Package ‘TargetScore’

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Type Package

Title TargetScore: Infer microRNA targets using microRNA-overexpression data and sequence information

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Description Infer the posterior distributions of microRNA targets by probabilistically modelling the likelihood microRNA-overexpression fold-changes and sequence-based scores. Variational Bayesian Gaussian mixture model (VB-GMM) is applied to log fold-changes and sequence scores to obtain the posteriors of latent variable being the miRNA targets. The final targetScore is computed as the sigmoid-transformed fold-change weighted by the averaged posteriors of target components over all of the features.

Depends pracma, Matrix

Suggests TargetScoreData, gplots, Biobase, GEOquery

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URL http://www.cs.utoronto.ca/~yueli/software.html

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biocViews miRNA

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Infer the posterior distributions of microRNA targets by probabilistically modeling the likelihood microRNA-overexpression fold-changes and sequence-based scores. Variational Bayesian Gaussian mixture model (VB-GMM) is applied to log fold-changes and sequence scores to obtain the posteriors of latent variable being the miRNA targets. The final targetScore is computed as the sigmoid-transformed fold-change weighted by the averaged posteriors of target components over all of the features.

The front-end main function `targetScore` should be used to obtain the probabilistic score of miRNA target. The workhorse function is `vbgmm`, which implementates multivariate variational Bayesian Gaussian mixture model.

**Author(s)**

Yue Li <yueli@cs.toronto.edu>

**References**


**See Also**

`targetScore`
Examples

library(TargetScore)
ls("package:TargetScore")

bsxfun.se

bsxfun with single expansion (real Matlab style) (Internal function)

Description

Depending on the dimension of x, repeat y in either by row or by column and apply element-wise operation defined by func.

Usage

bsxfun.se(func, x, y, expandByRow = TRUE)

Arguments

  func        function with two or more input parameters.
  x, y        two vectors, matrices, or arrays
  expandByRow expand by row or by column of x when nrow(x)==ncol(x)==length(y)

Details

  The function is used by vbgmm.

Value

  func(x,y)   A matrix of having the same dimension of x.

Note

  Internal function.

Author(s)

  Yue Li

See Also

  bsxfun

Examples

bsxfun.se("*", matrix(c(1:10), nrow=2), matrix(c(1:5), nrow=5))
**dot.ext**  
*Elementwise dot product (modified dot function) (Internal function)*

**Description**

Same as dot but handle single row matrix differently by multiplying each value but not sum them up.

**Usage**

```r
dot.ext(x, y, mydim)
```

**Arguments**

- `x`: numeric vector or matrix
- `y`: numeric vector or matrix
- `mydim`: Elementwise product (if 1); otherwise defined by `dot`

**Details**

Returns the 'dot' or 'scalar' product of vectors or columns of matrices. Two vectors must be of same length, two matrices must be of the same size. If `x` and `y` are column or row vectors, their dot product will be computed IF `mydim` is 1 (only difference from `dot`).

**Value**

A scalar or vector of length the number of columns of `x` and `y`.

**Author(s)**

Yue Li

**See Also**

`dot`

**Examples**

```r
dot.ext(1:5, 1:5)  
dot.ext(1:5, 1:5, 1)
```
getTargetScores

Compute targetScore of an overexpressed human microRNA

Description

Obtain for each gene the targetScore using using pre-computed (logFC) TargetScan context score and PCT as sequence score. TargetScanData package is needed.

Usage

```
getTargetScores(mirID, logFC, ...)
```

Arguments

- `mirID` A character string of microRNA ID (e.g., `hsa-miR-1`)
- `logFC` N x D numeric vector or matrix of logFC with D replicates for N genes.
- `...` Parameters passed to `vbglm`

Details

This is a convenient function for computing targetScore for a human miRNA using user-supplied or pre-computed logFC and (if available) two pre-computed sequence scores namely TargetScan context score and PCT (probability of conserved targeting). The function also searches for any validated targets from the MirTarBase human validated target list. The function requires TargetScanData to be installed first.

