Package ‘MixGHD’

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Using the Mixture of Generalized Hyperbolic Distributions
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Description Carries out model-based clustering, classification and discriminant analysis using five different models. The models are all based on the generalized hyperbolic distribution. The first model 'MGHD' (Browne and McNicholas (2015) <doi:10.1002/cjs.11246>) is the classical mixture of generalized hyperbolic distributions. The 'MGHFA' (Tortora et al. (2016) <doi:10.1007/s11634-015-0204-z>) is the mixture of generalized hyperbolic factor analyzers for high dimensional data sets. The 'MS-GHD' is the mixture of multiple scaled generalized hyperbolic distributions, the 'cMS-GHD' is a 'MSGHD' with convex contour plots and the 'MCGHD', mixture of coalesced generalized hyperbolic distributions is a new more flexible model (Tortora et al. (2019)<doi:10.1007/s00357-019-09319-3>. The paper related to the software can be found at <doi:10.18637/jss.v098.i03>.
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ARI

Adjusted Rand Index.

Description

Compared two classifications using the adjusted Rand index (ARI).

Usage

ARI(x=NULL, y=NULL)

Arguments

x A n dimensional vector of class labels.

y A n dimensional vector of class labels.

Details

The ARI has expected value 0 in case of random partition, it is equal to one in case of perfect agreement.

Value

The adjusted Rand index value
banknote

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References

Examples
```r
#loading banknote data
data(banknote)

#model estimation
res=MGHD(data=banknote[,2:7], G=2)

#result
ARI(res@map, banknote[,1])
```

---

### banknote

*Swiss Banknote data*

**Description**
The data set contain 6 measures of 100 genuine and 100 counterfeit Swiss franc banknotes.

**Usage**
data(banknote)

**Format**
A data frame with the following variables:

- **Status**  the status of the banknote: genuine or counterfeit
- **Length**  Length of bill (mm)
- **Left**  Width of left edge (mm)
- **Right**  Width of right edge (mm)
- **Bottom**  Bottom margin width (mm)
- **Top**  Top margin width (mm)
- **Diagonal**  Length of diagonal (mm)

**References**
Bankruptcy data

Description
The data set contain the ratio of retained earnings (RE) to total assets, and the ratio of earnings before interests and taxes (EBIT) to total assets of 66 American firms recorded in the form of ratios. Half of the selected firms had filed for bankruptcy.

Usage
data(bankruptcy)

Format
A data frame with the following variables:

Y   the status of the firm: 0 bankruptcy or 1 financially sound.
RE  ratio
EBIT ratio

References

---

cMSGHD

Convex mixture of multiple scaled generalized hyperbolic distributions (cMSGHD).

Description
Carries out model-based clustering using the convex mixture of multiple scaled generalized hyperbolic distributions. The cMSGHD only allows convex level sets.

Usage
cMSGHD(data=NULL,gpar0=NULL,G=2,max.iter=100,label=NULL,eps=1e-2, method="km",scale=TRUE,nr=10, modelSel="AIC"
Arguments

data A \( n \times p \) matrix or data frame such that rows correspond to observations and columns correspond to variables.

gpar0 (optional) A list containing the initial parameters of the mixture model. See the 'Details' section.

G The range of values for the number of clusters.

max.iter (optional) A numerical parameter giving the maximum number of iterations each EM algorithm is allowed to use.

label (optional) A \( n \) dimensional vector, if \( \text{label}[i]=k \) then observation \( i \) belongs to group \( k \), if NULL then the data has no known groups.

eps (optional) A number specifying the epsilon value for the convergence criteria used in the EM algorithms. For each algorithm, the criterion is based on the difference between the log-likelihood at an iteration and an asymptotic estimate of the log-likelihood at that iteration. This asymptotic estimate is based on the Aitken acceleration.

method (optional) A string indicating the initialization criterion, if not specified kmeans clustering is used. Alternative methods are: hierarchical "hierarchical", random "random", kmedoids "kmedoids", and model based "modelBased"

scale (optional) A logical value indicating whether or not the data should be scaled, true by default.

nr (optional) A number indicating the number of starting value when random is used, 10 by default.

modelSel (optional) A string indicating the model selection criterion, if not specified AIC is used. Alternative methods are: BIC, ICL, and AIC3

Details

The arguments gpar0, if specified, is a list structure containing at least one \( p \) dimensional vector mu, alpha and phi, a \( p \times p \) matrix gamma, and a \( p \times 2 \) matrix cpl containing the vector omega and the vector lambda.

Value

A S4 object of class MixGHD with slots:

index Value of the index used for model selection (AIC or ICL or BIC or AIC3) for each \( G \), the index used is specified by the user, if not specified AIC is used.

