list object, which defines subsets of the data for which different priors on the different models might be expected. See Details.

modelPriorValues If given, a list object which defines priors on the different models. See Details.

returnAll If TRUE, and bootStraps > 1, then instead of returning a single countData object, the function returns a list of countData objects; one for each bootstrap. Largely used for debugging purposes.

returnPD If TRUE, then the function returns the (log) likelihoods of the data given the models, rather than the posterior (log) likelihoods of the models given the data. Not recommended for general use.

verbose Should status messages be displayed? Defaults to TRUE.

discardSampling If TRUE, discards information about which data rows are sampled to generate prior information. May slightly degrade the results but reduce computational time required. Defaults to FALSE.

modelLikes If TRUE (default), returns likelihoods for each model. If FALSE, returns likelihoods for each hyper-parameter, from which the posterior joint distribution on hyper-parameters can be inferred.

c1 A SNOW cluster object.

tempFile Temporary file prefix for saving data likelihoods. Primarily for debugging purposes at this stage. Defaults to NULL, in which case no temporary data are saved.

largeness The maximum size over which data likelihoods are calculated. Objects larger than this are split. This is most useful in combination with the saving of temporary files in the case of excessively large analyses.

Details

These functions estimate, under the assumption of various distributions, the (log) posterior likelihoods that each count belongs to a group defined by the @group slot of the input object. The posterior likelihoods are stored on the natural log scale in the @posteriors slot of the countData object generated by this function. This is because the posterior likelihoods are calculated in this form, and ordering of the counts is better done on these log-likelihoods than on the likelihoods.

If 'pET = "none"' then no attempt is made to re-estimate the prior likelihoods given in the 'prs' variable. However, if 'pET = "BIC"', then the function will attempt to estimate the prior likelihoods by using the Bayesian Information Criterion to identify the proportion of the data best explained by
each model and taking these proportions as prior. Alternatively, an iterative re-estimation of priors
is possible (`pET = "iteratively"`), in which an initial estimate for the prior likelihoods of the
models is used to calculate the posteriors and then the priors are updated by taking the mean of
the posterior likelihoods for each model across all data. This often works well, particularly if the
'BIC' method is used (see Hardcastle & Kelly 2010 for details). However, if the data are sufficiently
non-independent, this approach may substantially mis-estimate the true priors. If it is possible to
select a representative subset of the data by setting the variable `subsetPriors` that is sufficiently
independent, then better estimates may be acquired.

In certain circumstances, it may be expected that certain subsets of the data are likely to behave
differently to others; for example, if a set of genes are expected in advance to be differentially
expressed, while the majority of the data are not. In this case, it may be advantageous (in terms of
improving false discovery rates) to specify these different subsets in the `modelPriorSets` variable.
However, care should be taken downstream to avoid confirmation bias.

Filtering the data may be extremely advantageous in reducing run time. This can be done by passing
a numeric vector to `subset` defining a subset of the data for which posterior likelihoods are required.
See Hardcastle & Kelly (2010) for a definition of the negative binomial methods.

A `cluster` object is strongly recommended in order to parallelise the estimation of posterior like-
lihoods, particularly for the negative binomial method. However, passing NULL to the `cl` variable
will allow the functions to run in non-parallel mode.

The `getLikelihoods.NB` and `getLikelihoods.BB` functions are now deprecated and will soon be
removed.

Value

A `countData` object.

Author(s)

Thomas J. Hardcastle

References

Expression In Sequence Count Data. BMC Bioinformatics (2010)

