Package ‘EMCluster’

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Description EM algorithms and several efficient initialization methods for model-based clustering of finite mixture Gaussian distribution with unstructured dispersion in both of unsupervised and semi-supervised learning.
License Mozilla Public License 2.0

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**Description**

EMCluster provides EM algorithms and several efficient initialization methods for model-based clustering of finite mixture Gaussian distribution with unstructured dispersion in both of unsupervised and semi-supervised clustering.

**Details**

- **Package**: EMCluster
- **Type**: Package
- **License**: GPL
- **LazyLoad**: yes

The install command is simply as
Assign Class Id

Description

This function assigns cluster id to each observation in \( x \) according to the desired model \( \text{emobj} \) or specified parameters \( \pi, \mu, \) and \( \Sigma \).

Usage

\[
\text{assign.class}(x, \text{emobj} = \text{NULL}, \pi = \text{NULL}, \mu = \text{NULL}, \Sigma = \text{NULL},
\text{lab} = \text{NULL}, \text{return.all} = \text{TRUE})
\]

Arguments

- \( x \) the data matrix, dimension \( n \times p \).
- \( \text{emobj} \) the desired model which is a list mainly contains \( \pi, \mu, \) and \( \Sigma \), usually a returned object from \text{init.EM}.
- \( \pi \) the mixing proportion, length \( K \).
- \( \mu \) the centers of clusters, dimension \( K \times p \).
Conversion

\[
\text{LTSigma} \quad \text{the lower triangular matrices of dispersion, dimension } K \times \frac{p(p+1)}{2}.
\]
lab \quad \text{labeled data for semi-supervised clustering, length } n.
return.all \quad \text{if returning with a whole emobj object.}

Details

This function are based either an input emobj or inputs \( \pi, \mu, \) and LTSigma to assign class id to each observation of \( x \).

If lab is submitted, then the observation with label id greater 0 will not be assigned new class.

Value

This function returns a list containing mainly two new variables: \( \text{nc} \) (length \( K \) numbers of observations in each class) and \( \text{class} \) (length \( n \) class id).

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

init.EM, emcluster.

Examples

library(EMCluster, quietly = TRUE)
set.seed(1234)
x2 <- da$da

ret <- init.EM(x2, nclass = 2)
ret.new <- assign.class(x2, ret, return.all = FALSE)
str(ret.new)

---

Conversion

| Convert Matrices in Different Format |

Description

These utility functions are to convert matrices in different formats.
Conversion

Usage

LTSigma2variance(x)
variance2LTSigma(x)
LTSigma2var(x1, p = NULL)
var2LTSigma(x1)
class2Gamma(class)
Gamma2class(Gamma)

Arguments

x a matrix/array to be converted, the dimension could be $K \times p(p + 1)/2$ or $p \times p$.
x1 a vector/matrix to be converted, the length and dimension could be $p(p + 1)/2$ and $p \times p$.
p dimension of matrix.
class id of clusters for each observation, length $n$.
Gamma containing posterior probabilities if normalized, otherwise containing component densities weighted by mixing proportion, dimension $n \times K$.

Details

LTSigma2variance converts LTSigma format to 3D array, and variance2LTSigma is the inversion function.
LTSigma2var converts LTSigma format to a matrix, and var2LTSigma is the inversion function. Note that LTSigma is one component of LTSigma.
class2Gamma converts id to a Gamma matrix where with probability 1 for the cluster where the observation belongs to, and Gamma2class converts posterior to cluster id where largest posterior is picked for each observation.

Value

A vector/matrix/array is returned.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

init.EM, emcluster.
Examples

```r
## Not run:
library(EMCluster, quietly = TRUE)
x <- da2$LTSigma
class <- da2$class

y <- LTSigma2variance(x)
str(y)
y <- variance2LTSigma(y)
str(y)
sum(x != y)

Gamma <- class2Gamma(class)
class.new <- Gamma2class(Gamma)
sum(class != class.new)

## End(Not run)
```

---

### Dataset

**Dataset for demonstrations**

### Description

There are four small datasets to test and demonstrate EMCluster.