Value

- `targetScores` numeric matrix of probabilistic targetScores together with the input variable and a binary vector indicating whether each gene is a validated target (if available).

Author(s)

Yue Li

References


See Also

```
targetScore
```
Examples

```r
if(interactive()) {

library(TargetScoreData)
library(Biobase)
library(GEOquery)

# compute targetScore from pre-computed logFC and sequence socres
# for hsa-miR-1
mir1.score <- getTargetScores("hsa-miR-1", tol=1e-3, maxiter=200)

# download fold-change data from GEO for hsa-miR-124 overexpression in HeLa
gset <- getGEO("GSE2075", GSEMatrix =TRUE, AnnotGPL=TRUE)
if (length(gset) > 1) idx <- grep("GPL1749", attr(gset, "names")) else idx <- 1
gset <- gset[[idx]]
sampleinfo <- as.character(pData(gset)$title)
geneInfo <- fData(gset)

# only 24h data are used (discard 12h data)
logfc.mir124 <- as.matrix(exprs(gset)[,
    grep("HeLa transfected with miR-1 versus control transfected HeLa, 24 hours", sampleinfo)])
rownames(logfc.mir124) <- geneInfo$"Gene symbol"
mir124.score <- getTargetScores("hsa-miR-124", logfc.mir124, tol=1e-3, maxiter=200)

head(mir124.score)
}
```

initialization

*Initialization of latent variable assignments (responsibility) of the VB-GMM (Internal function)*

**Description**

Initialize latent variables based on the number of components. The function is run before the VB-EM iteration in vbgmm.

**Usage**

```r
initialization(X, init)
```

**Arguments**

- `X`: D x N numeric vector or matrix of observations
- `init`: Based on the dimension, init is expected to be one of the followings: scalar: number of components; vector: initial class labels; matrix: initialize with a D x K matrix for D variables and K components.
Details

The function is expected to be used by vbgmm to initialize assignments of latent variables before VM-EM iterations.

Value

R

N by K matrix for N observations and K latent components (defined by init)

Author(s)

Yue Li

References


See Also

vbgmm

Examples

```r
tmp <- initialization(matrix(c(rnorm(100,mean=2), rnorm(100,mean=3)),nrow=1), init=2)
```

logmvgamma

Logarithmic multivariate Gamma function (Internal function)

Description

Compute logarithm multivariate Gamma function.

Usage

`logmvgamma(x, d)`

Arguments

x numeric vector or matrix
d dimension

Details

\[
\Gamma_p(x) = \pi^{p(p-1)/4} \prod_{j=1}^p \Gamma(x+(1-j)/2)
\]

\[
\log \Gamma_p(x) = p(p-1)/4 \log \pi + \sum_{j=1}^p \log \Gamma(x+(1-j)/2)
\]

Value

Matrix of the same dimension as x.
logsumexp

Author(s)
Yue Li

References

See Also
lgamma

Examples
logmvgamma(matrix(1:6,nrow=3), 2)

Description
Compute \( \log(\text{sum}(\exp(x),\text{dim})) \) while avoiding numerical underflow.

Usage
logsumexp(x, margin = 1)

Arguments
x numeric vector or matrix
margin dimension to apply summation

Value
numeric vector or matrix of the same columns or rows (depending on margin) as x

Author(s)
Yue Li

References

Examples
logsumexp(matrix(c(1:5)), 2)
**sort_components**

Sort mixture components in increasing order of averaged means (Internal function)

**Description**
Sort Gaussian mixture components with model parameters in increasing order of averaged means of d variables.

**Usage**

```r
sort_components(model)
```

**Arguments**

- `model` A list containing trained parameters of the Baysian GMM (see Value section in `vbgmm`).