See Also

countData, getPriors, topCounts, getTPs

Examples

```r
# See vignette for more examples.

# If we do not wish to parallelise the functions we set the cluster
# object to NULL.

c1 <- NULL

# Alternatively, if we have the 'snow' package installed we
getPosteriors

An internal function in the baySeq package for calculating posterior likelihoods given likelihoods of the data.

Description

For likelihoods of the data given a set of models, this function calculates the posterior likelihoods of the models given the data. An internal function of baySeq, which should not in general be called by the user.

Usage

getPosteriors(ps, prs, pET = "none", marginalise = FALSE, groups, priorSubset = NULL, maxit = 100, accuracy = 1e-5, eqOverRep = NULL, cl = cl)
Arguments

ps
A matrix containing likelihoods of the data for each count (rows) under each model (columns).

prs
(Initial) prior probabilities for each of the models.

pET
What type of prior re-estimation should be attempted? Defaults to "none"; "BIC" and "iteratively" are also available.

marginalise
Should an attempt be made to numerically marginalise over a prior distribution iteratively estimated from the posterior distribution? Defaults to FALSE, as in general offers little performance gain and increases computational cost considerably.

groups
Group structure from which likelihoods in 'ps' were defined.

priorSubset
If 'estimatePriors = TRUE', what subset of the data should be used to re-estimate the priors? Defaults to NULL, implying all data will be used.

maxit
What is the maximum number of iterations that should be tried if we are bootstrapping prior probabilities from the data?

accuracy
How small should the difference in estimated priors be before we stop bootstrapping.

eqOverRep
A boolean describing which prior values are equally marginally distributed over replicates.

c1
Parallelisation cluster object.

Details

An internal function, that will not in general be called by the user. It takes the log-likelihoods of the data given the models being tested and returns the posterior likelihoods of the models.

The function may attempt to estimate the prior likelihoods either by using the Bayesian Information Criterion ('pET = "BIC"') to identify the proportion of the data best explained by each model and taking these proportions as prior. Alternatively, an iterative re-estimation of priors is possible ('pET = "iteratively"'), in which an initial estimate for the prior likelihoods of the models is used to calculated the posteriors and then the priors are updated by taking the mean of the posterior likelihoods for each model across all data.

Value

A list containing posteriors: estimated posterior likelihoods of the model for each count (log-scale)

priors: estimated (or given) prior probabilities of the model

Author(s)

Thomas J. Hardcastle

References

getPriors

See Also

getLikelihoods

Examples

# Simulate some log-likelihoods of data given models (each model
# describes one column of the 'ps' object).
ps <- log(rbind(
    cbind(runif(10000, 0, 0.1), runif(10000, 0.3, 0.9)),
    cbind(runif(10000, 0.4, 0.9), runif(1000, 0, 0.2))))

# get posterior log-likelihoods of model, estimating prior likelihoods
# of each model from the data.
pps <- getPosteriors(ps, prs <- c(0.5, 0.5), pET = "none", cl =
    NULL)
pps$priors
pps$posteriors[1:10,]

getPriors A countData object.
samplesize How large a sample should be taken in estimating the priors?
samplingSubset If given, the priors will be sampled only from the subset specified.
consensus If TRUE, creates a consensus distribution rather than a separate distribution for
each member of the groups structure in the 'cD' object. See Details.
getPriors

cl A SNOW cluster object.
verbose Should status messages be displayed? Defaults to TRUE.
equalDispersions Should we assume equal dispersions of data across all groups in the 'cD' object? Defaults to TRUE; see Details.
estimation Defaults to "QL", indicating quasi-likelihood estimation of priors. Currently, the only other possibilities are "ML", a maximum-likelihood method, and "edgeR", the moderated dispersion estimates produced by the 'edgeR' package. See Details.
zeroML Should parameters from zero data (rows that within a group are all zeros) be estimated using maximum likelihood methods (which will result in zeros in the parameters)? See Details.
... Additional parameters to be passed to the estimateTagwiseDisp function if 'estimation = "edgeR"'.

Details

These functions empirically estimate prior parameters for the distributions used in estimating posterior likelihoods of each count belonging to a particular group.

For priors estimated for the negative binomial methods, three options are available. Differences in the options focus on the way in which the dispersion is estimated for the data. In simulation studies, quasi-likelihood methods ('estimation = "QL"') performed best and so these are used by default. Alternatives are maximum-likelihood methods ('estimation = "ML"'), and the 'edgeR' packages moderated dispersion estimates ('estimation = "edgeR"').

The priors estimated for the negative binomial methods ('getPriors.NB') may assume that the dispersion of data for a given row is identical for all group structures defined in 'cD@groups' ('equalDispersions = TRUE'). Alternatively, the dispersions may be estimated individually for each group structure ('equalDispersions = FALSE'). Unless there is a strong reason for believing that the data are differently dispersed between groups, 'equalDispersions = TRUE' is recommended. If 'estimation = "edgeR"' then this parameter is ignored and dispersion is assumed identical for all group structures.

