

# Package ‘snipEM’

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**Type** Package

**Title** Snipping methods for robust estimation and clustering

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**Author** Alessio Farcomeni, Andy Leung

**Maintainer** Alessio Farcomeni <alessio.farcomeni@uniroma1.it>

**Description** Snipping methods

**License** GPL (>= 2)

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 ldmvnorm

*Multivariate Normal Log-Density for Complete and Incomplete Data*


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### Description

This function provides the log-density function for the multivariate normal distribution with mean equal to  $\mu$  and covariance matrix  $\Sigma$ . Marginal distributions will be used when the vector (or matrix) of quantiles is incomplete. That is, when the vector (or matrix) of quantiles contain NA.

### Usage

```
ldmvnorm(x, mu, Sigma, onNA=0)
```

### Arguments

<code>x</code>	Vector or matrix of quantiles. If <code>x</code> is a matrix, each row is taken to be a quantile.
<code>mu</code>	Mean vector, default is <code>rep(0, length = ncol(x))</code>
<code>Sigma</code>	Covariance matrix, default is <code>diag(ncol(x))</code> .
<code>onNA</code>	Action for a row on NAs. Default is to return 0.

### Author(s)

Alessio Farcomeni <alessio.farcomeni@uniroma1.it>, Andy Leung <andy.leung@stat.ubc.ca>

### Examples

```
## Not run:
x <- matrix(rnorm(1000),100, 10)
u <- matrix(rbinom(1000, 1, 0.1), 100, 10)
x[ u == 1 ] <- NA
mu <- rep(0,10)
Sigma <- diag(10)
ldmvnorm(x, mu, Sigma)

## End(Not run)
```

---

 sclust

*Snipping for robust model based clustering analysis with cellwise outliers*


---

### Description

Estimates a finite Gaussian mixture model optimized over a snipping set.

**Usage**

```
sclust(X, k, V, R, restr.fact=12, tol = 1e-04, maxiters = 100,
       maxiters.S = 1000, print.it = FALSE)
```

**Arguments**

X	Data.
k	Number of clusters
V	Binary matrix of the same size as X. Zeros correspond to initial snipped entries.
R	Initial guess for cluster labels, 1 to k.
restr.fact	Restriction factor, i.e., constraint on the condition number of all covariance matrices for each cluster. Default is 12.
tol	Tolerance for convergence. Default is 1e-4.
maxiters	Maximum number of iterations for the SM algorithm. Default is 100.
maxiters.S	Maximum number of iterations of the inner greedy snipping algorithm. Default is 1000.
print.it	Logical; if TRUE, partial results are print. Default is FALSE.

**Details**

This function computes the `sclust` estimator of Farcomeni (2014). It leads to robust mixture modeling in presence of entry-wise outliers. It is based on a classification-expectation-snip-maximize (CESM) algorithm. At the S step, the likelihood is optimized over the set of snipped entries, at the M step the location and scatter estimates are updated. The S step is based on a greedy algorithm, unlike the one proposed in Farcomeni (2014,2014a). The number of snipped entries  $\text{sum}(1-V)$  is kept fixed throughout. Note that initializing with labels arising from classical (non-robust) clustering methods may be detrimental for the final performance of `sclust` and may even yield an error due to empty clusters.

**Value**

A list with the following elements:

R	Final cluster labels.
mu	Estimated location matrix.
S	Array of estimated scatter matrices.
V	Final (optimal) V matrix.
lik	Gaussian log-likelihood at convergence.
iter	Number of outer iterations before convergence.

**Author(s)**

Alessio Farcomeni <alessio.farcomeni@uniroma1.it>, Andy Leung <andy.leung@stat.ubc.ca>

## References

- Farcomeni, A. (2014) Snipping for robust k-means clustering under component-wise contamination, *Statistics and Computing*, **24**, 909-917
- Farcomeni, A. (2014) Robust constrained clustering in presence of entry-wise outliers, *Technometrics*, **56**, 102-111

## See Also

[snipEM](#), [stEM](#), [generate.cellcontam](#), [sumlog](#), [ldmvnorm](#)