BIC Bayesian information criterion.

ICL Integrated completed likelihood.

AIC Akaike information criterion.

AIC3 Akaike information criterion 3.

gpar A list of the model parameters

loglik The log-likelihood values.

map A vector of integers indicating the maximum a posteriori classifications for the best model.

z A matrix giving the raw values upon which map is based.
Author(s)

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas. Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

References


See Also

MGHD MSGHD

Examples

```r
##Generate random data
set.seed(3)

mu1 <- mu2 <- c(0,0)
Sigma1 <- matrix(c(1,0.85,0.85,1),2,2)
Sigma2 <- matrix(c(1,-0.85,-0.85,1),2,2)

X1 <- mvrnorm(n=150,mu=mu1,Sigma=Sigma1)
X2 <- mvrnorm(n=150,mu=mu2,Sigma=Sigma2)

X <- rbind(X1,X2)

##model estimation
em=cMSGHD(X,G=2,max.iter=30,method="random",nr=2)

#result
plot(em)
```

###coef

*Coefficients for objects of class MixGHD*

Description

Coefficients of the estimated model.
Usage

## S4 method for signature 'MixGHD'
coef(object)

Arguments

object     An S4 object of class MixGHD.

Value

The coefficients of the estimated model

Author(s)

Cristina Tortora Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

Examples

##loading bankruptcy data
data(bankruptcy)

##model estimation
res=MCGHD(data=bankruptcy[,2:3],G=2,method="kmedoids",max.iter=30)
#coefficients of the model
coef(res)

contourpl

Description

Contour plot for a given set of parameters.

Usage

contourpl(input)

Arguments

input     An S4 object of class MixGHD.

Value

The contour plot

Contour plot

contourpl

Description

Contour plot for a given set of parameters.

Usage

contourpl(input)

Arguments

input     An S4 object of class MixGHD.

Value

The contour plot
Author(s)
Cristina Tortora
Maintainer: Cristina Tortora <cristina.tortora@sjtu.edu>

Examples

```r
# Loading bankruptcy data
data(bankruptcy)

# Model estimation
res <- MCGHD(data = bankruptcy[, 2:3], G = 2, method = "kmedoids", max.iter = 30)
# Result
contourpl(res)
```

DA

**Discriminant analysis using the mixture of generalized hyperbolic distributions.**

Description

Carries out model-based discriminant analysis using 5 different models: the mixture of multiple scaled generalized hyperbolic distributions (MGHD), the mixture of generalized hyperbolic factor analyzers (MGHFA), the mixture of multiple scaled generalized hyperbolic distributions (MSGHD), the mixture of convex multiple scaled generalized hyperbolic distributions (cMSGHD) and the mixture of coalesced generalized hyperbolic distributions (MCGHD).

Usage

```r
DA(train, trainL, test, testL, method = "MGHD", starting = "km", max.iter = 100, eps = 1e-2, q = 2, scale = TRUE)
```

Arguments

- **train**: A n1 x p matrix or data frame such that rows correspond to observations and columns correspond to variables of the training data set.
- **trainL**: A n1 dimensional vector of membership for the units of the training set. If trainL[i]=k then observation belongs to group k.
- **test**: A n2 x p matrix or data frame such that rows correspond to observations and columns correspond to variables of the test data set.
- **testL**: A n2 dimensional vector of membership for the units of the test set. If testL[i]=k then observation belongs to group k.
- **method** (optional): A string indicating the method to be used for discriminant analysis, if not specified MGHD is used. Alternative methods are: MGHFA, MSGHD, cMSGHD, MCGHD.
- **starting** (optional): A string indicating the initialization criterion, if not specified kmeans clustering is used. Alternative methods are: hierarchical "hierarchical", random "random", kmedoids "kmedoids", and model based "modelBased"
max.iter (optional) A numerical parameter giving the maximum number of iterations each EM algorithm is allowed to use.

eps (optional) A number specifying the epsilon value for the convergence criteria used in the EM algorithms. For each algorithm, the criterion is based on the difference between the log-likelihood at an iteration and an asymptotic estimate of the log-likelihood at that iteration. This asymptotic estimate is based on the Aitken acceleration.

q (optional) used only if MGHFA method is selected. A numerical parameter giving the number of factors.

scale (optional) A logical value indicating whether or not the data should be scaled, true by default.

Value

A list with components

- model An S4 object of class MixGHD with the model parameters.
- testMembership A vector of integers indicating the membership of the units in the test set
- ARItest A value indicating the adjusted rand index for the test set.
- ARItrain A value indicating the adjusted rand index for the train set.