If all counts in a given row for a given group are zero, then maximum and quasi-likelihood estimation methods will result in a zero parameter for the mean. In analyses where segment length is a factor, this makes it hard to differentiate between (for example) a region which contains no reads but is only ten bases long and one which likewise contains no reads but is ten megabases long. If 'zeroML' is FALSE, therefore, the dispersion is set to 1 and the mean estimated as the value that leaves the likelihood of zero data at fifty percent.

If 'consensus = TRUE', then a consensus distribution is created and used for each group in the 'cD' object. This allows faster computation of the priors and likelihoods, but with some degradation of accuracy.

A 'cluster' object is recommended in order to estimate the priors for the negative binomial distribution. Passing NULL to this variable will cause the function to run in non-parallel mode.

Value

A countData object.
getTPs

Author(s)

Thomas J. Hardcastle

References


See Also

countData, getLikelihoods

Examples

# See vignette for more examples.

# If we do not wish to parallelise the functions we set the cluster object to NULL.
cl <- NULL

# Alternatively, if we have the 'snow' package installed we can parallelise the functions. This will usually (not always) offer significant performance gain.
## Not run: try(library(snow))
## Not run: try(cl <- makeCluster(4, "SOCK"))

# load test data
data(simData)

# Create a {countData} object from test data.
groups <- list(NDE = c(1,1,1,1,1,1,1,1), DE = c(1,1,1,1,2,2,2,2))
CD <- new("countData", data = simData, replicates = replicates, groups = groups)

# estimate library sizes for countData object
libsizes(CD) <- getLibsizes(CD)

# Get priors for negative binomial method
CDPriors <- getPriors.NB(CD, samplesize = 10^5, estimation = "QL", cl = cl)

getTPs

gets the number of true positives in the top n counts selected by ranked posterior likelihoods
getTPs

Description
If the true positives are known, this function will return a vector, the ith member of which gives the number of true positives identified if the top i counts, based on estimated posterior likelihoods, are chosen.

Usage
getTPs(cD, group, decreasing = TRUE, TPs)

Arguments
cD countData object, containing posterior likelihoods for each group.
group Which group should we give the counts for? See Details.
decreasing Ordering on posterior likelihoods.
TPs Known true positives.

Details
In the rare (or simulated) cases where the true positives are known, this function will calculate the number of true positives selected at any cutoff.
The 'group' can be defined either as the number of the element in 'cD@groups' or as a string which will be partially matched to the names of the 'cD@groups' elements. If group = NULL, then the function looks at the posterior likelihoods that the data have no true differential expression (if calculated).

Value
A vector, the ith member of which gives the number of true positives identified if the top i counts are chosen.

Author(s)
Thomas J. Hardcastle

See Also
countData

Examples
# See vignette for more examples.

# We load in a `countData` object containing the estimated posterior likelihoods of expression (see `getLikelihoods`).
data(CDPost)

# If the first hundred rows in the 'simData' matrix are known to be truly differentially expressed (the second hypothesis defined in the
# 'groups' list) then we find the number of true positives for the top n genes selected as the nth member of

getTPs(CDPost, group = "DE", decreasing = TRUE, TPs = 1:100)

---

makeOrderings  
Construct orderings for count data given a model structure and an ordering function.

Description

Given a model structure as defined in the `@groups` slot of a countData object containing more than one group, it is often possible to define an ordering on the groups for a given genomic event. To take a simple example, if the average expression of a gene is higher in sample set A than in sample set B, then we might impose an ordering A>B.

Usage

makeOrderings(cD, orderingFunction)

Arguments

cD  A countData object, or a descendant thereof.
orderingFunction  A function defining the orderings. If not given, will be taken from the `@densityFunction` slot of `cD`. See Details, and examples below.

Details

The orderingFunction takes 'dat' and 'observables' as arguments. 'dat' is equivalent to the `@data` slot of the `cD` object, and 'observables' the combined data in the `@sampleObservables`, `@rowObservables` and `@cellObservables` slots.

Value

A countData with populated `@orderings` slot.

Author(s)

Thomas J. Hardcastle

References

Examples

# load test data
data(simData)

# Create a countData object from test data
groups <- list(NDE = c(1,1,1,1,1,1,1,1), DE = c(1,1,1,1,1,2,2,2))
CD <- new("countData", data = simData, replicates = replicates, groups = groups)
libsizes(CD) <- getLibsizes(CD)

# order on expression normalised for library size (scaling factor) and gene length
CD <- makeOrderings(CD, orderingFunction = function(dat, observables) dat / observables$libsizes)

# orderings calculated for DE group
head(CD@orderings)

