Package ‘MixGHD’

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Type Package

Title Model Based Clustering, Classification and Discriminant Analysis 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’ is the classical mixture of generalized hyperbolic distributions. The ‘MGHFA’ is the mixture of generalized hyperbolic factor analyzers for high dimensional data sets. The ‘MSGHD’, mixture of multiple scaled generalized hyperbolic distributions. The ‘cMSGHD’ is a ‘MSGHD’ with convex contour plots. The ‘MCGHD’, mixture of coalesced generalized hyperbolic distributions is a new more flexible model.

Imports Bessel, stats, mvtnorm, ghyp, numDeriv, mixture, e1071, cluster, methods

Depends MASS, R (>= 3.1.3)

NeedsCompilation yes

License GPL (>= 2)

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SystemRequirements GNU make

R topics documented:

ARI ...................................................... 2
banknote ............................................... 3
bankruptcy ........................................... 4
cMSGHD ............................................... 4
contourpl ............................................ 6
Adjusted Rand Index.

Description

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

Usage

```r
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

Author(s)

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

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, gpar=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 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 pxp matrix gamma, and a px2 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 value.
ICL ICL index.
AIC AIC index.
AIC3 AIC3 index.
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, 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,.85,.85,1),2,2)
Sigma2 <- matrix(c(1,-.85,-.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)
```

**Description**

Contour plot for a given set of parameters.

**Usage**

`contourpl(input)`

**Arguments**

- `input` An S4 object of class `MixGHD`. 
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 (MS-GHD), the mixture of convex multiple scaled generalized hyperbolic distributions (cMSGHD) and the mixture of coalesced generalized hyperbolic distributions (MCGHD).

Usage

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.
ARIttrain 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,]

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

# result
model$ARItest
```

---

**Description**

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

**Usage**

```r
MCGD(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 a 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 p x p matrix gamma, a p x 2 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 value.

ICL ICL index.

AIC AIC index.

AIC3 AIC3 index.

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)

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

References


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 value.

ICL ICL index.

AIC AIC index.

AIC3 AIC3 index.

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)

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

References


Examples

# loading crabs data
data(crabs)

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

# result
```r
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 purpose 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**

```r
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 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.

Author(s)

Cristina Tortora, Ryan P. Browne, 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
```
MixGHD class

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

# 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)**
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**See Also**
MixGHD-class

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

#model estimation
#res=MCHD(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 `MCHD,MCGHD,MSGHD,cMSGHD`.

**Details**
Plot the loglikhelyhood 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. 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)
```

<table>
<thead>
<tr>
<th>MSGHD</th>
<th>Mixture of multiple scaled generalized hyperbolic distributions (MS-GHD).</th>
</tr>
</thead>
</table>

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 pxp matrix gamma, and a px2 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 value.

- ICL: ICL index.
AIC  AIC index.
AIC3 AIC3 index.
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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Maintainer: Cristina Tortora <cristina.tortora@sjsu.edu>

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)
```

plot  *Plot objects of class MixGHD.*

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 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.

Methods

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

Author(s)

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See Also

`MixGHD-class,MGHD,MCGHD,MSGHD,CMGHD,MGHFA`

Examples

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

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

#result
plot(model)
```

---

### 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 summaryzing 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)
```
Index

*Topic Classification
MGHD, 11
MGHFA, 13

*Topic Clustering
cMSGHD, 4
DA, 7
MGHD, 9
MGHD, 11
MGHFA, 13
MixGHD-class, 16
MSGHD, 17
plot, 19
summary, 21

*Topic Generalized hyperbolic distribution
cMSGHD, 4
DA, 7
MGHD, 9
MGHD, 11
MGHFA, 13
MSGHD, 17

*Topic Plot
MixGHD-class, 16
plot, 19

*Topic data sets
banknote, 3
bankruptcy, 4
sonar, 20

*Topic methods
summary, 21

ARI, 2, 8

banknote, 3
bankruptcy, 4
cMSGHD, 4, 8, 15–17, 20, 21
contourpl, 6

DA, 7

MCGD, 8, 9, 15–17, 20, 21
MGHD, 6, 8, 10, 11, 15–17, 19–21
MGHFA, 8, 13, 15, 17, 20, 21
MixGHD, 5, 6, 8, 10, 12, 14, 18, 21
MixGHD (MixGHD class), 15
MixGHD class, 15
MixGHD-class, 16
MSGD, 6, 8, 10, 15–17, 17, 20, 21
plot, 19
plot, MixGHD, missing-method (plot), 19
plot, MixGHD-method (plot), 19
plot, MixGHD (plot), 19

sonar, 20
summary, 21