Author(s)

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References


See Also

"MixGHD" MGHD MGHFA MSGHD cMSGHD MCGHD ARI MixGHD-class MixGHD

Examples

```r
#loading banknote data
data(banknote)
banknote[,1]=as.numeric(factor(banknote[,1]))

#divide the data in training set and test set
train=banknote[c(1:74,126:200),]
test=banknote[75:125,]
```
## Density of a coalesced generalized hyperbolic distribution (MSGHD).

**Description**

Compute the density of a p dimensional coalesced generalized hyperbolic distribution.

**Usage**

```r
dCGHD(data, p, mu = rep(0, p), alpha = rep(0, p), sigma = diag(p), lambda = 1, omega = 1, omegav = rep(1, p), lambdav = rep(1, p), wg = 0.5, gam = NULL, phi = NULL)
```

**Arguments**

- **data**: n x p data set
- **p**: number of variables.
- **mu**: (optional) the p dimensional mean
- **alpha**: (optional) the p dimensional skewness parameter alpha
- **sigma**: (optional) the p x p dimensional scale matrix
- **lambda**: (optional) the 1 dimensional index parameter lambda
- **omega**: (optional) the 1 dimensional concentration parameter omega
- **omegav**: (optional) the p dimensional concentration parameter omega
- **lambdav**: (optional) the p dimensional index parameter lambda
- **wg**: (optional) weight
- **gam**: (optional) the pxp gamma matrix
- **phi**: (optional) the p dimensional vector phi

**Details**

The default values are: 0 for the mean and the skweness parameter alpha, diag(p) for sigma, 1 for omega, and 0.5 for lambda.

**Value**

A n dimensional vector with the density from a coalesced generalized hyperbolic distribution

```r
## model estimation
model = DA(train[,2:7], train[,1], test[,2:7], test[,1], method = "MGHD", max.iter = 20)

# result
model$ARItest
```
Author(s)
Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas.
Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

References

Examples

```r
x = seq(-3,3,length.out=30)
y = seq(-3,3,length.out=30)
xyS1 = matrix(0,nrow=length(x),ncol=length(y))
for(i in 1:length(x)){
  for(j in 1:length(y)){
    xy <- matrix(cbind(x[i],y[j]),1,2)
    xyS1[i,j] = dCGHD(xy,2)
  }
}
contour(x=x,y=y,z=xyS1, levels=c(.005,.01,.025,.05,.1,.25), main="CGHD",ylim=c(-3,3), xlim=c(-3,3))
```

dGHD

Density of a generalized hyperbolic distribution (GHD).

Description
Compute the density of a p dimensional generalized hyperbolic distribution.

Usage
dGHD(data,p, mu=rep(0,p),alpha=rep(0,p),sigma=diag(p),omega=1,lambda=0.5, log=FALSE)

Arguments
data           n x p data set
p               number of variables.
mu             (optional) the p dimensional mean
alpha           (optional) the p dimensional skewness parameter alpha
sigma           (optional) the p x p dimensional scale matrix
omega           (optional) the unidimensional concentration parameter omega
lambda          (optional) the unidimensional index parameter lambda
log             (optional) if TRUE returns the log of the density
Details

The default values are: 0 for the mean and the skweness parameter alpha, diag(p) for sigma, 1 for omega, and 0.5 for lambda.

Value

A n dimensional vector with the density from a generalized hyperbolic distribution

Author(s)

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas.
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References


Examples

```r
x = seq(-3,3,length.out=50)
y = seq(-3,3,length.out=50)
xyS1 = matrix(0,nrow=length(x),ncol=length(y))
for(i in 1:length(x)){
  for(j in 1:length(y)){
    xy <- matrix(cbind(x[i],y[j]),1,2)
    xyS1[i,j] = dGHD(xy,2)
  }
}
contour(x=x,y=y,z=xyS1, levels=c(.005,.01,.025,.05,.1,.25), main="MGHD", ylim=c(-3,3), xlim=c(-3,3))
```

<table>
<thead>
<tr>
<th>dMSGHD</th>
<th>Density of a multiple-scaled generalized hyperbolic distribution (MS-GHD).</th>
</tr>
</thead>
</table>

Description

Compute the density of a p dimensional multiple-scaled generalized hyperbolic distribution.
**Usage**

```r
dMSGHD(data,p,mu=rep(0,p),alpha=rep(0,p),sigma=diag(p),omegav=rep(1,p),
       lambdav=rep(0.5,p),gam=NULL,phi=NULL,log=FALSE)
```

**Arguments**

- `data` n x p data set
- `p` number of variables.
- `mu` (optional) the p dimensional mean
- `alpha` (optional) the p dimensional skewness parameter alpha
- `sigma` (optional) the p x p dimensional scale matrix
- `omegav` (optional) the p dimensional concentration parameter omega
- `lambdav` (optional) the p dimensional index parameter lambda
- `gam` (optional) the pxp gamma matrix
- `phi` (optional) the p dimensional vector phi
- `log` (optional) if TRUE returns the log of the density

**Details**

The default values are: 0 for the mean and the skewness parameter alpha, diag(p) for sigma, 1 for omega, and 0.5 for lambda.

