Package ‘GeneSelectMMD’

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Type Package

Title Gene selection based on the marginal distributions of gene profiles that characterized by a mixture of three-component multivariate distributions

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Description Gene selection based on a mixture of marginal distributions

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Calculating FDR, FNDR, FPR, and FNR for a real microarray data set

Description

Calculating FDR, FNDR, FPR, and FNR for a real microarray data set based on the mixture of marginal distributions.

Usage

errRates(obj.gsMMD)

Arguments

obj.gsMMD

an object returned by gsMMD, gsMMD.default, gsMMD2, or gsMMD2.default

Details

We first fit the real microarray data set by the mixture of marginal distributions. Then we calculate the error rates based on the posterior distributions of a gene belonging to a gene cluster given its gene profiles. Please refer to Formula (7) on the page 6 of the paper listed in the Reference section.

Value

A vector of 4 elements:

- FDR: the percentage of nondifferentially expressed genes among selected genes.
- FNDR: the percentage of differentially expressed genes among unselected genes.
- FPR: the percentage of selected genes among nondifferentially expressed genes.
- FNR: the percentage of un-selected genes among differentially expressed genes.

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References


Examples

```r
## Not run:
library(ALL)
data(ALL)
eSet1 <- ALL[1:100, ALL$BT == "B3" | ALL$BT == "T2"]
mem.str <- as.character(eSet1$BT)
```
gsMMD

Gene selection based on a mixture of marginal distributions

Description

Gene selection based on the marginal distributions of gene profiles that characterized by a mixture of three-component multivariate distributions. Input is an object derived from the class ExpressionSet. The function will obtain initial gene cluster membership by its own.

Usage

gsMMD(obj.eSet,  
memSubjects,  
maxFlag = TRUE,  
thrshPostProb = 0.5,  
geneNames = NULL,  
alpha = 0.05,  
iniGeneMethod = "Ttest",  
transformFlag = FALSE,  
transformMethod = "boxcox",  
scaleFlag = TRUE,  
criterion = c("cor", "skewness", "kurtosis"),  
minL = -10,  
maxL = 10,  
stepL = 0.1,  
eps = 0.001,  
ITMAX = 100,  
plotFlag = FALSE,  
quiet=TRUE)

Arguments

obj.eSet an object derived from the class ExpressionSet which contains the matrix of gene expression levels. The rows of the matrix are genes. The columns of the matrix are subjects.

memSubjects a vector of membership of subjects. memSubjects[i]=1 means the i-th subject belongs to diseased group, 0 otherwise.

maxFlag logical. Indicate how to assign gene class membership. maxFlag=TRUE means that a gene will be assigned to a class in which the posterior probability of the gene belongs to this class is maximum. maxFlag=FALSE means that a gene
will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. Similarly, a gene will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. If the posterior probability is less than thrshPostProb, the gene will be assigned to class 2 (non-differentially expressed gene group).

thrshPostProb
threshold for posterior probabilities. For example, if the posterior probability that a gene belongs to cluster 1 given its gene expression levels is larger than thrshPostProb, then this gene will be assigned to cluster 1.

geneNames
an optional character vector of gene names

alpha
significant level which is equal to 1-conf.level, conf.level is the argument for the function t.test.

iniGeneMethod
method to get initial 3-cluster partition of genes. Available methods are: "Ttest", "Wilcox".

transformFlag
logical. Indicate if data transformation is needed

transformMethod
method for transforming data. Available methods include "boxcox", "log2", "log10", "log", "none".

scaleFlag
logical. Indicate if gene profiles are to be scaled to have mean zero and variance one. If transformFlag=TRUE and scaleFlag=TRUE, then scaling is performed after transformation. To avoid linear dependence of tissue samples after scaling gene profiles, we delete one tissue sample after scaling (c.f. details).

criterion
if transformFlag=TRUE, criterion indicates what criterion to determine if data looks like normal. “cor” means using Pearson’s correlation. The idea is that the observed quantiles after transformation should be close to theoretical normal quantiles. So we can use Pearson’s correlation to check if the scatter plot of theoretical normal quantiles versus observed quantiles is a straight line. “skewness” means using skewness measure to check if the distribution of the transformed data are close to normal distribution; “kurtosis” means using kurtosis measure to check normality.

minL
lower limit for the lambda parameter used in Box-Cox transformation

maxL
upper limit for the lambda parameter used in Box-Cox transformation

stepL
tolerance when searching the optimal lambda parameter used in Box-Cox transformation

eps
a small positive value. If the absolute value of a value is smaller than eps, this value is regarded as zero.

ITMAX
maximum iteration allowed for iterations in the EM algorithm

plotFlag
logical. Indicate if the Box-Cox normality plot should be output.

quiet
logical. Indicate if intermediate results should be printed out.

Details

We assume that the distribution of gene expression profiles is a mixture of 3-component multivariate normal distributions \( \sum_{k=1}^{3} \pi_k f_k(x|\theta) \). Each component distribution \( f_k \) corresponds to a gene cluster. The 3 components correspond to 3 gene clusters: (1) up-regulated gene cluster, (2) non-differentially expressed gene cluster, and (3) down-regulated gene cluster. The model parameter vector is \( \theta = (\pi_1, \pi_3, \mu_{c1}, \sigma_{c1}^2, \rho_c, \mu_n, \sigma_n^2, \rho_n, \mu_{c2}, \sigma_{c2}^2, \rho_{c2}, \mu_{c3}, \sigma_{c3}^2, \rho_{c3}, \mu_{n3}, \sigma_{n3}^2, \rho_{n3}) \), where \( \pi_1, \pi_2, \) and \( \pi_3 \) are the mixing proportions; \( \mu_{c1}, \sigma_{c1}^2, \) and \( \rho_c \) are the marginal mean, variance, and correlation of gene expression levels of cluster 1 (up-regulated genes) for diseased subjects;
\[ \mu_{n1}, \sigma_{\mu1}^2, \text{ and } \rho_{n1} \text{ are the marginal mean, variance, and correlation of gene expression levels of cluster 1 (up-regulated genes) for non-diseased subjects; } \mu_{n2}, \sigma_{\mu2}^2, \text{ and } \rho_{n2} \text{ are the marginal mean, variance, and correlation of gene expression levels of cluster 2 (non-differentially expressed genes); } \mu_{c3}, \sigma_{\mu3}^2, \text{ and } \rho_{c3} \text{ are the marginal mean, variance, and correlation of gene expression levels of cluster 3 (up-regulated genes) for diseased subjects; } \mu_{n3}, \sigma_{\mu3}^2, \text{ and } \rho_{n3} \text{ are the marginal mean, variance, and correlation of gene expression levels of cluster 3 (up-regulated genes) for non-diseased subjects.} \]

Note that genes in cluster 2 are non-differentially expressed across abnormal and normal tissue samples. Hence there are only 3 parameters for cluster 2.