### Usage

- da1
- da2
- da3
- myiris

### Format

- da1, da2, da3 are in list, and myiris is in matrix.

### Details

- da1 has 500 observations in two dimensions da1$da$x and da1$da$y, and they are in 10 clusters given in da1$class.
- da2 has 2,500 observations in two dimensions, too. The true parameters are given in da1$pi, da1$Mu, and da1$LTSigma. There are 40 clusters given in da1$class for this dataset.
- da3 is similar to da2, but with lower overlaps between clusters.
- myiris is selected from the original Iris dataset given by R.

### Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.
EM Algorithm

References

https://www.stat.iastate.edu/people/ranjan-maitra/

EM Algorithm for model-based clustering

Description

These are core functions of EMCluster performing EM algorithm for model-based clustering of finite mixture multivariate Gaussian distribution with unstructured dispersion.

Usage

emcluster(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL,
lab = NULL, EMC = .EMC, assign.class = FALSE)
shortemcluster(x, emobj = NULL, pi = NULL, Mu = NULL,
LTSigma = NULL, maxiter = 100, eps = 1e-2)
simple.init(x, nclass = 1)

Arguments

x the data matrix, dimension n × p.
emobj the desired model which is a list mainly contains pi, Mu, and LTSigma, usually a returned object from init.EM.
pi the mixing proportion, length K.
Mu the centers of clusters, dimension K × p.
LTSigma the lower triangular matrices of dispersion, K × p(p + 1)/2.
lab labeled data for semi-supervised clustering, length n.
EMC the control for the EM iterations.
assign.class if assigning class id.
maxiter maximum number of iterations.
eps convergent tolerance.
nclass the desired number of clusters, K.

Details

The emcluster mainly performs EM iterations starting from the given parameters emobj without other initializations.

The shortemcluster performs short-EM iterations as described in init.EM.
Value

The emcluster returns an object emobj with class emret which can be used in post-process or other functions such as e.step, m.step, assign.class, em.ic, and dmixmvn.

The shortemcluster also returns an object emobj with class emret which is the best of several random initializations.

The simple.init utilizes rand.EM to obtain a simple initial.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

init.EM, e.step, m.step, EMControl.

Examples

library(EMCluster, quietly = TRUE)
set.seed(1234)
x1 <- da$da

emobj <- simple.init(x1, nclass = 10)
emobj <- shortemcluster(x1, emobj)
summary(emobj)

ret <- emcluster(x1, emobj, assign.class = TRUE)
summary(ret)

---

EM Control

EM Control Generator and Controller

Description

The .EMControl generates an EM control (.EMC) controlling the options and conditions of EM algorithms, i.e. this function generate a default template. One can either modify .EMC or employ this function to control EM algorithms. By default, .EMC, .EMC.Rnd, and .EC.Rndp are three native controllers as the EMCluster is loaded.
EM Control

Usage

```r
.EMControl(alpha = 0.99, short.iter = 200, short.eps = 1e-2,
    fixed.iter = 1, n.candidate = 3,
    em.iter = 1000, em.eps = 1e-6, exhaust.iter = 5)
```

Arguments

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<td>alpha</td>
<td>only used in emgroup for &quot;SVD&quot; initialization.</td>
</tr>
<tr>
<td>short.iter</td>
<td>number of short-EM steps, default = 200.</td>
</tr>
<tr>
<td>short.eps</td>
<td>tolerance of short-EM steps, default = 1e-2.</td>
</tr>
<tr>
<td>fixed.iter</td>
<td>fixed iterations of EM for &quot;RndEM&quot; initialization, default = 1.</td>
</tr>
<tr>
<td>n.candidate</td>
<td>reserved for other initialization methods (unimplemented).</td>
</tr>
<tr>
<td>em.iter</td>
<td>maximum number of long-EM steps, default = 1000.</td>
</tr>
<tr>
<td>em.eps</td>
<td>tolerance of long-EM steps, default = 1e-6.</td>
</tr>
<tr>
<td>exhaust.iter</td>
<td>number of iterations for &quot;exhaustEM&quot; initialization, default = 5.</td>
</tr>
</tbody>
</table>

Details

- exhaust.iter and fixed.iter are used to control the iterations of initialization procedures.
- short.iter and short.eps are used to control the short-EM iterations.
- em.iter and em.eps are used to control the long-EM iterations.