**Value**

A n dimensional vector with the density from a multiple-scaled generalized hyperbolic distribution

**Author(s)**

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**References**


**Examples**

```r
x = seq(-3,3,length.out=50)
y = seq(-3,3,length.out=50)
xyS1 = matrix(0,nrow=length(x),ncol=length(y))
for(i in 1:length(x)){
  for(j in 1:length(y)){
    xy <- matrix(cbind(x[i],y[j]),1,2)
    xyS1[i,j] = dMSGHD(xy)
  }
}
```
\[
\text{xyS1}[i,j] = dMSGHD(xy,2)
\]

\}
\}
contour(x=x, y=y, z=xyS1, levels=seq(.005,.25,by=.005), main="MSGHD")

---

**MCGHD**

*Mixture of coalesced generalized hyperbolic distributions (MCGHD).*

---

**Description**

Carries out model-based clustering using the mixture of coalesced generalized hyperbolic distributions.

**Usage**

```r
MCGHD(data=NULL, gpar0=NULL, G=2, max.iter=100, eps=1e-2, label=NULL, method="km", scale=TRUE, nr=10, modelSel="AIC")
```

**Arguments**

- **data**
  - A n x p matrix or data frame such that rows correspond to observations and columns correspond to variables.

- **gpar0**
  - (optional) A list containing the initial parameters of the mixture model. See the 'Details' section.

- **G**
  - The range of values for the number of clusters.

- **max.iter**
  - (optional) A numerical parameter giving the maximum number of iterations each EM algorithm is allowed to use.

- **eps**
  - (optional) A number specifying the epsilon value for the convergence criteria used in the EM algorithms. For each algorithm, the criterion is based on the difference between the log-likelihood at an iteration and an asymptotic estimate of the log-likelihood at that iteration. This asymptotic estimate is based on the Aitken acceleration.

- **label**
  - (optional) A n dimensional vector, if label[i]=k then observation i belongs to group k. If label[i]=0 then observation i has no known group, if NULL then the data has no known groups.

- **method**
  - (optional) A string indicating the initialization criterion, if not specified kmeans clustering is used. Alternative methods are: hierarchical "hierarchical", random "random", and model based "modelBased"

- **scale**
  - (optional) A logical value indicating whether or not the data should be scaled, true by default.

- **nr**
  - (optional) A number indicating the number of starting value when random is used, 10 by default.

- **modelSel**
  - (optional) A string indicating the model selection criterion, if not specified AIC is used. Alternative methods are: BIC, ICL, and AIC3
Details
The arguments gpar0, if specified, has to be a list structure containing as much element as the
number of components G. Each element must include the following parameters: one p dimensional
vector mu, alpha and phi, a pxp matrix gamma, a px2 vector cpl containing the vectors omega and
lambda, and a 2-dimensional vector containing the omega0 and lambda0.

Value
A S4 object of class MixGHD with slots:

index Value of the index used for model selection (AIC or ICL or BIC or AIC3) for
each G, the index used is specified by the user, if not specified AIC is used.
BIC Bayesian information criterion.
ICL Integrated completed likelihood.
AIC Akaike information criterion.
AIC3 Akaike information criterion 3.
gpar A list of the model parameters in the rotated space.
loglik The log-likelihood values.
map A vector of integers indicating the maximum a posteriori classifications for the
best model.
par A list of the model parameters.
z A matrix giving the raw values upon which map is based.

Author(s)
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References
C. Tortora, R. P. Browne, A. ElSherbiny, B. C. Franczak, and P. D. McNicholas (2021). Model-Based Clustering,
Classification, and Discriminant Analysis using the Generalized Hyperbolic Distribution: MixGHD
R package, *Journal of Statistical Software* 98(3) 1–24, <doi:10.18637/jss.v098.i03>.

See Also
MGHD, MSGHD

Examples
```r
# loading banknote data
data(banknote)

# model estimation
model=MCGHD(banknote[,2:7],G=2,max.iter=20)
```
#result
#summary(model)
#plot(model)
table(banknote[,1],model@map)

**MGHD**

*Mixture of generalized hyperbolic distributions (MGHD).*

**Description**

Carries out model-based clustering and classification using the mixture of generalized hyperbolic distributions.