To make sure the identifiability, we set the following contraints: \( \mu_{c1} > \mu_{n1} \) and \( \mu_{c3} < \mu_{n3} \).

To make sure the marginal covariance matrices are positive definite, we set the following contraints:

\[
-1/(n_0 - 1) < \rho_{n1} < 1, -1/(n_1 - 1) < \rho_{n1} < 1, -1/(n_1 - 1) < \rho_{c1} < 1,
-1/(n_1 - 1) < \rho_{c3} < 1.
\]

We also has the following constraints for the mixing proportion: \( \pi_3 = 1 - \pi_1 - \pi_2, \pi_k > 0, k = 1, 2, 3. \)

We apply the EM algorithm to estimate the model parameters. We regard the cluster membership of genes as missing values.

To facilitate the estimation of the parameters, we reparameterize the parameter vector as \( \theta^* = (\pi_1, \pi_2, \mu_{c1}, \sigma_{\mu1}^2, r_{c1}, \delta_{n1}, \sigma_{\mu1}^2, r_{n1}, \mu_2, \sigma_{\mu2}^2, r_{c2}, \delta_{c2}, \sigma_{\mu2}^2, r_{c3}, \delta_{c3}, \sigma_{\mu3}^2, r_{n3}), \) where \( \mu_{n1} = \mu_{c1} - \exp(\delta_{n1}), \mu_{n3} = \mu_{c3} + \exp(\delta_{n3}), \rho_{c1} = (\exp(r_{c1}) - 1)/(n_1 - 1)/(1 + \exp(r_{c1})), \rho_{c3} = (\exp(r_{c3}) - 1)/(n_1 - 1)/(1 + \exp(r_{c3})), \rho_{n3} = (\exp(r_{n3}) - 1)/(n_1 - 1)/(1 + \exp(r_{n3})). \)

Given a gene, the expression levels of the gene are assumed independent. However, after scaling, the scaled expression levels of the gene are no longer independent and the rank \( r^* = r - 1 \) of the covariance matrix for the scaled gene profile will be one less than the rank \( r \) for the un-scaled gene profile. Hence the covariance matrix of the gene profile will no longer be positive-definite. To avoid this problem, we delete a tissue sample after scaling since its information has been incorporated by other scaled tissue samples. We arbitrarily select the tissue sample, which has the biggest label number, from the tissue sample group that has larger size than the other tissue sample group. For example, if there are 6 cancer tissue samples and 10 normal tissue samples, we delete the 10-th normal tissue sample after scaling.

**Value**

A list contains 18 elements.

- **dat** the (transformed) microarray data matrix. If tranformation performed, then dat will be different from the input microarray data matrix.
- **memSubjects** the same as the input **memSubjects**.
- **memGenes** a vector of cluster membership of genes. 1 means up-regulated gene; 2 means non-differentially expressed gene; 3 means down-regulated gene.
- **memGenes2** an variant of the vector of cluster membership of genes. 1 means differently expressed gene; 0 means non-differentially expressed gene.
- **para** parameter estimates (c.f. details).
- **llkh** value of the loglikelihood function.
- **wiMat** posterior probability that a gene belongs to a cluster given the expression levels of this gene. Column i is for cluster i.
- **wiArray** posterior probability matrix for different initial gene selection methods.
memIniMat  a matrix of initial cluster membership of genes.
paraIniMat a matrix of parameter estimates based on initial gene cluster membership.
llkhIniVec a vector of values of loglikelihood function.
memMat    a matrix of cluster membership of genes based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.
paraMat   a matrix of parameter estimates based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.
llkhVec   a vector of values of loglikelihood function based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.
lambda    the parameter used to do Box-Cox transformation
paraRP    parameter estimates for reparametrized parameter vector (c.f. details).
paraIniMatRP a matrix of parameter estimates for reparametrized parameter vector based on initial gene cluster membership.
paraMatRP a matrix of parameter estimates for reparametrized parameter vector based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.

Note
The speed of the program can be slow for large data sets, however it has been improved using Fortran code.

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References

See Also
gsMMD.default, gsMMD2, gsMMD2.default

Examples
library(ALL)
data(ALL)
eSet1 <- ALL[1:100, ALL$BT == "B3" | ALL$BT == "T2"]
mem.str <- as.character(eSet1$BT)
nSubjects <- length(mem.str)
memSubjects <- rep(0, nSubjects)
# B3 coded as 0, T2 coded as 1
memSubjects[mem.str == "T2"] <- 1
obj.gsMMD <- gsMMD(eSet1, memSubjects, transformFlag = TRUE,
Gene selection based on a mixture of marginal distributions

Description

Gene selection based on the marginal distributions of gene profiles that characterized by a mixture of three-component multivariate distributions. Input is a data matrix. The function will obtain initial gene cluster membership by its own.