Moreover, short.eps and em.eps are for checking convergence of the iterations.

Value

This function returns a list as .EMC by default.

- The .EMC.Rnd is equal to .EMControl(short.eps = Inf) and usually used by the rand.EM method.
- The .EMC.Rndp is equal to .EMControl(fixed.iter = 5) where each random initials run 5 EM iterations in the rand.EM method.

Author(s)

Wei-Chen Chen (<wccsnow@gmail.com>) and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

init.EM, emcluster.
Examples

library(EMCluster, quietly = TRUE)
.EMC <- .EMControl()
.EMC.Rnd <- .EMControl(short.eps = Inf)
.EMC.Rndp <- .EMControl(fixed.iter = 5)

Description

These functions are tools for compute information criteria for the fitted models.

Usage

em.ic(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL,
      llhdval = NULL)
em.aic(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL)
em.bic(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL)
em.clc(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL)
em.icl(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL)
em.icl.bic(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL)

Arguments

x the data matrix, dimension \( n \times p \).
emobj the desired model which is a list mainly contains pi, Mu, and LTSigma, usually
       a returned object from init.EM.
pi the mixing proportion, length \( K \).
Mu the centers of clusters, dimension \( K \times p \).
LTSigma the lower triangular matrices of dispersion, \( K \times (p+1)/2 \).
llhdval the total log likelihood value of x given emobj.

Details

The em.ic calls all other functions to compute AIC (em.aic), BIC (em.bic), CLC (em.clc), ICL
(em.icl), and ICL.BIC (em.icl.bic). All are useful information criteria for model selections,
mainly choosing number of cluster.

Value

em.ic returns a list containing all other information criteria for given the data x and the desired
model emobj.


**Initialization and EM**

**Author(s)**
Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra

**References**
https://www.stat.iastate.edu/people/ranjan-maitra/

**See Also**
`init.EM`.

**Examples**

```r
library(EMCluster, quietly = TRUE)
x2 <- da2$da

emobj <- list(pi = da2$pi, Mu = da2$Mu, LTSigma = da2$LTSigma)
em.ic(x2, emobj = emobj)
```

---

**Initialization and EM Algorithm**

**Description**
These functions perform initializations (including em.EM and RndEM) followed by the EM iterations for model-based clustering of finite mixture multivariate Gaussian distribution with unstructured dispersion in both of unsupervised and semi-supervised clusterings.

**Usage**

```r
init.EM(x, nclass = 1, lab = NULL, EMC = .EMC,
stable.solution = TRUE, min.n = NULL, min.n.iter = 10,
method = c("em.EM", "Rnd.EM"))
em.EM(x, nclass = 1, lab = NULL, EMC = .EMC,
stable.solution = TRUE, min.n = NULL, min.n.iter = 10)
rnd.EM(x, nclass = 1, lab = NULL, EMC = .EMC.Rnd,
stable.solution = TRUE, min.n = NULL, min.n.iter = 10)
exhaust.EM(x, nclass = 1, lab = NULL,
EMC = .EMControl(short.iter = 1, short.eps = Inf),
method = c("em.EM", "Rnd.EM"),
stable.solution = TRUE, min.n = NULL, min.n.iter = 10);
```
Arguments

- **x** the data matrix, dimension $n \times p$.
- **nclass** the desired number of clusters, $K$.
- **lab** labeled data for semi-supervised clustering, length $n$.
- **EMC** the control for the EM iterations.
- **stable_solution** if returning a stable solution.
- **min.n** restriction for a stable solution, the minimum number of observations for every final clusters.
- **min.n.iter** restriction for a stable solution, the minimum number of iterations for trying a stable solution.
- **method** an initialization method.

Details

The `init.EM` calls either `em.EM` if `method="em.EM"` or `rand.EM` if `method="Rnd.EM"`.