**Usage**

```r
MGHD(data=NULL,gpar0=NULL,G=2,max.iter=100,label=NULL,eps=1e-2,
method="kmeans",scale=TRUE,nr=10, modelSel="AIC")
```

**Arguments**

- `data` A n x p matrix or data frame such that rows correspond to observations and columns correspond to variables.
- `gpar0` (optional) A list containing the initial parameters of the mixture model. See the 'Details' section.
- `G` The range of values for the number of clusters.
- `max.iter` (optional) A numerical parameter giving the maximum number of iterations each EM algorithm is allowed to use.
- `label` (optional) A n dimensional vector, if label[i]=k then observation i belongs to group k, If label[i]=0 then observation i has no known group, if NULL then the data has no known groups.
- `eps` (optional) A number specifying the epsilon value for the convergence criteria used in the EM algorithms. For each algorithm, the criterion is based on the difference between the log-likelihood at an iteration and an asymptotic estimate of the log-likelihood at that iteration. This asymptotic estimate is based on the Aitken acceleration.
- `method` (optional) A string indicating the initialization criterion, if not specified kmeans clustering is used. Alternative methods are: hierarchical "hierarchical", random "random", and model based "modelBased" clustering.
- `scale` (optional) A logical value indicating whether or not the data should be scaled, true by default.
- `nr` (optional) A number indicating the number of starting value when random is used, 10 by default.
- `modelSel` (optional) A string indicating the model selection criterion, if not specified AIC is used. Alternative methods are: BIC,ICL, and AIC3.
Details

The arguments gpar0, if specified, is a list structure containing at least one p dimensional vector mu, and alpha, a p x p matrix sigma, and a 2 dimensional vector containing omega and lambda.

Value

A S4 object of class MixGHD with slots:

- index: Value of the index used for model selection (AIC or ICL or BIC or AIC3) for each G, the index used is specified by the user, if not specified AIC is used.
- BIC: Bayesian information criterion.
- ICL: Integrated completed likelihood.
- AIC: Akaike information criterion.
- AIC3: Akaike information criterion 3.
- gpar: A list of the model parameters.
- loglik: The log-likelihood values.
- map: A vector of integers indicating the maximum a posteriori classifications for the best model.
- z: A matrix giving the raw values upon which map is based.

Author(s)

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas.

Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

References


Examples

```r
# loading crabs data
data(crabs)

# model estimation
model=MGHD(data=crabs[,4:8], G=2)

# result
plot(model)
table(model@map, crabs[,2])

# Classification
# loading bankruptcy data
data(bankruptcy)
```
#70% belong to the training set
label=bankruptcy[,1]
#for a Classification porpuse the label cannot be 0
label[1:33]=2
a=round(runif(20)*65+1)
label[a]=0

##model estimation
model=MGHD(data=bankruptcy[,2:3], G=2, label=label )

#result
table(model@map,bankruptcy[,1])
plot(model)

---

**MGHFA**

*Mixture of generalized hyperbolic factor analyzers (MGHFA).*

###Description

Carries out model-based clustering and classification using the mixture of generalized hyperbolic factor analyzers.

###Usage

```
MGHFA(data=NULL, gpar0=NULL, G=2, max.iter=100, label=NULL, q=2, eps=1e-2, method="kmeans", scale=TRUE, nr=10)
```

###Arguments

- **data**
  A matrix or data frame such that rows correspond to observations and columns correspond to variables.

- **gpar0**
  (optional) A list containing the initial parameters of the mixture model. See the 'Details' section.

- **G**
  The range of values for the number of clusters.

- **max.iter**
  (optional) A numerical parameter giving the maximum number of iterations each EM algorithm is allowed to use.

- **label**
  (optional) A n dimensional vector, if label[i]=k then observation i belongs to group k. If label[i]=0 then observation i has no known group, if NULL then the data has no known groups.

- **q**
  The range of values for the number of factors.

- **eps**
  (optional) A number specifying the epsilon value for the convergence criteria used in the EM algorithms. For each algorithm, the criterion is based on the difference between the log-likelihood at an iteration and an asymptotic estimate of the log-likelihood at that iteration. This asymptotic estimate is based on the Aitken acceleration.
method (optional) A string indicating the initialization criterion, if not specified kmeans clustering is used. Alternative methods are: hierarchical "hierarchical" and model based "modelBased" clustering.

scale (optional) A logical value indicating whether or not the data should be scaled, true by default.

nr (optional) A number indicating the number of starting value when random is used, 10 by default.