Usage

gsMMD.default(X, 
  memSubjects, 
  maxFlag = TRUE, 
  thrshPostProb = 0.5, 
  geneNames = NULL, 
  alpha = 0.05, 
  iniGeneMethod = "Ttest", 
  transformFlag = FALSE, 
  transformMethod = "boxcox", 
  scaleFlag = TRUE, 
  criterion = c("cor", "skewness", "kurtosis"), 
  minL = -10, 
  maxL = 10, 
  stepL = 0.1, 
  eps = 0.001, 
  ITMAX = 100, 
  plotFlag = FALSE, 
  quiet=TRUE)

Arguments

X a data matrix. The rows of the matrix are genes. The columns of the matrix are subjects.

memSubjects a vector of membership of subjects. memSubjects[i]=1 means the i-th subject belongs to diseased group, 0 otherwise.

maxFlag logical. Indicate how to assign gene class membership. maxFlag=TRUE means that a gene will be assigned to a class in which the posterior probability of the gene belongs to this class is maximum. maxFlag=FALSE means that a gene will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. Similarly, a gene will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. If the posterior probability is less than thrshPostProb, the gene will be assigned to class 2 (non-differentially expressed gene group).

thrshPostProb threshold for posterior probabilities. For example, if the posterior probability that a gene belongs to cluster 1 given its gene expression levels is larger than thrshPostProb, then this gene will be assigned to cluster 1.
geneNames  an optional character vector of gene names
alpha      significant level which is equal to 1-conf.level, conf.level is the argument for the function t.test.
iniGeneMethod method to get initial 3-cluster partition of genes. Available methods are: “Ttest”, “Wilcox”.
transformFlag logical. Indicate if data transformation is needed
transformMethod method for transforming data. Available methods include "boxcox", "log2", "log10", "log", "none".
scaleFlag   logical. Indicate if gene profiles are to be scaled. If transformFlag=TRUE and scaleFlag=TRUE, then scaling is performed after transformation. To avoid linear dependence of tissue samples after scaling gene profiles, we delete one tissue sample after scaling (c.f. details).
criterion   if transformFlag=TRUE, criterion indicates what criterion to determine if data looks like normal. “cor” means using Pearson’s correlation. The idea is that the observed quantiles after transformation should be close to theoretical normal quantiles. So we can use Pearson’s correlation to check if the scatter plot of theoretical normal quantiles versus observed quantiles is a straightline. “skewness” means using skewness measure to check if the distribution of the transformed data are close to normal distribution; “kurtosis” means using kurtosis measure to check normality.
minL        lower limit for the lambda parameter used in Box-Cox transformation
maxL        upper limit for the lambda parameter used in Box-Cox transformation
stepL       tolerance when searching the optimal lambda parameter used in Box-Cox transformation
eps         a small positive value. If the absolute value of a value is smaller than eps, this value is regarded as zero.
ITMAX       maximum iteration allowed for iterations in the EM algorithm
plotFlag    logical. Indicate if the Box-Cox normality plot should be output.
quiet       logical. Indicate if intermediate results should be printed out.

Details

We assume that the distribution of gene expression profiles is a mixture of 3-component multivariate normal distributions $\sum_{k=1}^{3} \pi_k f_k(x | \theta)$. Each component distribution $f_k$ corresponds to a gene cluster. The 3 components correspond to 3 gene clusters: (1) up-regulated gene cluster, (2) non-differentially expressed gene cluster, and (3) down-regulated gene cluster. The model parameter vector is $\theta = (\pi_1, \pi_2, \pi_3, \mu_{c1}, \mu_{n1}, \sigma_{c1}^2, \sigma_{n1}^2, \rho_{c1}, \rho_{n1}, \mu_{c2}, \mu_{n2}, \sigma_{c2}^2, \sigma_{n2}^2, \rho_{c2}, \rho_{n2}, \mu_{c3}, \sigma_{c3}^2, \sigma_{n3}^2, \rho_{c3}, \rho_{n3})$, where $\pi_1, \pi_2, \text{ and } \pi_3$ are the mixing proportions; $\mu_{c1}, \sigma_{c1}^2, \text{ and } \rho_{c1}$ are the marginal mean, variance, and correlation of gene expression levels of cluster 1 (up-regulated genes) for diseased subjects; $\mu_{n1}, \sigma_{n1}^2, \text{ and } \rho_{n1}$ are the marginal mean, variance, and correlation of gene expression levels of cluster 1 (up-regulated genes) for non-diseased subjects; $\mu_{c2}, \sigma_{c2}^2, \text{ and } \rho_{c2}$ are the marginal mean, variance, and correlation of gene expression levels of cluster 2 (non-differentially expressed genes); $\mu_{c3}, \sigma_{c3}^2, \text{ and } \rho_{c3}$ are the marginal mean, variance, and correlation of gene expression levels of cluster 3 (up-regulated genes) for diseased subjects; $\mu_{n3}, \sigma_{n3}^2, \text{ and } \rho_{n3}$ are the marginal mean, variance, and correlation of gene expression levels of cluster 3 (up-regulated genes) for non-diseased subjects.

Note that genes in cluster 2 are non-differentially expressed across abnormal and normal tissue samples. Hence there are only 3 parameters for cluster 2.
To make sure the identifiability, we set the following contraints: \( \mu_{c1} > \mu_{n1} \) and \( \mu_{c3} < \mu_{n3} \).

To make sure the marginal covariance matrices are positive definite, we set the following contraints:

\[
-1/(n_c - 1) < \rho_{c1} < 1, \quad -1/(n_n - 1) < \rho_{n1} < 1, \quad -1/(n_c - 1) < \rho_{c3} < 1, \quad -1/(n_n - 1) < \rho_{n3} < 1.
\]

We also has the following constraints for the mixing proportion: \( \pi_3 = 1 - \pi_1 - \pi_2, \pi_k > 0, k = 1, 2, 3. \)

We apply the EM algorithm to estimate the model parameters. We regard the cluster membership of genes as missing values.