**Value**
VB-GMM model list in increasing order of averaged means.

**Author(s)**
Yue Li

**See Also**
`vbgmm`

**Examples**

```r
tmp <- vbgmm(c(rnorm(100,mean=2), rnorm(100,mean=3)), tol=1e-3)
tmp$mu
```

---

**targetScore**

Probabilistic score of genes being the targets of an overexpressed microRNA

**Description**
Given the overexpression fold-change and sequence-scores (optional) of all of the genes, calculate for each gene the TargetScore as a probability of miRNA target.

**Usage**

```r
targetScore(logFC, seqScores, ...)
```
Arguments

logFC numeric vector of log fold-changes of N genes in treatment (miRNA overexpression) vs control (mock).

seqScores N x D numeric vector or matrix of D sequence-scores for N genes. Each score vector is expected to be equal to or less than 0. The more negative the scores, the more likely the corresponding target.

Details

Given expression fold-change (due to miRNA transfection), we use a three-component VB-GMM to infer down-regulated targets accounting for genes with little or positive log fold-change (due to off-target effects (Khan et al., 2009)). Otherwise, two-component VB-GMM is applied to unsigned sequence scores (seqScores). The parameters for the VB-GMM are optimized using Variational Bayesian Expectation-Maximization (VB-EM) algorithm. Presumably, the mixture component with the largest absolute means of observed negative fold-change or sequence score is associated with miRNA targets and denoted as “target component”. The other components correspond to the “background component”. It follows that inferring miRNA-mRNA interactions most likely explained by the observed data is equivalent to inferring the posterior distribution of the target component given the observed variables. The targetScore is computed as the sigmoid-transformed fold-change weighted by the averaged posteriors of target components over all of the features. Specifically, we define the targetScore as a composite probabilistic score of a gene being the target t of a miRNA:

\[ \text{sigmoid}(-\text{logFC}) \left( \frac{1}{K+1} \right) \sum_{x} \text{p}(t | x) \]

where \( \text{sigmoid}(-\text{logFC}) = \frac{1}{1 + \exp(\text{logFC})} \) and p(t | x) is the posterior of the first component computed by \text{vbgmm}.

Value

targetScore numeric vector of probabilistic targetScores for N genes

Author(s)

Yue Li

References


See Also

\text{vbgmm}
Examples

# A toy example:
# 10 down-reg, 1000 unchanged, 90 up-reg genes
due to overexpressing a miRNA
trmt <- c(rnorm(10, mean=0.01), rnorm(1000, mean=1), rnorm(90, mean=2)) + 1e3
ctrl <- c(rnorm(1100, mean=1)) + 1e3
logFC <- log2(trmt) - log2(ctrl)

# 8 out of the 10 down-reg genes have prominent seq score A
seqScoreA <- c(rnorm(8, mean=-2), rnorm(1092, mean=0))

# 10 down-reg genes plus 10 more genes have prominent seq score B
seqScoreB <- c(rnorm(20, mean=-2), rnorm(1080, mean=0))
seqScores <- cbind(seqScoreA, seqScoreB)
p.targetScore <- targetScore(logFC, seqScores, tol=1e-3)

vbgmm

Variational Bayesian Gaussian mixture model (VB-GMM)

Description

Given a N x D matrix of N observations and D variables, compute VB-GMM via VB-EM.

Usage

vbgmm(data, init = 2, prior, tol = 1e-20, maxiter = 2000, mirprior = TRUE, expectedTargetFreq = 0.01, verbose = FALSE)

Arguments

data N x D numeric vector or matrix of N observations (rows) and D variables (columns)
init Based on the dimension, init is expected to be one of the followings: scalar: number of components; vector: initial class labels; matrix: initialize with a D x K matrix for D variables and K components.
prior A list containing the hyperparameters including alpha (Dirichlet), m (Gaussian mean), kappa (Gaussian variance), v (Wishart degree of freedom), M (Wishart precision matrix).
tol Threshold that defines termination/convergence of VB-EM when abs(L[t] - L[t-1])/abs(L[t]) < tol
maxiter Scalar for maximum number of EM iterations
mirprior Boolean to indicate whether to use expectedTargetFreq to initialize alpha0 for the hyperparameters of Dirichlet.
expectedTargetFreq Expected target frequency within the gene population. By default, it is set to 0.01, which is consistent with the widely accepted prior knowledge that 200/20000 targets per miRNA.
verbose Boolean indicating whether to show progress in terms of lower bound (vbound) of VB-EM (default: FALSE)
Details

The function implements variation Bayesian multivariate GMM described in Bishop (2006). Please refer to the reference below for more details. This is the workhorse of targetScore. Alternatively, user can choose to apply this function to other problems other than miRNA target prediction.