The `em.EM` has two steps: short-EM has loose convergent tolerance controlled by `EMC$short.eps` and try several random initializations controlled by `EMC$short.iter`, while long-EM starts from the best short-EM result (in terms of log likelihood) and run to convergence with a tight tolerance controlled by `EMC$em.eps`.

The `rand.EM` also has two steps: first randomly pick several random initializations controlled by `EMC$short.iter`, and second starts from the best of the random result (in terms of log likelihood) and run to convergence.

The `lab` is only for the semi-supervised clustering, and it contains pre-labeled indices between 1 and $K$ for labeled observations. Observations with index 0 is non-labeled and has to be clustered by the EM algorithm. Indices will be assigned by the results of the EM algorithm. See `demo(allinit_ss,'EMCluster')` for details.

The `exhaust.EM` also calls the `init.EM` with different `EMC` and perform `exhaust.iter` times of EM algorithm with different initials. The best result is returned.

Value

These functions return an object `emobj` with class `emret` which can be used in post-process or other functions such as `e.step, m.step, assign.class, em.ic, and dmixmvn`.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

[https://www.stat.iastate.edu/people/ranjan-maitra/](https://www.stat.iastate.edu/people/ranjan-maitra/)

See Also

- `emcluster, EMControl`
Examples

```r
## Not run:
library(EMCluster, quietly = TRUE)
set.seed(1234)
x <- da$da

ret.em <- init.EM(x, nclass = 10, method = "em.EM")
ret.Rnd <- init.EM(x, nclass = 10, method = "Rnd.EM", EMC = .EMC.Rnd)

emobj <- simple.init(x, nclass = 10)
ret.init <- emcluster(x, emobj, assign.class = TRUE)

par(mfrow = c(2, 2))
plotem(ret.em, x)
plotem(ret.Rnd, x)
plotem(ret.init, x)
```

Description

This function returns the Jaccard index for binary ids.

Usage

`Jaccard.Index(x, y)`

Arguments

- `x` true binary ids, 0 or 1.
- `y` predicted binary ids, 0 or 1.

Details

All ids, `x` and `y`, should be either 0 (not active) or 1 (active). Any value other than 1 will be converted to 0.

Value

Return the value of Jaccard index.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.
Likelihood Mixture Tests

References

https://www.stat.iastate.edu/people/ranjan-maitra/

Examples

```r
library(EMCluster, quietly = TRUE)
x.id <- c(1, 1, 1, 0, 0, 3, 3, 3)
y.id <- c(0, 1, 0, 1, 1, 0, 1, 1)
Jaccard.Index(x.id, y.id)
```

Description

This function test two mixture Gaussian models with unstructured covariance matrix and different numbers of clusters.

Usage

```r
lmt(emobj, emobj.a, x, tau = 0.5, n.mc.E.delta = 1000, n.mc.E.chi2, verbose = FALSE)
```

Arguments

- `emobj`: a `emret` object for the null hypothesis.
- `emobj.a`: a `emret` object for the alternative hypothesis.
- `x`: the data matrix, dimension $n \times p$.
- `tau`: proportion of null and alternative hypotheses.
- `n.mc.E.delta`: number of Monte Carlo simulations for expectation of delta (difference of logL).
- `n.mc.E.chi2`: number of Monte Carlo simulations for expectation of chisquare statistics.
- `verbose`: if verbose.

Details

This function calls several subroutines to compute information, likelihood ratio statistics, degrees of freedom, non-centrality of chi-squared distributions ... etc. Based on Monte Carlo methods to estimate parameters of likelihood mixture tests, this function return a p-value for testing H0: emobj.0 v.s. Ha: emobj.a.
**LMT Functions**

**Value**

A list of class `lmt` are returned.

**Author(s)**

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

**References**

https://www.stat.iastate.edu/people/ranjan-maitra/

**See Also**

`init.EM`.