# load test (paired) data
data(pairData)

# create a countData object from paired data
pairCD <- new("countData", data = list(pairData[,1:4], pairData[,5:8]),
             replicates = c(1,1,2,2),
             groups = list(NDE = c(1,1,1,1), DE = c(1,1,2,2)),
             densityFunction = bbDensity)
libsizes(pairCD) <- getLibsizes(pairCD)

# order on (log-)ratio of pairs, with fudge-factor on zeros.
pairCD <- makeOrderings(pairCD, orderingFunction = function(dat, observables) {
    data <- dat / observables$libsizes
    adjmin <- min(data[data > 0]) / 10
    log(data[,1] + adjmin) - log(data[,2] + adjmin)
})

# orderings calculated for DE group
head(pairCD@orderings)

marginaliseEqual

Computes marginal likelihoods that two replicate groups are equal.

Description

In cases where multiple models are simultaneously evaluated in the 'getLikelihoods' function, the posterior likelihoods for each model in which two conditions are equivalent can be summed to give the marginal likelihood of equivalence for all biomolecular events (i.e., data rows).
Usage
marginaliseEqual(cD, r1, r2)

Arguments
cD A countData object with evaluated posterior likelihoods in the '@posteriors' slot.
r1 A defined group name to identify in the '@groups' slot of the countData object 'cD'.
r2 A defined group name to identify in the '@groups' slot of the countData object 'cD'.

Value
A vector of marginal posterior likelihoods defining the probability that the two group identifiers are equal for each row of the data.

Author(s)
Thomas J. Hardcastle

See Also
allModels marginalisePairwise

Examples
# load test data
data(simData)

# Create a (countData) object from test data, supposing that there are multiple experimental groups present.
CD <- new("countData", data = simData, replicates = replicates)
CD <- allModels(CD)

# The total number of models generated is high.
length(CD@groups)

# Priors and likelihoods acquired through standard means.
## Not run: CD <- getPriors(CD, cl = cl)
## Not run: CD <- getLikelihoods(CD, cl = cl)

# Marginal likelihood that 'simA' and 'simD' replicate groups are equal
# for each row of the data.
## Not run: marginaliseEqual(CD, "simA", "simD")
marginalisePairwise

Computes marginal likelihoods that two replicate groups differ, in a particular direction.

Description

In cases where multiple models are simultaneously evaluated in the 'getLikelihoods' function, the posterior likelihoods for each model in which one condition is greater than another can be summed to give the marginal likelihood of (directed) difference for all biomolecular events (i.e., data rows).

Usage

marginalisePairwise(cD, greaterThan, lessThan)

Arguments

cD: A countData object with evaluated posterior likelihoods in the '@posteriors' slot.
greaterThan: A defined group name (or vector of group names) to identify in the '@groups' slot of the countData object 'cD'; the function will identify all models in which these groups are equivalent and greater than that defined in the 'lessThan' variable.
lessThan: A defined group name (or vector of group names) to identify in the '@groups' slot of the countData object 'cD'; the function will identify all models in which these groups are equivalent and less than that defined in the 'greaterThan' variable.

Value

A vector of marginal posterior likelihoods defining the probability that the two group identifiers are (directionally) different for each row of the data.

Author(s)

Thomas J. Hardcastle

See Also

allModels marginaliseEqual

Examples

# load test data
data(simData)

# Create a (countData) object from test data, supposing that there are # multiple experimental groups present.
replicates <- c("simA", "simA", "simB", "simC", "simD", "simE", "simE", "simF", "simG")
CD <- new("countData", data = simData, replicates = replicates)
CD <- allModels(CD)

# The total number of models generated is high.
length(CD@groups)

# Priors and likelihoods acquired through standard means.

## Not run: CD <- getPriors(CD, cl = cl)
## Not run: CD <- getLikelihoods(CD, cl = cl)

# Marginal likelihood that 'simA' condition is greater than 'simD' group
# for each row of the data.

## Not run: marginalisePairwise(CD, "simA", "simD")

methObservables

Generation of intermediate values in likelihood estimation for methylation data.

Description

Estimating prior and posterior values for methylation data that account for non-conversion rates is a time-consuming process. Significant increases in speed can be made by calculating in advance sets of data that will be re-used at several points of these analyses. This function populates the '@cellObservables' slot of a 'countData' object that contains a 'nonconversion' object in the '@sampleObservables' slot.

Usage

methObservables(mD, tail = 0.01)

Arguments

mD A countData object, or descendant, which contains a numeric vector 'nonconversion' in the '@sampleObservables' slot.

tail A cutoff on the quantile (upper and lower) of the distribution on the non-conversion. Smaller values will give a marginal increase in accuracy at high computational cost. Large values will decrease accuracy somewhat but reduce the time needed for analysis. See Details.

Details

For loci with large numbers of observed cytosines, the full dataset to be pre-computed will be very large. However, only the pre-computations near the average expression level will contribute significantly to the estimated priors and posteriors. The 'tail' parameter sets the quantile at which the distribution is considered to no longer contribute significantly to the results. Values below 0.1 are probably acceptable under nearly all circumstances.