To facilitate the estimation of the parameters, we reparametrize the parameter vector as \( \theta^* = (\pi_1, \pi_2, \mu_{c1}, \sigma_{\mu c1}^2, \rho_{c1}, \delta_{\mu c1}, \sigma_{\delta c1}^2, r_{c1}, \mu_{n1}, \sigma_{\mu n1}^2, \rho_{n1}, \delta_{\mu n1}, \sigma_{\delta n1}^2, r_{n1}, \mu_{c2}, \sigma_{\mu c2}^2, \rho_{c2}, \delta_{\mu c2}, \sigma_{\delta c2}^2, r_{c2}, \mu_{c3}, \sigma_{\mu c3}^2, \rho_{c3}, \delta_{\mu c3}, \sigma_{\delta c3}^2, r_{c3}), \) where \( \mu_{n1} = \mu_{c1} - \exp(\delta_{n1}), \mu_{n3} = \mu_{c3} + \exp(\delta_{n3}), \rho_{n1} = (\exp(r_{c1})-1/(n_c-1))/(1+\exp(r_{c1})), \rho_{n3} = (\exp(r_{n1})-1/(n_n-1))/(1+\exp(r_{n1})), \rho_{c2} = (\exp(r_{c2})-1/(n_c-1))/(1+\exp(r_{c2})), \rho_{c3} = (\exp(r_{c3})-1/(n_c-1))/(1+\exp(r_{c3})). \)

Given a gene, the expression levels of the gene are assumed independent. However, after scaling, the scaled expression levels of the gene are no longer independent and the rank \( r^* = r - 1 \) of the covariance matrix for the scaled gene profile will be one less than the rank \( r \) for the un-scaled gene profile. Hence the covariance matrix of the gene profile will no longer be positive-definite. To avoid this problem, we delete a tissue sample after scaling since its information has been incorrporated by other scaled tissue samples. We arbitrarily select the tissue sample, which has the biggest label number, from the tissue sample group that has larger size than the other tissue sample group. For example, if there are 6 cancer tissue samples and 10 normal tissue samples, we delete the 10-th normal tissue sample after scaling.

**Value**

A list contains 18 elements.

- **dat** the (transformed) microarray data matrix. If transformation performed, then dat will be different from the input microarray data matrix.
- **memSubjects** the same as the input memSubjects.
- **memGenes** a vector of cluster membership of genes. 1 means up-regulated gene; 2 means non-differentially expressed gene; 3 means down-regulated gene.
- **memGenes2** an variant of the vector of cluster membership of genes. 1 means differentially expressed gene; 0 means non-differentially expressed gene.
- **para** parameter estimates (c.f. details).
- **llkh** value of the loglikelihood function.
- **wiMat** posterior probability that a gene belongs to a cluster given the expression levels of this gene. Column i is for cluster i.
- **wiArray** posterior probability matrix for different initial gene selection methods.
- **memIniMat** a matrix of initial cluster membership of genes.
- **paraIniMat** a matrix of parameter estimates based on initial gene cluster membership.
- **llkhIniVec** a vector of values of loglikelihood function.
- **memMat** a matrix of cluster membership of genes based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.
- **paraMat** a matrix of parameter estimates based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.
llkhVec a vector of values of loglikelihood function based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.

lambda the parameter used to do Box-Cox transformation

paraRP parameter estimates for reparametrized parameter vector (c.f. details).

paraIniMatRP a matrix of parameter estimates for reparametrized parameter vector based on initial gene cluster membership.

paraMatRP a matrix of parameter estimates for reparametrized parameter vector based on the mixture of marginal models with initial parameter estimates obtained initial gene cluster membership.

Note

The speed of the program can be slow for large data sets, however it has been improved using Fortran code.

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References


See Also

gsMMD, gsMMD2, gsMMD2.default

Examples

```r
## Not run:
library(ALL)
data(ALL)
eSet1 <- ALL[1:100, ALL$BT == "B3" | ALL$BT == "T2"]
mat <- exprs(eSet1)

mem.str <- as.character(eSet1$BT)
nSubjects <- length(mem.str)
memSubjects <- rep(0, nSubjects)
# B3 coded as 0, T2 coded as 1
memSubjects[mem.str == "T2"] <- 1

obj.gsMMD <- gsMMD.default(mat, memSubjects, iniGeneMethod = "Ttest",
transformFlag = TRUE, transformMethod = "boxcox", scaleFlag = TRUE)
round(obj.gsMMD$para, 3)

## End(Not run)
```
Gene selection based on a mixture of marginal distributions

Description
Gene selection based on the marginal distributions of gene profiles that characterized by a mixture of three-component multivariate distributions. Input is an object derived from the class ExpressionSet. The user needs to provide initial gene cluster membership.

Usage

\[
gsMMD2(obj.eSet, 
  memSubjects, 
  memIni, 
  maxFlag = TRUE, 
  thrshPostProb = 0.5, 
  geneNames = NULL, 
  alpha = 0.05, 
  transformFlag = FALSE, 
  transformMethod = "boxcox", 
  scaleFlag = TRUE, 
  criterion = c("cor", "skewness", "kurtosis"), 
  minL = -10, 
  maxL = 10, 
  stepL = 0.1, 
  eps = 0.001, 
  ITMAX = 100, 
  plotFlag = FALSE, 
  quiet=TRUE) 
\]

Arguments

- **obj.eSet**: an object derived from the class ExpressionSet which contains the matrix of gene expression levels. The rows of the matrix are genes. The columns of the matrix are subjects.
- **memSubjects**: a vector of membership of subjects. memSubjects[1]=1 means that the i-th subject belongs to diseased group, 0 otherwise.
- **memIni**: a vector of user-provided gene cluster membership.
- **maxFlag**: logical. Indicate how to assign gene class membership. maxFlag=TRUE means that a gene will be assigned to a class in which the posterior probability of the gene belongs to this class is maximum. maxFlag=FALSE means that a gene will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. Similarly, a gene will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. If the posterior probability is less than thrshPostProb, the gene will be assigned to class 2 (non-differentially expressed gene group).
- **thrshPostProb**: threshold for posterior probabilities. For example, if the posterior probability that a gene belongs to cluster 1 given its gene expression levels is larger than thrshPostProb, then this gene will be assigned to cluster 1.
geneNames  an optional character vector of gene names
alpha    significant level which is equal to 1-conf.level, conf.level is the argument for the function t.test.
transformFlag logical. Indicate if data transformation is needed
transformMethod method for transforming data. Available methods include "boxcox", "log2", "log10", "log", "none".
scaleFlag logical. Indicate if gene profiles are to be scaled. If transformFlag=TRUE and
               scaleFlag=TRUE, then scaling is performed after transformation. To avoid lin-
               ear dependence of tissue samples after scaling gene profiles, we delete one tissue
               sample after scaling (c.f. details).
criterion if transformFlag=TRUE, criterion indicates what criterion to determine if
               data looks like normal. “cor” means using Pearson’s correlation. The idea is
               that the observed quantiles after transformation should be close to theoretical
               normal quantiles. So we can use Pearson’s correlation to check if the scatter
               plot of theoretical normal quantiles versus observed quantiles is a straightline.
               “skewness” means using skewness measure to check if the distribution of the
               transformed data are close to normal distribution; "kurtosis" means using kurto-
               sis measure to check normality.
minL      lower limit for the \lambda parameter used in Box-Cox transformation
maxL      upper limit for the \lambda parameter used in Box-Cox transformation
stepL    tolerance when searching the optimal \lambda parameter used in Box-Cox trans-
         formation
eps       a small positive value. If the absolute value of a value is smaller than eps, this
         value is regarded as zero.
ITMAX     maximum iteration allowed for iterations in the EM algorithm
plotFlag logical. Indicate if the Box-Cox normality plot should be output.
quiet     logical. Indicate if intermediate results should be printed out.