**Examples**

```r
## Not run:
library(EMCluster, quietly = TRUE)
set.seed(1234)

x <- as.matrix(iris[, 1:4])
p <- ncol(x)
min.n <- p * (p + 1) / 2
.EMC$short.iter <- 200

ret.2 <- init.EM(x, nclass = 2, min.n = min.n, method = "Rnd.EM")
ret.3 <- init.EM(x, nclass = 3, min.n = min.n, method = "Rnd.EM")
ret.4 <- init.EM(x, nclass = 4, min.n = min.n, method = "Rnd.EM")

(lmt.23 <- lmt(ret.2, ret.3, x))
(lmt.34 <- lmt(ret.3, ret.4, x))
(lmt.24 <- lmt(ret.2, ret.4, x))

## End(Not run)
```

---

**LMT Functions**

**Likelihood Mixture Test (LMT) Functions of EMCluster**

**Description**

All likelihood mixture test (LMT) functions are for testing and can be utilized by advanced developers with caution.

Currently, these are only for workflows.

**Author(s)**

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.
References

https://www.stat.iastate.edu/people/ranjan-maitra/

Density of (Mixture) Multivariate Normal Distribution

Description

These functions are tools for compute density of (mixture) multivariate Gaussian distribution with unstructured dispersion.

Usage

\begin{verbatim}
dmvn(x, mu, Lsigma, log = FALSE)
dlmvn(x, mu, Lsigma, log = TRUE)
dmixmvn(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL, log = FALSE)
logL(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL)
\end{verbatim}

Arguments

- \(x\) the data matrix, dimension \(n \times p\).
- \(mu\) the centers of clusters, length \(p\).
- \(Lsigma\) the lower triangular matrices of dispersion, length \(p(p + 1)/2\).
- \(log\) if logarithm returned.
- \(emobj\) the desired model which is a list mainly contains \(pi\), \(Mu\), and \(LTSigma\), usually a returned object from \texttt{init.EM}.
- \(pi\) the mixing proportion, length \(K\).
- \(Mu\) the centers of clusters, dimension \(K \times p\).
- \(LTSigma\) the lower triangular matrices of dispersion, \(K \times p(p + 1)/2\).

Details

The \texttt{dmvn} and \texttt{dlmvn} compute density and log density of multivariate distribution.

The \texttt{dmixmvn} computes density of mixture multivariate distribution and is based either an input \texttt{emobj} or inputs \(pi\), \(Mu\), and \(LTSigma\) to assign class id to each observation of \(x\).

The \texttt{logL} returns the value of the observed log likelihood function of the parameters at the current values of the parameters \(pi\), \(Mu\), and \(LTSigma\), with the supplied data matrix \(x\).

Value

A density value is returned.

Author(s)

Wei-Chen Chen \texttt{<wccsnow@gmail.com>} and Ranjan Maitra.
Other Initializations

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

init.EM, emcluster.

Examples

library(EMCluster, quietly = TRUE)
x2 <- da2$da
x3 <- da3$da

emobj2 <- list(pi = da2$pi, Mu = da2$Mu, LTSigma = da2$LTSigma)
emobj3 <- list(pi = da3$pi, Mu = da3$Mu, LTSigma = da3$LTSigma)

logl(x2, emobj = emobj2)
logl(x3, emobj = emobj3)

dmixmvn2 <- dmixmvn(x2, emobj2)
dmixmvn3 <- dmixmvn(x3, emobj3)

dlvmn(da2$da[,1], da2$Mu[,1], da2$LTSigma[,1])
log(dmvn(da2$da[,1], da2$Mu[,1], da2$LTSigma[,1]))

Description

Two more functions with different initialization method.

Usage

starts.via.svd(x, nclass = 1, method = c("em", "kmeans"),
               EMC = .EMC)
emgroup(x, nclass = 1, EMC = .EMC)

Arguments

x the data matrix, dimension $n \times p$.
nclass the desired number of clusters, $K$.
method method with the svd initializations.
EMC the control for the EM iterations.
Plot EM Results

Details

The `starts.via.svd` utilizes SVD to initial parameters, and the `emgroup` runs the EM algorithm starting from the initial.

Value

The `starts.via.svd` returns an object with class `svd`, and the `emgroup` returns an object `emobj` with class `emret`.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

`init.EM`, `EMControl`.