Value

A `countData` object with the `@cellObservables` slot populated with temporary values useful in the faster calculation of likelihoods.

Author(s)

Thomas J. Hardcastle

---

mobAnnotation

Annotation data for a set of small RNA loci derived from sequencing of grafts of Arabidopsis thaliana intended for differential expression analyses.

Description

This data set is a data.frame (`mobAnnotation`) describing three thousand small RNA loci identified in a set of Arabidopsis grafting experiments.

The data acquired through sequencing for these loci is found in data file `mobData`.

Usage

data(mobAnnotation)

Format

A data.frame defining chromosome and position of the sRNA loci.

Source

Illumina sequencing.

References


See Also

mobData
Data from a set of small RNA sequencing experiments carried out on grafts of Arabidopsis thaliana intended for differential expression analyses.

Description

This data set is a matrix (‘mobData’) of counts acquired for three thousand small RNA loci from a set of Arabidopsis grafting experiments. Three different biological conditions exist within these data; one in which a Dicer 2,3,4 triple mutant shoot is grafted onto a Dicer 2,3,4 triple mutant root (SL236 and SL260), one in which a wild-type shoot is grafted onto a wild-type root (SL239 and SL240), and one in which a wild-type shoot is grafted onto a Dicer 2,3,4 triple mutant root (SL237 and SL238). Dicer 2,3,4 is required for the production of 22nt and 24nt small RNAs, as well as some 21nt ones. Consequently, if we detect differentially expressed sRNA loci in the root stock of the grafts, we can make inferences about the mobility of small RNAs.

The annotation of the loci from which these data derive is in data file ‘mobAnnotation’.

Usage

data(mobData)

Format

A matrix of which each of the six columns represents a sample, and each row an sRNA locus (acquired by sequencing).

Source

Illumina sequencing.

References


See Also

mobAnnotation
**pairData**

Simulated data for testing the baySeq package methods for paired data

**Description**

This data set is a matrix (‘pairData’) of simulated counts from a set of high-throughput sequencing data from a paired experimental design. The first four columns of data are to be paired with the second four columns of data respectively. The first two paired samples form one replicate group, the second two paired samples form another replicate group. The first hundred rows of the data are truly differentially expressed between replicate groups, the second hundred are differentially expressed between pairs, the remainder have no differential expression.

It is simulated according to a set of Poisson distributions whose parameters for each row are determined by a beta distribution on the relative proportions of data in each pairing.

**Usage**

data(pairData)

**Format**

A matrix of which each of the eight columns represents a sample, and each row some discrete data (acquired by sequencing).

**Source**

Simulation.

---

**plotMA.CD**

'MA'-plot for count data.

**Description**

This function creates an MA-plot from two sets of samples. For those data where the log-ratio is infinite (because in one set of sample data all observed counts are zero), we plot instead the log-values of the other group.

**Usage**

plotMA.CD(cD, samplesA, samplesB, normaliseData = TRUE, scale = NULL, xlab = "A", ylab = "M", ...)

plotMA.CD

Arguments

cD A countData object.
samplesA Either a character vector, identifying sample set A by either replicate name or sample name, or a numerical vector giving the columns of data in the 'countData' object that forms sample set A. See Details.
samplesB Either a character vector, identifying sample set B by either replicate name or sample name, or a numerical vector giving the columns of data in the 'countData' object that forms sample set B. See Details.
normaliseData Should the data be normalised by library size before computing log-ratios? Defaults to TRUE.
scale If given, defines the scale on which the log-ratios will be plotted. Defaults to NULL, implying that the scale will be calculated by the function.
xlab Label for the X-axis. Defaults to "A".
ylab Label for the Y-axis. Defaults to "M".
... Any other parameters to be passed to the plot function.

Details

The samples sets can be identified either by a numeric vector which specifies the columns of data from the countData object 'cD', or by a character vector. If a character vector is used, the members of the character vector will first be searched for in the @replicates slot of the 'cD' object. Any members of the vector not found in the replicates slot, will be searched for in the column names of the @data slot of the 'cD' object. Different classes of vector can be used for 'samplesA' and 'samplesB', as shown in the example below.

Value

Plotting function.

Author(s)

Thomas J. Hardcastle

See Also

countData

Examples

data(simData)
groups <- list(NDE = c(1,1,1,1,1,1,1,1,1,1), DE = c(1,1,1,1,2,2,2,2,2,2))
CD <- new("countData", data = simData, replicates = replicates, groups = groups)

# estimate library sizes for countData object
libsizes(CD) <- getLibsizes(CD)
#MA-plot comparing replicate groups