Details

We assume that the distribution of gene expression profiles is a mixture of 3-component multivari-
ate normal distributions \sum_{k=1}^{3} \pi_k f_k(x|\theta). Each component distribution f_k corresponds to a gene
cluster. The 3 components correspond to 3 gene clusters: (1) up-regulated gene cluster, (2) non-
differentially expressed gene cluster, and (3) down-regulated gene cluster. The model parameter
vector is \theta = (\pi_1, \pi_2, \pi_3, \mu_{c1}, \sigma^2_{c1}, \rho_{c1}, \mu_{n1}, \sigma^2_{n1}, \rho_{n1}, \mu_{c2}, \sigma^2_{c2}, \rho_{c2}, \mu_{c3}, \sigma^2_{c3}, \rho_{c3}, \mu_{n3}, \sigma^2_{n3}, \rho_{n3}),
where \pi_1, \pi_2, and \pi_3 are the mixing proportions; \mu_{c1}, \sigma^2_{c1}, and \rho_{c1} are the marginal mean, variance,
and correlation of gene expression levels of cluster 1 (up-regulated genes) for diseased subjects;
\mu_{n1}, \sigma^2_{n1}, and \rho_{n1} are the marginal mean, variance, and correlation of gene expression levels of
cluster 1 (up-regulated genes) for non-diseased subjects; \mu_{c2}, \sigma^2_{c2}, and \rho_{c2} are the marginal mean,
variance, and correlation of gene expression levels of cluster 2 (non-differentially expressed genes);
\mu_{c3}, \sigma^2_{c3}, and \rho_{c3} are the marginal mean, variance, and correlation of gene expression levels of
cluster 3 (up-regulated genes) for diseased subjects; \mu_{n3}, \sigma^2_{n3}, and \rho_{n3} are the marginal mean, variance,
and correlation of gene expression levels of cluster 3 (up-regulated genes) for non-diseased
subjects.

Note that genes in cluster 2 are non-differentially expressed across abnormal and normal tissue
samples. Hence there are only 3 parameters for cluster 2.

To make sure the identifiability, we set the following contraints: \mu_{c1} > \mu_{n1} and \mu_{c3} < \mu_{n3}.
To make sure the marginal covariance matrices are positive definite, we set the following constraints:
\[-1/(n_c - 1) < \rho_{c1} < 1, -1/(n_n - 1) < \rho_{n1} < 1, -1/(n - 1) < \rho_2 < 1, -1/(n_c - 1) < \rho_{c3} < 1, -1/(n_n - 1) < \rho_{n3} < 1.\]

We also have the following constraints for the mixing proportion: \(\pi_3 = 1 - \pi_1 - \pi_2, \pi_k > 0, k = 1, 2, 3.\)

We apply the EM algorithm to estimate the model parameters. We regard the cluster membership of genes as missing values.

To facilitate the estimation of the parameters, we reparametrize the parameter vector as \(\theta^* = (\pi_1, \pi_2, \mu_{c1}, \sigma_{c1}^2, r_{c1}, \delta_{n1}, \sigma_{n1}^2, r_{n1}, \mu_2, \sigma_2^2, r_2, \mu_{c3}, \sigma_{c3}^2, r_{c3}, \delta_{n3}, \sigma_{n3}^2, r_{n3}),\) where \(\mu_{n1} = \mu_{c1} - \exp(\delta_{n1}), \mu_{n3} = \mu_{c3} + \exp(\delta_{n3}), \rho_{c1} = (\exp(r_{c1}) - 1/(n_c - 1))/(1 + \exp(r_{c1})), \rho_{n1} = (\exp(r_{n1}) - 1/(n_n - 1))/(1 + \exp(r_{n1})),\) \(\rho_2 = (\exp(r_2) - 1/(n - 1))/(1 + \exp(r_2)),\) \(\rho_{c3} = (\exp(r_{c3}) - 1/(n_c - 1))/(1 + \exp(r_{c3})),\) \(\rho_{n3} = (\exp(r_{n3}) - 1/(n_n - 1))/(1 + \exp(r_{n3})).\)

Given a gene, the expression levels of the gene are assumed independent. However, after scaling, the scaled expression levels of the gene are no longer independent and the rank \(r^* = r - 1\) of the covariance matrix for the scaled gene profile will be one less than the rank \(r\) for the un-scaled gene profile. Hence the covariance matrix of the gene profile will no longer be positive-definite. To avoid this problem, we delete a tissue sample after scaling since its information has been incorporated by other scaled tissue samples. We arbitrarily select the tissue sample, which has the biggest label number, from the tissue sample group that has larger size than the other tissue sample group. For example, if there are 6 cancer tissue samples and 10 normal tissue samples, we delete the 10-th normal tissue sample after scaling.

**Value**

A list contains 13 elements.