Examples

```r
library(EMCluster, quietly = TRUE)
set.seed(1234)
x1 <- da1$da

emobj <- emgroup(x1, nclass = 10)
summary(emobj)

ret.0 <- starts.via.svd(x1, nclass = 10, method = "kmeans")
summary(ret.0)
```

---

Plot EM Results  Plot Two Dimensional Data with clusters  

Description

The functions plot two dimensional data for clusters.

Usage

```r
plotem(emobj, x, main = NULL, xlab = NULL, ylab = NULL, 
...)
plot2d(x, emobj = NULL, k = NULL, color.pch = 1, 
append.BN = TRUE, ...)
```
Arguments

emobj the desired model which is a list mainly contains \( \pi, \mu, \) and \( \Sigma \), usually a returned object from \texttt{init.EM}.

x the data matrix, dimension \( n \times p \).

main title of plot.

xlab label of x-axis.

ylab label of y-axis.

... other parameters to the plot.

k index for symbols.

color.pch color and style for symbols.

append.BN if appending bivariate normal ellipsoid.

Details

This a simple x-y lot.

Value

A plot is returned.

Author(s)

Wei-Chen Chen \(<\texttt{wccsnow@gmail.com}>\) and Ranjan Maitra.

References

\url{https://www.stat.iastate.edu/people/ranjan-maitra/}

See Also

\texttt{init.EM}, \texttt{emcluster}.

Examples

```r
## Not run:
library(EMCluster, quietly = TRUE)
x1 <- da$d

ret.1 <- starts.via.svd(x1, nclass = 10, method = "em")
summary(ret.1)

plotem(ret.1, x1)
## End(Not run)
```
Description

The function plots multivariate data for clusters as the parallel coordinates plot.

Usage

plotmd(x, class = NULL, xlab = "Variables", ylab = "Data", ...)

Arguments

x          the data matrix, dimension $n \times p$.
class      class id for all observations.
xlab       label of x-axis.
ylab       label of y-axis.
...        other parameters to the plot.

Details

This a simplified parallel coordinate plot.

Value

A plot is returned.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

init.EM, emcluster.
Examples

```r
## Not run:
library(EMCluster, quietly = TRUE)
set.seed(1234)

x <- myiris
ret <- em.EM(x, nclass = 5)
plotmd(x, ret$class)

## End(Not run)
```

---

**Description**

The function plots multivariate data on 2D plane with contour. Typically, the contour is built via projection pursuit or SVD algorithms, such as `project.on.2d()`.

**Usage**

```r
plotppcontour(da, Pi, Mu, S, class, class.true = NULL, n.grid = 128,
angle = 0, xlab = "", ylab = "", main = "")
```

**Arguments**

- `da`: a projected data matrix, dimension $n \times 2$.
- `Pi`: proportion, length $K$.
- `Mu`: the projected centers of cluster, dimension $K \times 2$.
- `S`: projected matrices of dispersion, dimension $p \times p \times K$.
- `class`: id of classifications, length $n$.
- `class.true`: true id of classifications if available, length $n$.
- `n.grid`: number of grid points.
- `angle`: a rotation angle (0 to $2\pi$).
- `xlab`: an option for `plot()` function.
- `ylab`: an option for `plot()` function.
- `main`: an option for `plot()` function.

**Details**

This function plots projection output of `project.on.2d()`.

da, Mu, and S are projected by some projection matrices obtained via SVD or projection pursuit algorithms. The projection is made on a 2D plane in the direction in which clusters of data $x$ are most distinguishable to visualize.
Post I Information Functions

Value
A 2D projection plot is returned.

Note
Only distinguishable for up to 7 clusters due to the limited color schemes.

Author(s)
Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References
https://www.stat.iastate.edu/people/ranjan-maitra/

See Also
project.on.2d().