```r
plotMA.CD(CD, samplesA = "simA", samplesB = 6:10)
```

---

## plotNullPrior

*Plots distribution of null function and shows the threshold separator.*

### Description

In sequencing expression of various genomic events, it is not uncommon to find a subset of genomic events that are qualitatively different from the remainder of the data. Thus, for some function of the estimated priors, we may observe bimodality or long tails which correlate to this subset.

### Usage

```r
plotNullPrior(cD, ...)
```

### Arguments

- `cD`: A `countData` object with a `@nullFunction` slot in its `@densityFunction`.
- `...`: Additional arguments to be passed to `plot`

### Value

Invisibly, the numeric value of the threshold.

### Author(s)

Thomas J. Hardcastle

---

## plotPosteriors

*Plots the posterior likelihoods estimated for a `countData` object against the log-ratios observed between two sets of sample data.*

### Description

This function plots the posterior likelihoods estimated for a `countData` object against the log-ratios observed between two sets of sample data. For those data where the log-ratio is infinite (because in one set of sample data all observed counts are zero), we plot instead the log-values of the other group.

### Usage

```r
plotPosteriors(cD, group, samplesA, samplesB, ...)
```
### Arguments

- **cD**
  - A *countData* object, for which posterior likelihoods have been estimated (see `getPosteriors`).

- **group**
  - From which group (as defined in the 'cD@groups' slot) should posterior likelihoods be shown? Can be defined either as the number of the element in 'cD@groups' or as a string which will be partially matched to the names of the 'cD@groups' elements.

- **samplesA**
  - A numerical vector giving the columns of data in the 'countData' object that forms sample set A.

- **samplesB**
  - A numerical vector giving the columns of data in the 'countData' object that forms sample set B.

- **...**
  - Any other parameters to be passed to the `plot` function.

### Value

Plotting function.

### Author(s)

Thomas J. Hardcastle

### See Also

- `getPosteriors`

### Examples

```r
# We load in a `countData` object containing the estimated posterior likelihoods of expression (see `getLikelihoods`).
data(CDPost)

plotPosteriors(CDPost, group = "DE", samplesA = 1:5, samplesB = 6:10)