- **dat** the (transformed) microarray data matrix. If transformation performed, then dat will be different from the input microarray data matrix.
- **memSubjects** the same as the input memSubjects.
- **memGenes** a vector of cluster membership of genes. 1 means up-regulated gene; 2 means non-differentially expressed gene; 3 means down-regulated gene.
- **memGenes2** an variant of the vector of cluster membership of genes. 1 means differentially expressed gene; 0 means non-differentially expressed gene.
- **para** parameter estimates (c.f. details).
- **lkh** value of the loglikelihood function.
- **wiMat** posterior probability that a gene belongs to a cluster given the expression levels of this gene. Column i is for cluster i.
- **memIni** the initial cluster membership of genes.
- **paraIni** the parameter estimates based on initial gene cluster membership.
- **lkhIni** the value of loglikelihood function.
- **lambda** the parameter used to do Box-Cox transformation
- **paraRP** parameter estimates for reparametrized parameter vector (c.f. details).
- **paraIniRP** the parameter estimates for reparametrized parameter vector based on initial gene cluster membership.

**Note**

The speed of the program can be slow for large data sets, however it has been improved using Fortran code.
gsMMD2

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References


See Also
gsMMD, gsMMD.default, gsMMD2.default

Examples

```r
## Not run:
library(ALL)
data(ALL)
eSet1 <- ALL[1:100, ALL$BT == "B3" | ALL$BT == "T2"]

mem.str <- as.character(eSet1$BT)
nSubjects <- length(mem.str)
memSubjects <- rep(0, nSubjects)
# B3 coded as 0, T2 coded as 1
memSubjects[mem.str == "T2"] <- 1

myWilcox <-
function(x, memSubjects, alpha = 0.05)
{
  xc <- x[memSubjects == 1]
  xn <- x[memSubjects == 0]

  m <- sum(memSubjects == 1)
  res <- wilcox.test(x = xc, y = xn, conf.level = 1 - alpha)
  res2 <- c(res$p.value, res$statistic - m * (m + 1) / 2)
  names(res2) <- c("p.value", "statistic")
  return(res2)
}

mat <- exprs(eSet1)
tmp <- t(apply(mat, 1, myWilcox, memSubjects = memSubjects))
colnames(tmp) <- c("p.value", "statistic")
memIni <- rep(2, nrow(mat))
memIni[tmp[, 1] < 0.05 & tmp[, 2] > 0] <- 1
memIni[tmp[, 1] < 0.05 & tmp[, 2] < 0] <- 3

cat("initial gene cluster size>>"); print(table(memIni)); cat("n");

obj.gsMMD <- gsMMD2(eSet1, memSubjects, memIni, transformFlag = TRUE, transformMethod = "boxcox", scaleFlag = TRUE, quiet = FALSE)
round(obj.gsMMD$para, 3)

## End(Not run)
```
Description

Gene selection based on the marginal distributions of gene profiles that characterized by a mixture of three-component multivariate distributions. Input is a data matrix. The user needs to provide initial gene cluster membership.

Usage

gsMMD2.default(X, memSubjects, memIni, maxFlag = TRUE, thrshPostProb = 0.5, geneNames = NULL, alpha = 0.05, transformFlag = FALSE, transformMethod = "boxcox", scaleFlag = TRUE, criterion = c("cor", "skewness", "kurtosis"), minL = -10, maxL = 10, stepL = 0.1, eps = 0.001, ITMAX = 100, plotFlag = FALSE, quiet = TRUE)

Arguments

X a data matrix. The rows of the matrix are genes. The columns of the matrix are subjects.

memSubjects a vector of membership of subjects. memSubjects[i]=1 means the i-th subject belongs to diseased group, 0 otherwise.

memIni a vector of user-provided gene cluster membership.

maxFlag logical. Indicate how to assign gene class membership. maxFlag=TRUE means that a gene will be assigned to a class in which the posterior probability of the gene belongs to this class is maximum. maxFlag=FALSE means that a gene will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. Similarly, a gene will be assigned to class 1 if the posterior probability of the gene belongs to class 1 is greater than thrshPostProb. If the posterior probability is less than thrshPostProb, the gene will be assigned to class 2 (non-differentially expressed gene group).

thrshPostProb threshold for posterior probabilities. For example, if the posterior probability that a gene belongs to cluster 1 given its gene expression levels is larger than thrshPostProb, then this gene will be assigned to cluster 1.

geneNames an optional character vector of gene names
alpha  

Significant level which is equal to \(1 - \text{conf.level}\), \text{conf.level} is the argument for the function \(t\text{.test}\).

transformFlag  

Logical. Indicate if data transformation is needed.

transformMethod  

Method for transforming data. Available methods include "boxcox", "log2", "log10", "log", "none".

scaleFlag  

Logical. Indicate if gene profiles are to be scaled. If \(\text{transformFlag} = \text{TRUE}\) and \(\text{scaleFlag} = \text{TRUE}\), then scaling is performed after transformation. To avoid linear dependence of tissue samples after scaling gene profiles, we delete one tissue sample after scaling (c.f. details).

criterion  

If \(\text{transformFlag} = \text{TRUE}\), \text{criterion} indicates what criterion to determine if data looks like normal. "cor" means using Pearson’s correlation. The idea is that the observed quantiles after transformation should be close to theoretical normal quantiles. So we can use Pearson’s correlation to check if the scatter plot of theoretical normal quantiles versus observed quantiles is a straight line. "skewness" means using skewness measure to check if the distribution of the transformed data are close to normal distribution; "kurtosis" means using kurtosis measure to check normality.

minL  

Lower limit for the \(\lambda\) parameter used in Box-Cox transformation.

maxL  

Upper limit for the \(\lambda\) parameter used in Box-Cox transformation.

stepL  

Tolerance when searching the optimal \(\lambda\) parameter used in Box-Cox transformation.

eps  

A small positive value. If the absolute value of a value is smaller than \(\text{eps}\), this value is regarded as zero.

ITMAX  

Maximum iteration allowed for iterations in the EM algorithm.

plotFlag  

Logical. Indicate if the Box-Cox normality plot should be output.

quiet  

Logical. Indicate if intermediate results should be printed out.