Details
The arguments gpar0, if specified, is a list structure containing at least one p dimensional vector mu, alpha and phi, a pxp matrix gamma, a 2 dimensional vector cpl containing omega and lambda.

Value
A S4 object of class MixGHD with slots:

- **Index** Bayesian information criterion value for each combination of G and q.
- **BIC** Bayesian information criterion.
- **gpar** A list of the model parameters.
- **loglik** The log-likelihood values.
- **map** A vector of integers indicating the maximum a posteriori classifications for the best model.
- **z** A matrix giving the raw values upon which map is based.

Author(s)
Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas.
Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

References

Examples
```r
## Classification
#70% belong to the training set
data(sonar)
label=sonar[,61]
set.seed(4)
a=round(runif(62)*207+1)
label[a]=0
```
## model estimation

Model estimation:

```r
model = MGHFA(data = sonar[,1:60], G = 2, max.iter = 25, q = 2, label = label)
```

# Result

```r
# result
table(model@map, sonar[,61])
summary(model)
```

---

**MixGHD class**

Class "MixGHD"

**Description**

This class pertains to results of the application of function `MGHD`, `MSGHD`, `cMSGHD`, `MCGHD`, and `MGHFA`.

**Objects from the Class**

Objects can be created as a result to a call to `MGHD`, `MSGHD`, `cMSGHD`, `MCGHD`, and `MGHFA`.

**Slots**

- `index`: Value of the index used for model selection (AIC or ICL or BIC or AIC3) for each G, the index used is specified by the user, if not specified AIC is used.
- `BIC`: Bayesian information criterion value.
- `ICL`: ICL index.
- `AIC`: AIC index.
- `AIC3`: AIC3 index.
- `gpar`: A list of the model parameters (in the rotated space for MCGHD).
- `loglik`: The log-likelihood values.
- `map`: A vector of integers indicating the maximum a posteriori classifications for the best model.
- `par`: Only for MCGHD. A list of the model parameters.
- `z`: A matrix giving the raw values upon which map is based.

**Methods**

- `plot signature(x = "MixGHD")`: Provides plots of `MixGHD-class` by plotting the following elements:
  - the value of the log likelihood for each iteration.
  - Scatterplot of the data of all the possible couples of coordinates coloured according to the cluster. Only for less than 10 variables.
  - If the number of variables is two: scatterplot and contour plot of the data coloured according to the cluster.
**summary** summary(x = "MixGHD").

Provides a summary of **MixGHD-class** objects by printing the following elements:

- The number components used for the model
- BIC;
- AIC;
- AIC3;
- ICL;
- A table with the number of element in each cluster.

**Author(s)**

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas. Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

**See Also**

MixGHD-class

**Examples**

```r
#loading bankruptcy data
data(bankruptcy)

##model estimation
#res=MCGHD(data=bankruptcy[,2:3],G=2,method="kmedoids",max.iter=30)
#result
#plot(res)
#summary(res)
```

**MixGHD-class**

*Class MixGHD.*

**Description**

This class pertains to results of the application of function **MGHD,MCGHD,MSGHD,cMSGHD**.

**Details**

Plot the loglikelihood vale for each iteration of the EM algorithm. If p=2 it shows a contour plot. If 2<p<10 shows a splom of the data colored according to the cluster membership.
Slots

- **Index**  Bayesian information criterion value for each combination of G and q.
- **BIC**  Bayesian information criterion value.
- **gpar**  A list of the model parameters.
- **loglik**  The log-likelihood values.
- **map**  A vector of integers indicating the maximum a posteriori classifications for the best model.
- **z**  A matrix giving the raw values upon which map is based.
- **method**  A string indicating the used method: MGHD, MGHFA, MSGHD, cMSGHD, MCGHD.
- **data**  A matrix or data frame such that rows correspond to observations and columns correspond to variables.
- **par**  (only for MCGHD) A list of the model parameters in the rotated space.

Methods

signature(x = "MixGHD", y = "missing")  S4 method for plotting objects of MixGHD-class.

Author(s)

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas. 
Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

See Also

MixGHD-class, MGHD, MCGHD, MSGHD, cMSGHD, MGHFA

Examples

```r
# loading banknote data
data(bankruptcy)

# model estimation
model = MSGHD(bankruptcy[, 2:3], G=2, max.iter=30)

# result
summary(model)
plot(model)
```
**MSGHD**

*Mixture of multiple scaled generalized hyperbolic distributions (MSGHD).*

**Description**

Carries out model-based clustering using the mixture of multiple scaled generalized hyperbolic distributions.