## Examples

```
## Not run:
X <- matrix(NA,1000,5)
# two clusters
k <- 2
X[1:500,] <- rnorm(500*5)
X[501:1000,] <- rnorm(500*5,15)
R <- rep(c(1,2), each=500)

# 5% cellwise outliers
s <- sample(1000*5,1000*5*0.05)
X[s] <- runif(1000*5*0.05,-100,100)
V <- X
V[s] <- 0
V[-s] <- 1

# Initial V and R
Vinit <- matrix(1, nrow(X), ncol(X))
Vinit[which(X > quantile(X,0.975) | X < quantile(X,0.025))] <- 0
Rinit <- kmeans(X,2)$clust

# Snipped robust clustering
sc <- sclust(X,2,Vinit,Rinit)
table(R,Rinit)
table(R,sc$R)

## End(Not run)
```

---

skmeans

*Snipped k-means clustering with cellwise outliers*

---

## Description

Perform k-means clustering on a data matrix with cellwise outliers using a snipping algorithm.

## Usage

```
skmeans(X, k, V, clust, s, itersmax = 10^5, D = 1e-1)
```

**Arguments**

X	Data.
k	Integer; number of clusters, $k > 1$ .
V	Binary matrix of the same size as X. Zeros correspond to initial snipped entries.
clust	Vector of size n containing values from 1 to k. Starting solution for class labels.
itersmax	Max number of iterations of the algorithm. Default is $3 \times 10^5$ .
s	Binary vector of size n for trimming, starting solution. Number of zeros will be preserved and correspond to trimmed rows. If the vector is <code>rep(1, n)</code> , it performs no trimming. Default is <code>rep(1, n)</code> .
D	Tuning parameter for the fitting algorithm. Corresponds approximately to the maximal change in loss by switching two non outlying entries. Comparing different choices is recommended. Default is $1e-1$ .

**Details**

This function computes the skmeans estimator of Farcomeni (2014). It leads to robust k-means in presence of entry-wise and cellwise outliers. The number of snipped entries  $\text{sum}(1-V)$  and trimmed rows  $\text{sum}(1-s)$  is kept fixed throughout. Initial estimates for V, s and clust should be provided. Note that initializing with labels arising from classical (non-robust) clustering methods may be detrimental for the final performance of skmeans and may even yield an error due to empty clusters.

**Value**

A list with the following elements:

loss	Loss function (the total sum of squares) at convergence.
mu	Estimated locations.
s	Final (optimal) trimmed rows in vector of size n.
V	Final (optimal) V matrix.
clust	Final (optimal) class labels as vector of size n.

**Author(s)**

Alessio Farcomeni <alessio.farcomeni@uniroma1.it>, Andy Leung <andy.leung@stat.ubc.ca>

**References**

Farcomeni, A. (2014) Snipping for robust k-means clustering under component-wise contamination, *Statistics and Computing*, **24**, 909-917

**See Also**

[sclust](#), [stEM](#), [snipEM](#), [generate.casecontam](#), [generate.cellcontam](#)

**Examples**

```

## Not run:
X <- matrix(NA,1000,5)
# two clusters
k <- 2
X[1:500,] <- rnorm(500*5)
X[501:1000,] <- rnorm(500*5,15)
clust <- rep(c(1,2), each=500)

# 5% cellwise outliers
s <- sample(1000*5,1000*5*0.05)
X[s] <- runif(1000*5*0.05,-100,100)
V <- X
V[s] <- 0
V[-s] <- 1

# Initial V and R
Vinit <- matrix(1, nrow(X), ncol(X))
Vinit[which(X > quantile(X,0.975) | X < quantile(X,0.025))] <- 0
km <- kmeans(X,k)
clustinit <- km$clust

# Snipped robust clustering
skm <- skmeans(X, k, Vinit, clustinit)

table(clust,km$clust)
table(clust,skm$clust)

## End(Not run)

```

---

snipEM

*Snipping for location and scatter estimation with cellwise outliers*


---

**Description**

Computes an estimator optimizing the Gaussian likelihood over a snipping set. The function `snipEM.initialV` can be used to perform some iterations to initialize  $V$ .

**Usage**

```

snipEM(X, V, tol = 1e-04, maxiters = 500, maxiters.S = 1000, print.it = FALSE)

snipEM.initialV(X, V, mu0, S0, maxiters.S = 100, greedy = TRUE)

```

**Arguments**

$X$	Data.
$V$	Binary matrix of the same size as $X$ . Zeros correspond to initial snipped entries.