# equivalent to plotPosteriors(CDPost, group = 2, samplesA = 1:5, samplesB = 6:10)
```

---

**plotPriors**

Plots the density of the log values estimated for the mean rate in the prior data for the Negative Binomial approach to detecting differential expression

### Description

This function plots the density of the log values estimated for the mean rate in the data used to estimate a prior distribution for data under the assumption of a Negative Binomial distribution. This function is useful for looking for bimodality of the distributions, and thus determining whether we should try and identify data with no true expression.
Usage

plotPriors(cD, group, par = 1)

Arguments

cD countData object, for which priors have been estimated using the assumption
of a Negative Binomial distribution (see getPriors.NB).
group Which group should we plot the priors for? In general, should be the group that
defines non-differentially expressed data. Can be defined either as the number
of the element in 'cD@groups' or as a string which will be partially matched to
the names of the 'cD@groups' elements.
par The parameter of the prior that will be plotted.

Details

If the plot of the data appears bimodal, then it may be sensible to try and look for data with no true
expression by using the option nullPosts = TRUE in getLikelihoods.NB.

Value
Plotting function.

Author(s)
Thomas J. Hardcastle

See Also
getPriors.NB, getLikelihoods.NB

Examples

# We load in a `countData' object containing the estimated priors (see `getPriors').
data(CDPriors)
plotPriors(CDPriors, group = "NDE", par = 1)

selectTop Selects the top genomic events, based on posterior likelihoods, from a
`countData' object.

Description
This function subsets a countData object by selecting those events that best (or least) represent a
model, based on the posterior likelihoods estimated for that model and some threshold. Selection
can be done for a specific model (and ordering of the data under that model) or for all models (and
all orderings).
Usage

```r
selectTop(cD, group, ordering, orderings = TRUE, decreasing = TRUE, number = 10, likelihood, FDR, FWER, posteriors)
```

Arguments

- **cD**: A `countData` object, with a populated `@posteriors` slot (unless `posteriors` is specified; see below).
- **group**: Optionally, the model of interest, as defined in the `@groups` slot of the `countData` object. If unspecified, subsets for all models will be returned as a list.
- **ordering**: If `group` is specified, a particular ordering of the data based on that group can also be specified.
- **orderings**: If no group is specified, should the selection of models also be split by the orderings of the data under the models? Defaults to TRUE.
- **decreasing**: If FALSE, considers the data with the lowest posterior likelihoods, rather than the greatest (i.e., selects those data least likely to conform to a particular model.
- **number**: If given, selects the top `number` of genomic events for each model (and optionally, ordering). Ignored if another selection criteria is chosen, unless this criteria would return no values.
- **likelihood**: If given, selects all genomic events for a given model (and optionally, ordering) with posterior likelihood exceeding this value.
- **FDR**: If given, selects all genomic events for a given model (and optionally, ordering) with false discovery rate below this value. Ignored if likelihood is specified.
- **FWER**: If given, selects all genomic events for a given model (and optionally, ordering) with family-wise error rate below this value. Ignored if likelihood or FDR is specified.
- **posteriors**: If given, a vector of log-posterior likelihoods to use instead of those in the `@posteriors` slot of the `cD` object.

Value

Either a single `countData` object (if `group` is specified), or a named list of `countData` objects.

Author(s)

Thomas J. Hardcastle

See Also

topCounts

Examples

```r
# We load in a `countData` object containing the estimated posterior likelihoods of expression (see `getLikelihoods`).
data(CDPost)
```
# select from all models and orderings with FDR equal to or lower than 0.01.

selectTop(CDPost, FDR = 0.01)

---

| simData | Simulated data for testing the baySeq package methods |

**Description**

This data set is a matrix (‘simData’) of simulated counts from a simple pairwise expression analysis. It is simulated according to a negative binomial distribution with varying parameters for each row. The first hundred rows of the data are truly differentially expressed, the remainder have no differential expression.

**Usage**

data(simData)

**Format**

A matrix of which each of the ten columns represents a sample, and each row some discrete data (acquired by sequencing).

**Source**

Simulation.

**References**


---

| summarisePosteriors | Summarises expected number of genomic events given the calculated posterior likelihoods of a countData object. |

**Description**

Given posterior likelihoods for each model, we can calculate the expected number of genomic events corresponding to each model (and to each ordering within each model) by summing the posterior likelihoods.

**Usage**

summarisePosteriors(cD, orderings = TRUE)
**topCounts**

**Arguments**

- `cD` A `countData` object.
- `orderings` Indicates whether models should be split by orderings of the data under the model (defaults to TRUE).

**Value**

Numeric vector of expected number of genomic events belonging to each model (optionally, split by orderings).

**Author(s)**

Thomas J. Hardcastle

**See Also**

`topCounts`, `selectTop`

**Examples**