**Usage**

```r
MSGHD(data=NULL,gpar0=NULL,G=2,max.iter=100,label=NULL,eps=1e-2,
method="km",scale=TRUE,nr=10, modelSel="AIC")
```

**Arguments**

- `data` A n x p matrix or data frame such that rows correspond to observations and columns correspond to variables.
- `gpar0` (optional) A list containing the initial parameters of the mixture model. See the 'Details' section.
- `G` The range of values for the number of clusters.
- `max.iter` (optional) A numerical parameter giving the maximum number of iterations each EM algorithm is allowed to use.
- `label` (optional) A n dimensional vector, if label[i]=k then observation i belongs to group k, If label[i]=0 then observation i has no known group, if NULL then the data has no known groups.
- `eps` (optional) A number specifying the epsilon value for the convergence criteria used in the EM algorithms. For each algorithm, the criterion is based on the difference between the log-likelihood at an iteration and an asymptotic estimate of the log-likelihood at that iteration. This asymptotic estimate is based on the Aitken acceleration.
- `method` (optional) A string indicating the initialization criterion, if not specified kmeans clustering is used. Alternative methods are: hierarchical "hierarchical", random "random", and model based "modelBased" clustering
- `scale` (optional) A logical value indicating whether or not the data should be scaled, true by default.
- `nr` (optional) A number indicating the number of starting value when random is used, 10 by default.
- `modelSel` (optional) A string indicating the model selection criterion, if not specified AIC is used. Alternative methods are: BIC,ICL, and AIC3

**Details**

The arguments `gpar0`, if specified, is a list structure containing at least one p dimensional vector `mu`, alpha and phi, a p x p matrix `gamma`, and a p x 2 matrix `cpl` containing the vector `omega` and the vector `lambda`.
Value

A S4 object of class `MixGHD` with slots:

- **index**: Value of the index used for model selection (AIC or ICL or BIC or AIC3) for each G, the index used is specified by the user, if not specified AIC is used.
- **BIC**: Bayesian information criterion.
- **ICL**: Integrated completed likelihood.
- **AIC**: Akaike information criterion.
- **AIC3**: Akaike information criterion 3.
- **gpar**: A list of the model parameters
- **loglik**: The log-likelihood values.
- **map**: A vector of integers indicating the maximum a posteriori classifications for the best model.
- **z**: A matrix giving the raw values upon which map is based.

Author(s)

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References


See Also

MGHD

Examples

```r
# loading banknote data
data(banknote)

# model estimation
model=MSGHD(banknote[,2:7],G=2,max.iter=30)

# result
table(banknote[,1],model@map)
summary(model)
plot(model)
```
Description

Plots the loglikelihood function and for p<10 shows the splom of the data.

Usage

## S4 method for signature 'MixGHD'
plot(x,y)

Arguments

x
A object of MixGHD-class;
y
Not used; for compatibility with generic plot.

Details

Plot the loglikelihood value for each iteration of the EM algorithm. If p=2 it shows a contour plot. If 2<p<10 shows a splom of the data colored according to the cluster membership.

Methods

signature(x = "MixGHD", y = "missing") S4 method for plotting objects of MixGHD-class.

Author(s)

Cristina Tortora. Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

See Also

MixGHD-class,MGHD,MCGHD,MSGHD,cMSGHD,MGHFA

Examples

##loading banknote data
data(bankruptcy)

##model estimation
model=MCGHD(bankruptcy[,2:3],G=2,max.iter=30)

#result
plot(model)
predict  

Membership prediction for objects of class MixGHD

Description

Cluster membership

Usage

## S4 method for signature 'MixGHD'
predict(object)

Arguments

object  

An S4 object of class MixGHD.

Value

The cluster membership

Author(s)

Cristina Tortora  
Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

Examples

##loading bankruptcy data
data(bankruptcy)

##model estimation
res=MCGHD(data=bankruptcy[,2:3],G=2,method="kmedoids",max.iter=30)
#rcoefficients of the model
predict(res)

rCGHD

Pseudo random number generation from a coalesced generalized hyperbolic distribution (MSGHD).