Details

We assume that the distribution of gene expression profiles is a mixture of 3-component multivariate normal distributions \(\sum_{k=1}^{3} \pi_k f_k(x|\theta)\). Each component distribution \(f_k\) corresponds to a gene cluster. The 3 components correspond to 3 gene clusters: (1) up-regulated gene cluster, (2) non-differentially expressed gene cluster, and (3) down-regulated gene cluster. The model parameter vector is \(\theta = (\pi_1, \pi_2, \pi_3, \mu_{c1}, \sigma_{c1}^2, \rho_{c1}, \mu_{n1}, \sigma_{n1}^2, \rho_{n1}, \mu_2, \sigma_2^2, \rho_2, \mu_3, \sigma_3^2, \rho_3, \mu_{n3}, \sigma_{n3}^2, \rho_{n3})\), where \(\pi_1, \pi_2, \pi_3\) are the mixing proportions; \(\mu_{c1}, \sigma_{c1}^2,\) and \(\rho_{c1}\) are the marginal mean, variance, and correlation of gene expression levels of cluster 1 (up-regulated genes) for diseased subjects; \(\mu_{n1}, \sigma_{n1}^2,\) and \(\rho_{n1}\) are the marginal mean, variance, and correlation of gene expression levels of cluster 1 (up-regulated genes) for non-diseased subjects; \(\mu_2, \sigma_2^2,\) and \(\rho_2\) are the marginal mean, variance, and correlation of gene expression levels of cluster 2 (non-differentially expressed genes); \(\mu_3, \sigma_3^2,\) and \(\rho_3\) are the marginal mean, variance, and correlation of gene expression levels of cluster 3 (down-regulated genes) for diseased subjects; \(\mu_{n3}, \sigma_{n3}^2,\) and \(\rho_{n3}\) are the marginal mean, variance, and correlation of gene expression levels of cluster 3 (down-regulated genes) for non-diseased subjects.

Note that genes in cluster 2 are non-differentially expressed across abnormal and normal tissue samples. Hence there are only 3 parameters for cluster 2.

To make sure the identifiability, we set the following constraints: \(\mu_{c1} > \mu_{n1}\) and \(\mu_{c3} < \mu_{n3}\).
To make sure the marginal covariance matrices are positive definite, we set the following constraints:

\[ -1/(n_e - 1) < \rho_{e1} < 1, -1/(n_n - 1) < \rho_{n1} < 1, -1/(n - 1) < \rho_2 < 1, -1/(n_e - 1) < \rho_{e3} < 1, -1/(n_n - 1) < \rho_{n3} < 1. \]

We also have the following constraints for the mixing proportion: \( \pi_3 = 1 - \pi_1 - \pi_2, \pi_k > 0, k = 1, 2, 3. \)

We apply the EM algorithm to estimate the model parameters. We regard the cluster membership of genes as missing values.

To facilitate the estimation of the parameters, we reparametrize the parameter vector as \( \theta^* = (\pi_1, \pi_2, \mu_{e1}, \sigma_{e1}^2, \delta_{n1}, \sigma_{n1}^2, r_{n1}, \mu_2, \sigma_2^2, r_2, \mu_{c3}, \sigma_{c3}^2, r_{c3}, \delta_n, \sigma_n^2, r_{c3}). \) where \( \mu_{e1} = \mu_{e1} - \exp(\delta_{n1}), \mu_{n1} = \mu_{c3} + \exp(\delta_n), \rho_1 = (\exp(r_{n1}) - 1/(n_e - 1))/(1 + \exp(r_{n1})), \rho_2 = (\exp(r_2) - 1/(n - 1))/(1 + \exp(r_2)), \rho_{c3} = (\exp(r_{c3}) - 1/(n_e - 1))/(1 + \exp(r_{c3})), \rho_{n3} = (\exp(r_{n3}) - 1/(n_n - 1))/(1 + \exp(r_{n3})). \)

Given a gene, the expression levels of the gene are assumed independent. However, after scaling, the scaled expression levels of the gene are no longer independent and the rank \( r^* = r - 1 \) of the covariance matrix for the scaled gene profile will be one less than the rank \( r \) for the un-scaled gene profile. Hence the covariance matrix of the gene profile will no longer be positive-definite. To avoid this problem, we delete a tissue sample after scaling since its information has been incorporated by other scaled tissue samples. We arbitrarily select the tissue sample, which has the biggest label number, from the tissue sample group that has larger size than the other tissue sample group. For example, if there are 6 cancer tissue samples and 10 normal tissue samples, we delete the 10-th normal tissue sample after scaling.

**Value**

A list contains 13 elements.

- **dat** the (transformed) microarray data matrix. If transformation performed, then dat will be different from the input microarray data matrix.
- **memSubjects** the same as the input memSubjects.
- **memGenes** a vector of cluster membership of genes. 1 means up-regulated gene; 2 means non-differentially expressed gene; 3 means down-regulated gene.
- **memGenes2** an variant of the vector of cluster membership of genes. 1 means differentially expressed gene; 0 means non-differentially expressed gene.
- **para** parameter estimates (c.f. details).
- **llkh** value of the loglikelihood function.
- **wiMat** posterior probability that a gene belongs to a cluster given the expression levels of this gene. Column i is for cluster i.
- **memIni** the initial cluster membership of genes.
- **paraIni** the parameter estimates based on initial gene cluster membership.
- **llkhIni** the value of loglikelihood function.
- **lambda** the parameter used to do Box-Cox transformation
- **paraRP** parameter estimates for reparametrized parameter vector (c.f. details).
- **paraIniRP** the parameter estimates for reparametrized parameter vector based on initial gene cluster membership.