Value

A list containing:

- `label`: a vector of maximum-a-posteriori (MAP) assignments of latent discrete values based on the posteriors of latent variables.
- `R`: \( N \times D \) matrix of posteriors of latent variables
- `mu`: Gaussian means of the latent components
- `full.model`: A list containing posteriors `R`, log`R`, and the model parameters including alpha (Dirichlet), m (Gaussian mean), kappa (Gaussian variance), v (Wishart degree of freedom), M (Wishart precision matrix)
- `L`: A vector of variational lower bound at each EM iterations (should be strictly increasing)

Author(s)

Yue Li

References


See Also

- targetScore

Examples

```r
X <- c(rnorm(100, mean=2), rnorm(100, mean=3))
tmp <- vbgmm(X, tol=1e-3)
names(tmp)
```

---

### vbound

#### Variational Lower Bound Evaluation

**Description**

Evaluate variational lower bound to determine when to stop VB-EM iteration (convergence).

**Usage**

```r
vbound(X, model, prior)
```
vexp

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>D x N numeric vector or matrix of N observations (columns) and D variables (rows)</td>
</tr>
<tr>
<td>model</td>
<td>List containing model parameters (see vbgmm)</td>
</tr>
<tr>
<td>prior</td>
<td>numeric vector or matrix containing the hyperparameters for the prior distributions</td>
</tr>
</tbody>
</table>

Value

A continuous scalar indicating the lower bound (the higher the more converged)

Note

X is expected to be D x N for N observations (columns) and D variables (rows)

Author(s)

Yue Li

References


See Also

vbgmm

Examples

```r
X <- c(rnorm(100, mean=2), rnorm(100, mean=3))
tmp <- vbgmm(X, tol=1e-3)
head(tmp$L) # lower bound should be strictly increasing
```

---

vexp Variational-Expectation in VB-EM (Internal function)

Description

The E step in VB-EM iteration.

Usage

vexp(X, model)
Arguments

X  D x N numeric vector or matrix of N observations (columns) and D variables (rows)

model  List containing model parameters (see \texttt{vbgmm})

Value

model  A list containing the updated model parameters including alpha (Dirichlet), m (Gaussian mean), kappa (Gaussian variance), v (Wishart degree of freedom), M (Wishart precision matrix).

Note

X is expected to be D x N for N observations (columns) and D variables (rows)

Author(s)

Yue Li

References


See Also

\texttt{vbgmm}

Examples

X <- c(rnorm(100,mean=2), rnorm(100,mean=3))
tmp <- vbgmm(X, tol=1e-3)
dim(tmp$R); head(tmp$R)

---

\texttt{vmax}  \textit{Variational-Maximimization in VB-EM (Internal function)}

Description

The M step in VB-EM iteration.

Usage

\texttt{vmax(X, model, prior)}
Arguments

X  D x N numeric vector or matrix of N observations (columns) and D variables (rows)
model List containing model parameters (see vbgmm)
prior List containing the hyperparameters defining the prior distributions

Value

model A list containing the updated model parameters including alpha (Dirichlet), m (Gaussian mean), kappa (Gaussian variance), v (Wishart degree of freedom), M (Wishart precision matrix).

Note

X is expected to be D x N for N observations (columns) and D variables (rows)

Author(s)

Yue Li

References


See Also

vbgmm

Examples

X <- c(rnorm(100,mean=2), rnorm(100,mean=3))
tmp <- vbgmm(X, tol=1e-3)
names(tmp$full.model)
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