<code>tol</code>	Tolerance for convergence. Default is $1e-4$ .
<code>maxiters</code>	Maximum number of iterations for the SM algorithm. Default is 500.
<code>maxiters.S</code>	Maximum number of iterations of the inner greedy snipping algorithm. Default is 1000.
<code>print.it</code>	Logical; if TRUE, partial results are print. Default is FALSE.
<code>mu0</code>	Initial estimate for the mean vector that is used in the initialization stage.
<code>S0</code>	Initial estimate for the covariance matrix that is used in the initialization stage.
<code>greedy</code>	Logical; if TRUE, perform the greedy snipping algorithm in search for the binary matrix that gives the largest likelihood value throughout <code>maxiters.S</code> iterations. If FALSE, stop right after the snipping algorithm finds a binary matrix that gives a larger likelihood value than the initial one. Default is TRUE.

### Details

This function computes the `sclust` estimator of Farcomeni (2014) with  $k = 1$ . It therefore provides a robust estimate of location and scatter in presence of entry-wise outliers. It is based on a snip-maximize (SM) algorithm. At the S step, the likelihood is optimized over the set of snipped entries, at the M step the location and scatter estimates are updated. The S step is based on a greedy algorithm, unlike the one proposed in Farcomeni (2014,2014a). The number of snipped entries  $\text{sum}(1-V)$  is kept fixed throughout.

Results depend on good initialization of the V matrix. A boxplot rule (see examples) usually works well. The function `snipEM.initialV` can be used to improve the initial choice through some iterations updating only V from initial (robust) estimates `mu0` and `S0`. In the example, the EMVE is used to obtain `mu0` and `S0`.

### Value

A list with the following elements:

<code>mu</code>	Estimated location.
<code>S</code>	Estimated scatter matrix.
<code>V</code>	Final (optimal) V matrix.
<code>lik</code>	Gaussian log-likelihood at convergence.
<code>iter</code>	Number of outer iterations before convergence.

### Author(s)

Alessio Farcomeni <alessio.farcomeni@uniroma1.it>, Andy Leung <andy.leung@stat.ubc.ca>

### References

- Farcomeni, A. (2014) Snipping for robust k-means clustering under component-wise contamination, *Statistics and Computing*, **24**, 909-917
- Farcomeni, A. (2014) Robust constrained clustering in presence of entry-wise outliers, *Technometrics*, **56**, 102-111

**See Also**

[sclust](#), [stEM](#), [generate.cellcontam](#), [sumlog](#), [ldmvnorm](#)

**Examples**

```
## Not run:
# 10% cellwise outliers
n=100
p=10
Xc <- generate.cellcontam(100, 10, 100, 5, 0.10)
A <- Xc$A # true correlation matrix
Uc <- Xc$u # (true outlier) binary matrix
Xc <- Xc$x

# initial V
V <- matrix(1,n,p)
V[!is.na(match(as.vector(Xc),boxplot(as.vector(Xc),plot=FALSE)$out))] <- 0
Xna <- Xc
Xna[ which( V == 0) ] <- NA
resEMVE <- emve(Xna)
V <- snipEM.initialV(Xc, V, resEMVE@mu, resEMVE@S)$V

# Performance in LRT distance
resSEM <- snipEM(Xc, V)
slrt(resSEM$S, A)
slrt(cov(Xc), A)

## End(Not run)
```

---

stEM

*Snipping and trimming for location and scatter estimation with case-wise and cellwise outliers*

---

**Description**

Computes an estimator optimizing the Gaussian likelihood over a snipping and trimming set.

**Usage**

```
stEM(X, V, tol = 1e-4, maxiters = 500, maxiters.S = 1000, print.it = FALSE)
```

**Arguments**

X	Data.
V	Binary matrix of the same size as X. Zeros correspond to initial snipped entries, rows of zeros correspond to initial trimmed entries.
tol	Tolerance for convergence. Default is 1e-4.
maxiters	Maximum number of iterations for the SM algorithm. Default is 500.



maxiters.S	Maximum number of iterations of the inner greedy snipping algorithm. Default is 1000.
print.it	Logical; if TRUE, partial results are print. Default is FALSE.

### Details

This function combines computes the snipEM estimator of Farcomeni (2014) with trimming. Optimization over a trimming set is performed via usual concentration steps (Rousseeuw and van Driessen, 1999). It therefore provides a robust estimate of location and scatter in presence of entry-wise and case-wise outliers. The number of snipped entries and trimmed rows is kept fixed throughout. V must contain at least one row of zeros (otherwise use [snipEM](#)).