Examples
```r
## Not run:
library(EMCluster, quietly = TRUE)
library(MASS, quietly = TRUE)
set.seed(1234)

### Crabs.
x <- as.matrix(crabs[, 4:8])
ret <- init.EM(x, nclass = 4, min.n = 20)
ret.proj <- project.on.2d(x, ret)

### Plot.
pdf("crabs_ppcontour.pdf", height = 5, width = 5)
plotppcontour(ret.proj$da, ret.proj$Pi, ret.proj$mu, ret.proj$s,
              ret.proj$class, angle = pi/6, main = "Crabs K = 4")
dev.off()

## End(Not run)
```

Post I Information Functions

Post I Information Functions of EMCluster

Description
All post I information functions are for computing relative quantities and can be utilized by advanced developers with caution.
Currently, these are only for workflows.
Print and Summary

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

Print and Summary

Functions for Printing or Summarizing Objects According to Classes

Description

Several classes are declared in EMCluster, and these are functions to print and summary objects.

Usage

```r
## S3 method for class 'emret'
print(x, digits = max(4,getOption("digits") - 3), ...)
## S3 method for class 'emret'
summary(object, ...)
## S3 method for class 'svd'
summary(object, ...)
```

Arguments

- `x`: an object with the class attributes.
- `digits`: for printing out numbers.
- `object`: an object with the class attributes.
- `...`: other possible options.

Details

These are useful functions for summarizing and debugging.

Value

The results will cat or print on the STDOUT by default.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/
Projection On 2D

See Also

init_EM, emcluster, starts.via.svd.

Examples

```r
## Not run:
library(EMCluster, quietly = TRUE)
x2 <- da$da

emobj <- list(pi = da$pi, Mu = da$Mu, LTSigma = da$LTSigma)
eobj <- e.step(x2, emobj = emobj)
emobj <- m.step(x2, emobj = eobj)
summary(emobj)

ret <- starts.via.svd(x2, nclass = 10, method = "kmeans")
summary(ret)
## End(Not run)
```

Description

The function projects multivariate data on 2D plane which can be displayed by plotppcontour() later.

Usage

```r
project.on.2d(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL, class = NULL, method = c("PP", "SVD"))
```

Arguments

- **x**: the data matrix, dimension $n \times p$.
- **emobj**: the desired model which is a list mainly contains pi, Mu, and LTSigma, usually a returned object from init.EM.
- **pi**: the mixing proportion, length $K$.
- **Mu**: the centers of clusters, dimension $K \times p$.
- **LTSigma**: the lower triangular matrices of dispersion, $K \times (p(p + 1)/2)$.
- **class**: id of classifications, length $n$.
- **method**: either projection pursuit or singular value decomposition.

Details

This function produces projection outputs of x and emobj.
Value

A projection is returned which is a list contains

- \( \text{da} \) is a \( n \times 2 \) projected matrix of \( x \).
- \( \text{pi} \) is the original proportion \( \text{emobj}\$\text{pi} \) of length \( K \).
- \( \text{mu} \) is a \( K \times 2 \) projected matrix of \( \text{emobj}\$\text{mu} \).
- \( \text{S} \) is a \( 2 \times 2 \times K \) projected array of \( \text{emobj}\$\text{LTSigma} \).
- \( \text{class} \) is the original class id \( \text{emobj}\$\text{class} \).
- \( \text{proj.mat} \) is the projection matrix of dimension \( p \).

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

`project.on.2d()`.

Examples

```r
## Not run:
library(EMCluster, quietly = TRUE)
set.seed(1234)

### Iris.
x <- as.matrix(iris[, 1:4])
ret <- init.EM(x, nclass = 3, min.n = 30)
ret.proj <- project.on.2d(x, ret)

### Plot.
pdf("iris_ppcontour.pdf", height = 5, width = 5)
plotppcontour(ret.proj$da, ret.proj$Pi, ret.proj$Mu, ret.proj$S,
              ret.proj$class, main = "Iris K = 3")
dev.off()

## End(Not run)
```
Description

This function returns the Rand index and the adjusted Rand index for given true class ids and predicted class ids.

Usage

RRand(trcl, prcl, lab = NULL)

Arguments

trcl true class ids.
prcl predicted class ids.
lab known ids for semi-supervised clustering.