**Note**

The speed of the program can be slow for large data sets, however it has been improved using Fortran code.
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References

See Also
gsMMD, gsMMD.default, gsMMD2

Examples

```r
## Not run:
library(ALL)
data(ALL)
eSet1 <- ALL[1:100, ALL$BT == "B3" | ALL$BT == "T2"]
mat <- exprs(eSet1)

mem.str <- as.character(eSet1$BT)
nSubjects <- length(mem.str)
memSubjects <- rep(0, nSubjects)
# B3 coded as 0, T2 coded as 1
memSubjects[mem.str == "T2"] <- 1

myWilcox <-
  function(x, memSubjects, alpha = 0.05)
  {
    xc <- x[memSubjects == 1]
    xn <- x[memSubjects == 0]
    m <- sum(memSubjects == 1)
    res <- wilcox.test(x = xc, y = xn, conf.level = 1 - alpha)
    res2 <- c(res$p.value, res$statistic - m * (m + 1) / 2)
    names(res2) <- c("p.value", "statistic")
    return(res2)
  }

tmp <- t(apply(mat, 1, myWilcox, memSubjects = memSubjects))
colnames(tmp) <- c("p.value", "statistic")
memIni <- rep(2, nrow(mat))
memIni[tmp[, 1] < 0.05 & tmp[, 2] > 0] <- 1
memIni[tmp[, 1] < 0.05 & tmp[, 2] < 0] <- 3

cat("initial gene cluster size>>\n"); print(table(memIni)); cat("\n");

obj.gsMMD <- gsMMD2.default(mat, memSubjects, memIni = memIni,
  transformFlag = TRUE, transformMethod = "boxcox", scaleFlag = TRUE)
round(obj gsMMD$para, 3)
```
obtainResi

## End(Not run)

---

**obtainResi**

*Replace expression levels by the residuals of regression analysis to remove the confounding effects.*

**Description**

Replace expression levels by the residuals of regression analysis in which predictor of interest is not in the regression model. The purpose of this function is to remove potential confounding factors.

**Usage**

```r
obtainResi(es, fmla)
```

**Arguments**

- `es` An ExpressionSet object.
- `fmla` A formula object that specifies the covariates of the linear regression model. The variable of interest should not be included. No response variable should be specified in `fmla` since the response variable is always the expression level. See function `lmFit` of R Bioconductor package `limma`.

**Details**

To remove confounding effects, we can replace the expression level by the residuals of a linear regression model with response variable the expression level and covariates the potential confounders. The functions `lmFit` and `eBayes` will be used to obtain regression coefficients.

**Value**

An ExpressionSet object with expression levels replaced by residuals of linear regression analysis.

**Note**

The number of arrays of the returned ExpressionSet object might be smaller than that of the original ExpressionSet object, due to missing values in covariates.

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plotHistDensity  

Plot of histogram and density estimate of the pooled gene expression levels.

Description

Plot of histogram of pooled gene expression levels, composited with density estimate based on the mixture of marginal distributions. The density estimate is based on the assumption that the marginal correlations between subjects are zero.

Usage

```r
plotHistDensity(obj.gsMMD, 
    plotFlag="case", 
    plotComponent=FALSE, 
    myxlab="expression level", 
    myylab="density", 
    mytitle="Histogram of gene expression levels\nimposed with estimated density (case)", 
    x.legend=NULL, 
    y.legend=NULL, 
    numPoints=500, 
    mycol=1:4, 
    mylty=1:4, 
    mylwd=rep(3,4), 
    cex.main=2, 
    cex.lab=1.5, 
    cex.axis=1.5, 
    cex=2, 
    bty="n")
```

Arguments

- `obj.gsMMD`: an object returned by `gsMMD`, `gsMMD.default`, `gsMMD2`, or `gsMMD2.default`
- `plotFlag`: logical. Indicate the plot will based on which type of subjects.
- `plotComponent`: logical. Indicate if components of the mixture of marginal distribution will be plotted.
- `myxlab`: label for x-axis
- `myylab`: label for y-axis
- `mytitle`: title of the plot
- `x.legend`: the x-coordinates of the legend
- `y.legend`: the y-coordinates of the legend
- `numPoints`: logical. Indicate how many genes will be plots.
- `mycol`: color for the density estimates (overall and components)
- `mylty`: line styles for the density estimates (overall and components)
- `mylwd`: line width for the density estimates (overall and components)
- `cex.main`: font for main title
plotHistDensity

cex.lab: font for x- and y-axis labels

cex.axis: font for x- and y-axis

cex: font for texts

bty: the type of box to be drawn around the legend. The allowed values are "o" and "n" (the default).

Details

For a given type of subjects, we pool their expression levels together if the marginal correlations among subjects are zero. We then draw a histogram of the pooled expression levels. Next, we composite density estimates of gene expression levels for the overall distribution and the 3 component distributions.

Value

A list containing coordinates of the density estimates:

- **x**: sorted pooled gene expression levels for cases or controls.
- **x2**: a subset of x specified by the sequence: seq(from=1, to=len.x, by=delta), where len.x is the length of the vector x, and delta=floor(len.x/numpoints).
- **y**: density estimate corresponding to x2
- **y1**: weighted density estimate for gene cluster 1
- **y2**: weighted density estimate for gene cluster 2
- **y3**: weighted density estimate for gene cluster 3

Note

The density estimate is obtained based on the assumption that the marginal correlation among subjects is zero. If the estimated marginal correlation obtained by gsMMD is far from zero, then do not use this plot function.

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References


Examples

```r
## Not run:
library(ALL)
data(ALL)
eSet1 <- ALL[1:100, ALL$BT == "B3" | ALL$BT == "T2"]
mem.str <- as.character(eSet1$BT)
nSubjects <- length(mem.str)
```
memSubjects <- rep(0, nSubjects)
# B3 coded as 0 (control), T2 coded as 1 (case)
memSubjects[mem.str == "T2"] <- 1

obj.gsMMD <- gsMMD(eSet1, memSubjects, transformFlag = TRUE,
                   transformMethod = "boxcox", scaleFlag = TRUE, quiet = FALSE)

plotHistDensity(obj.gsMMD, plotFlag = "case",
                mytitle = "Histogram of gene expression levels for T2
imposed with estimated density (case)",
                plotComponent = TRUE,
                x.legend = c(0.8, 3),
                y.legend = c(0.3, 0.4),
                numPoints = 500)

## End(Not run)
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