```r
# We load in a `countData` object containing the estimated posterior likelihoods of expression (see `getLikelihoods`).
data(CDPost)

# summarise the expected number of genomic events in each category
summarisePosteriors(CDPost)
```

---

**topCounts**

Get the top counts corresponding to some group from a `countData` object

**Description**

Takes posterior likelihoods and returns the counts with highest (or lowest) likelihood of association with a given group.

**Usage**

```
topCounts(cD, group, ordering, decreasing = TRUE, number = 10, likelihood, FDR, FWER, normaliseData = FALSE, posteriors)
```
Arguments

cD \hspace{0.5cm} \textit{countData} object, containing posterior likelihoods for each group (unless ‘posteriors’ is specified; see below).
group \hspace{0.5cm} \text{Which group should we give the counts for? See Details.}
ordering \hspace{0.5cm} \text{If specified, restricts the analysis to a particular ordering on the group.}
decreasing \hspace{0.5cm} \text{Ordering on posterior likelihoods.}
number \hspace{0.5cm} \text{How many results should be returned?}
likelihood \hspace{0.5cm} \text{If given, ignores ‘number’ and returns all results above a certain likelihood (and FDR, and FWER, if given).}
FDR \hspace{0.5cm} \text{If given, ignores ‘number’ and returns all results with an FDR lower than this threshold (and likelihood, and FWER, if given).}
FWER \hspace{0.5cm} \text{If given, ignores ‘number’ and returns all results with an FWER lower than this threshold (and likelihood, and FDR, if given).}
normaliseData \hspace{0.5cm} \text{Should the displayed counts be normalised? See details. Defaults to FALSE.}
posteriors \hspace{0.5cm} \text{If given, a vector of log-posterior likelihoods to use instead of those in the ‘@posteriors’ slot of the ‘cD’ object.}

Details

The argument ‘group’ can be specified either as a number, giving the index of an element in the cD@groups list, or as a character string identifying an element by name. Partial matching is allowed.
If group = NULL, then the function looks at the posterior likelihoods that the data have no true differential expression (if calculated).

If a countData object is given, the returned dataframe will contain either the raw counts for that object, or (if ‘normaliseData = TRUE’ the counts normalised by library size.

Value

A dataframe of the top counts associated with some model (group), described by annotation drawn from the ‘@annotation’ slot of the ‘cD’ object and the raw data from the ‘@data’ slot, together with the posterior likelihoods and false discovery rates.

Author(s)

Thomas J. Hardcastle

See Also

\texttt{countData}

Examples

# We load in a `countData’ object containing the estimated posterior likelihoods of expression (see `getLikelihoods’).

data(CDPost)
# Report the top ten rows of data that have highest likelihood of belonging to
# group 2 of the data (i.e., differentially expressed)

topCounts(CDPost, group = "DE", number = 10)

# equivalently...

topCounts(CDPost, group = 2, number = 10)

# Report the top ten rows of data that have highest likelihood of belonging to
# group 2 of the data (i.e., differentially expressed), with group 1
# being overexpressed compared to group 2.

topCounts(CDPost, group = "DE", ordering = "1>2", number = 10)

---

**zimData**  
Simulated data for testing the baySeq package methods

**Description**

This data set is a matrix (‘zimData’) of zero-inflated simulated counts from a simple pairwise expression analysis. It is simulated according to a negative binomial distribution with varying parameters for each row, and with zero-inflation applied to each row. The first hundred rows of the data are truly differentially expressed, the remainder have no differential expression.

**Usage**

data(zimData)

**Format**

A matrix of which each of the ten columns represents a sample, and each row some discrete data (acquired by sequencing).

**Source**

Simulation.
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