Details

All ids, trcl and prcl, should be positive integers and started from 1 to K, and the maximums are allowed to be different.

lab used in semi-supervised clustering contains the labels which are known before clustering. It should be positive integer and started from 1 for labeled data and 0 for unlabeled data.

Value

Return a Class RRand contains Rand index and adjusted Rand index.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

Examples

library(EMCluster, quietly = TRUE)

true.id <- c(1, 1, 1, 2, 2, 3, 3, 3)
pred.id <- c(2, 1, 2, 1, 1, 1, 1, 1)
label <- c(0, 0, 0, 0, 1, 0, 2, 0, 0)

RRand(true.id, pred.id)
RRand(true.id, pred.id, lab = label)
Recolor Classification IDs

Recolor Classification IDs

Description

These functions return new classification IDs.

Usage

```r
recolor(id.target, id.class, scatter.class = NULL, scatter.target = NULL)
rematch(tg.id, cl.id)
recode(id)
```

Arguments

- `id.target`: target class ids.
- `id.class`: original class ids.
- `scatter.class`: scatter class ids.
- `scatter.target`: scatter target class ids.
- `id`: class ids.
- `tg.id`: target class ids.
- `cl.id`: class ids.

Details

The function `recolor` colors `id.target` in accordance with the most likely candidate in `id.class`. Note that if `scatter` is present, then the class given by 0 is represented as `scatter` and it is assumed to be the same for both classifications.

The function `rematch` returns a list as `id.trcl` and `id.prcl`. It is the heart of the `recolor` function and is usually called from `recolor`.

The function `recode` reorders classes to eliminate group ids without any members. It is assumed that the group ids are integers.

Value

See Details.

Author(s)

Ranjan Maitra.

References

[https://www.stat.iastate.edu/people/ranjan-maitra/](https://www.stat.iastate.edu/people/ranjan-maitra/)
Examples

```r
## Not run:
library(emcluster, quietly = TRUE)
true.id <- c(1, 1, 1, 2, 2, 3, 3)
pred.id <- c(2, 1, 2, 1, 1, 2, 1)
recolor(pred.id, true.id)
## End(Not run)
```

---

**Single Step**

**Single E- and M-step**

Description

These functions are single E- and M-step of EM algorithm for model-based clustering of finite mixture multivariate Gaussian distribution with unstructured dispersion.

Usage

```r
e.step(x, emobj = NULL, pi = NULL, Mu = NULL, LTSigma = NULL, norm = TRUE)
m.step(x, emobj = NULL, Gamma = NULL, assign.class = FALSE)
```

Arguments

- `x`: the data matrix, dimension \( n \times p \).
- `emobj`: the desired model which is a list mainly contains `pi`, `Mu`, and `LTSigma`, usually a returned object from `init.EM`.
- `pi`: the mixing proportion, length \( K \).
- `Mu`: the centers of clusters, dimension \( K \times p \).
- `LTSigma`: the lower triangular matrices of dispersion, \( K \times p(p + 1)/2 \).
- `norm`: if returning normalized `Gamma`.
- `Gamma`: containing posterior probabilities if normalized, otherwise containing component densities weighted by mixing proportion, dimension \( n \times K \).
- `assign.class`: if assigning class id.

Details

These two functions are mainly used in debugging for development and post process after model fitting.
Value

The e.step returns a list contains Gamma, the posterior probabilities if norm=TRUE, otherwise it contains component densities. This is one E-step and Gamma is used to update emobj in the M-step next.

The m.step returns a new emobj according to the Gamma from the E-step above.

Author(s)

Wei-Chen Chen <wccsnow@gmail.com> and Ranjan Maitra.

References

https://www.stat.iastate.edu/people/ranjan-maitra/

See Also

init.EM.

Examples

library(EMCluster, quietly = TRUE)
x2 <- da2$da

emobj <- list(pi = da2$pi, Mu = da2$Mu, LTSigma = da2$LTSigma)
eobj <- e.step(x2, emobj = emobj)
emobj <- m.step(x2, emobj = eobj)
emobj
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