Description

Generate n pseudo random numbers from a p dimensional coalesced generalized hyperbolic distribution.
rCGHD

Usage

```r
rCGHD(n,p,mu=rep(0,p),alpha=rep(0,p),sigma=diag(p),omega=1,lambda=0.5,
        omegav=rep(1,p),lambdav=rep(0.5,p),wg=0.5)
```

Arguments

- `n` number of observations.
- `p` number of variables.
- `mu` (optional) the $p$ dimensional mean
- `alpha` (optional) the $p$ dimensional skewness parameter $\alpha$
- `sigma` (optional) the $p \times p$ dimensional scale matrix
- `lambda` (optional) the 1 dimensional index parameter $\lambda$
- `omega` (optional) the 1 dimensional concentration parameter $\omega$
- `omegav` (optional) the $p$ dimensional concentration parameter $\omega$
- `lambdav` (optional) the $p$ dimensional index parameter $\lambda$
- `wg` (optional) the weight

Details

The default values are: 0 for the mean and the skewness parameter $\alpha$, `diag(p)` for $\sigma$, 1 for $\omega$, and 0.5 for $\lambda$.

Value

A $n \times p$ matrix of numbers pseudo randomly generated from a coalesced generalized hyperbolic distribution

Author(s)

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas.
Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

References


Examples

```r
data=rCGHD(300,2,alpha=c(2,-2),omegav=c(2,2),omega=3)
plot(data)
```
**rGHD**

*Pseudo random number generation from a generalized hyperbolic distribution (GHD).*

---

**Description**

Generate n pseudo random numbers from a p dimensional generalized hyperbolic distribution.

**Usage**

`rGHD(n, p, mu=rep(0,p), alpha=rep(0,p), sigma=diag(p), omega=1, lambda=0.5)`

**Arguments**

- `n` number of observations.
- `p` number of variables.
- `mu` (optional) the p dimensional mean
- `alpha` (optional) the p dimensional skewness parameter alpha
- `sigma` (optional) the p x p dimensional scale matrix
- `omega` (optional) the unidimensional concentration parameter omega
- `lambda` (optional) the unidimensional index parameter lambda

**Details**

The default values are: 0 for the mean and the skewness parameter alpha, diag(p) for sigma, 1 for omega, and 0.5 for lambda.

**Value**

A n times p matrix of numbers pseudo randomly generated from a generalized hyperbolic distribution

**Author(s)**

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas.

Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

**References**


**Examples**

```r
data=rGHD(300,2, alpha=c(2,-2))
plot(data)
```
Description

Generate n pseudo random numbers from a p dimensional multiple-scaled generalized hyperbolic distribution.

Usage

\[ \text{rMSGHD}(n, p, \mu=\text{rep}(0, p), \alpha=\text{rep}(0, p), \sigma=\text{diag}(p), \omega=\text{rep}(1, p), \lambda=\text{rep}(0.5, p)) \]

Arguments

- n: number of observations.
- p: number of variables.
- \( \mu \): (optional) the p dimensional mean.
- \( \alpha \): (optional) the p dimensional skewness parameter alpha.
- \( \sigma \): (optional) the p x p dimensional scale matrix.
- \( \omega \): (optional) the p dimensional concentration parameter omega.
- \( \lambda \): (optional) the p dimensional index parameter lambda.

Details

The default values are: 0 for the mean and the skewness parameter alpha, diag(p) for sigma, 1 for omega, and 0.5 for lambda.

Value

A n times p matrix of numbers pseudo randomly generated from a generalized hyperbolic distribution.

Author(s)

Cristina Tortora, Aisha ElSherbiny, Ryan P. Browne, Brian C. Franczak, and Paul D. McNicholas.

Maintainer: Cristina Tortora <cristina.tortora@sjedu.edu>

References


Examples

```r
data=rMSGHD(300,2,\alpha=c(2,-2),\omega=c(2,2))
plot(data)
```
sonar  

*Sonar data*

**Description**

The data report the patterns obtained by bouncing sonar signals at various angles and under various conditions. There are 208 patterns in all, 111 obtained by bouncing sonar signals off a metal cylinder and 97 obtained by bouncing signals off rocks. Each pattern is a set of 60 numbers (variables) taking values between 0 and 1.

**Usage**

```r
data(sonar)
```

**Format**

A data frame with 208 observations and 61 columns. The first 60 columns contain the variables. The 61st column gives the material: 1 rock, 2 metal.

**Source**

UCI machine learning repository

**References**


**summary**  

*Plot objects of class MixGHD.*

**Description**

Methods for function summary aimed at summarizing the S4 classes included in the *MixGHD*-package

**Arguments**

- **object**  
  A object of *MixGHD*-class.

**Methods**

- `signature(object = "MixGHD")`  
  S4 method for summaryizing objects of *MixGHD*-class.

**Author(s)**

Cristina Tortora. Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>
See Also

MixGHD MixGHD-class,MGHD,MCGHD,MSGHD,cMSGHD,MGHFA

Examples

```r
##loading banknote data
data(bankruptcy)

##model estimation
model=MSGHD(bankruptcy[,2:3],G=2,max.iter=30)

#result
summary(model)
```
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