### Value

A list with the following elements:

mu	Estimated location.
S	Estimated scatter matrix.
V	Final (optimal) V matrix.
lik	Gaussian log-likelihood at convergence.
iter	Number of outer iterations before convergence.

### Author(s)

Alessio Farcomeni <alessio.farcomeni@uniroma1.it>, Andy Leung <andy.leung@stat.ubc.ca>

### References

- Farcomeni, A. (2014) Snipping for robust k-means clustering under component-wise contamination, *Statistics and Computing*, **24**, 909-917
- Farcomeni, A. (2014) Robust constrained clustering in presence of entry-wise outliers, *Technometrics*, **56**, 102-111
- Rousseeuw, P. J. and Van Driessen, K. (1999) A fast algorithm for the minimum covariance determinant estimator, *Technometrics*, **41**, 212-223.

### See Also

[sclust](#), [snipEM](#), [generate.casecontam](#), [generate.cellcontam](#), [emve](#), [sumlog](#), [ldmvnorm](#)

### Examples

```
## Not run:
# 10% cellwise outliers
Xc <- generate.cellcontam(100, 10, 100, 5, 0.10)
A <- Xc$A # true correlation matrix
Uc <- Xc$u # (true outlier) binary matrix
Xc <- Xc$x
```

```

# 5% case-wise outliers
Xct <- generate.casecontam(100, 10, 100, 10, 0.05)
Xc <- rbind(Xc, Xct$x[ rowSums(Xct$u == 1) == 10,])
trim <- rep(1,105)
trim[101:105] <- 0 # (true casewise outlier) binary vector
Uc <- rbind(Uc, matrix(1,5,10))

# initial V
V <- matrix(1, 105, 10)
# identify rows to be trimmed
km <- kmeans(Xc,2)$clust
wtrim <- which(km==which.min(table(km)))
V[wtrim,] <- 0
Vtmp <- V[-wtrim,]

# identify cells to be snipped
Vtmp[!is.na(match(as.vector(Xc[-wtrim,]), boxplot(as.vector(Xc[-wtrim,]), plot=FALSE)$out))] <- 0
Xna <- Xc[-wtrim,]
Xna[ which( Vtmp == 0) ] <- NA
resEMVE <- emve(Xna)
Vtmp <- snipEM.initialV(Xc[-wtrim,], Vtmp, resEMVE@mu, resEMVE@S)
V[-wtrim,] <- Vtmp$V

# Performance in LRT distance
resSTEM <- stEM(Xc, V)
slrt(resSTEM$S, A)
slrt(cov(Xc), A)

## End(Not run)

```

---

sumlog

*Log-sum from log data*


---

### Description

Obtain  $\log(\text{sum}(x))$  from  $\log(x)$ , without passing to exponentials. It is based on the fact that  $\log(a + b) = \log(a) + \log(1 + \exp(\log(b) - \log(a)))$ .

### Usage

```
sumlog(x, lower=-745, upper=709)
```

### Arguments

x	Vector of log-values
lower	Value such that $\exp(\text{lower}-\text{epsilon})=0$
upper	Value such that $\exp(\text{upper}+\text{epsilon})=\text{Inf}$

**Details**

This function computes the logarithm of the sum of  $\exp(x)$ , without passing through exponentials. It shall be used to avoid under/over flow. It has proven useful in computing the likelihood of finite mixture models, normalization constants, importance sampling, etc. It is described in the appendix of Farcomeni (2012).

**Value**

A scalar equal to  $\log(\text{sum}(\exp(x)))$ .

**Author(s)**

Alessio Farcomeni <alessio.farcomeni@uniroma1.it>, Andy Leung <andy.leung@stat.ubc.ca>

**References**

Farcomeni, A. (2012) Quantile Regression for longitudinal data based on latent Markov subject-specific parameters. *Statistics and Computing*, **22**, 141-152

**Examples**

```
## Not run:
# complete underflow without sumlog
x <- c(-750, -752)
log(sum(exp(x)))
sumlog(x)

# imprecise sum
x <- c(-745, -752)
log(sum(exp(x)))
sumlog(x)

# no issues
x <- c(log(3), log(2))
log(5)
log(sum(exp(x)))
sumlog(x)

## End(Not run)
```

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