

Package ‘EMMIXcskew’

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Title Fitting Mixtures of CFUST Distributions

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Description

Functions to fit finite mixture of multivariate canonical fundamental skew t (FM-CFUST) distributions, random sample generation, 2D and 3D contour plots. See Lee and McLachlan (2017) <doi:10.18637/jss.v083.i03> for more information and examples.

License GPL

LazyLoad yes

Imports rgl, mnormt, graphics, MASS, grDevices, stats

Suggests KernSmooth

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EMMIXcskew-package	2
dfmcfust	2
fmcufust	4
fmcufust.contour.2d	6
fmmst	8
init.cfust	10
rfmcfust	12

Index	15
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EMMIXcskew-package *Finite mixture of multivariate canonical fundamental skew t-distributions*

Description

This package implements an EM algorithm for fitting mixtures of multivariate canonical fundamental skew t (FM-CFUST) distributions. Functions for random sample generation, initial value generation, and visualisation (in 2D and 3D) are also provided.

Details

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Author(s)

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References

Lee S.X. and McLachlan, G.J. (2016). Finite mixtures of canonical fundamental skew t-distributions: the unification of the restricted and unrestricted skew t-mixture models. *Statistics and Computing* 26, 573-589.

Lee S.X. and McLachlan, G.J. (2017). EMMIXcskew: An R Package for the Fitting of a Mixture of Canonical Fundamental Skew t-Distributions. *Journal of Statistical Software* 83(3), 1-32. URL [10.18637/jss.v083.i03](https://doi.org/10.18637/jss.v083.i03).

See Also

[fmcfust](#), [dfmcfust](#), [rfmcfust](#), [fmcfust.contour.3d](#)

dfmcfust

Multivariate canonical fundamental skew t-distribution

Description

The probability density function for the multivariate canonical fundamental skew t (CFUST) distribution and finite mixture of CFUST distributions

Usage

```
dfmcfust(dat, mu=NULL, sigma=NULL, delta=NULL, dof=NULL, pro=NULL, known=NULL)
dcfust(dat, mu=NULL, sigma=NULL, delta=NULL, dof=1, known=NULL)
```

Arguments

<code>dat</code>	the data matrix giving the coordinates of the point(s) where the density is evaluated. This is either a vector of length p or a matrix with p columns.
<code>mu</code>	for <code>dcfust</code> , this is a numeric vector of length p representing the location parameter; for <code>dfmcfust</code> , this is list of g numeric matrices each having p rows and 1 column containing the location parameter for each component.
<code>sigma</code>	for <code>dcfust</code> , this is a numeric positive definite matrix with dimension (p,p) representing the scale parameter; for <code>dfmcfust</code> , this is list of g numeric matrices containing the scale parameter for each component.
<code>delta</code>	for <code>dcfust</code> , this is a numeric matrix of size p by q representing the skewness matrix; for <code>rfmcfust</code> , this is list of g numeric matrices each having p rows and q column containing the skewness parameter for each component.
<code>dof</code>	for <code>dcfust</code> , this is a positive integer specifying the degrees of freedom; for <code>dfmcfust</code> , this is numeric vector of length g representing the degrees of freedom for each component.
<code>pro</code>	the mixing proportions; for <code>dcfust</code> , this is equal to 1; for <code>dfmcfust</code> , this is vector of length of g specifying the mixing proportions for each component.
<code>known</code>	a list containing the parameters of the model. If specified, it overwrites the values of <code>mu</code> , <code>sigma</code> , <code>delta</code> , <code>dof</code> and <code>pro</code> .

Details

The function `dcfust` computes the density value of a specified multivariate canonical fundamental skew t (CFUST) distribution. If any model parameters are not specified, their default values are used: `mu` and `delta` are zero vectors, `sigma` is the identity matrix, and `dof` is 1.

The function `dfmcfust` computes the density value for a specified mixture of MST distribution. Note that `dfmcfust` expects at least `dof` is specified. Other missing parameters will take the default value described above. When $g=1$, `dfmcfust` passes the call to `dcfust`. Model parameters can be passed to `dcfust` and `dfmcfust` through the argument `known` or listed as individual arguments. If both methods of input were used, the parameters specified in `known` will be used.

Value

`dcfust` and `dfmcfust` returns a numeric vector of density values

References

Lee S.X. and McLachlan, G.J. (2016). Finite mixtures of canonical fundamental skew t-distributions: the unification of the restricted and unrestricted skew t-mixture models. *Statistics and Computing* 26, 573-589.

Lee S.X. and McLachlan, G.J. (2017). EMMIXskew: An R Package for the Fitting of a Mixture of Canonical Fundamental Skew t-Distributions. *Journal of Statistical Software* 83(3), 1-32. URL [10.18637/jss.v083.i03](https://doi.org/10.18637/jss.v083.i03).

See Also

[rcfust](#), [rfmcfust](#)

Examples

```
dcfust(c(1,2), mu=c(1,5), sigma=diag(2), delta=matrix(c(-3,1,1,1),2,2), dof=4)
```

fmcfust	<i>Fitting Finite Mixtures of Multivariate Canonical Fundamental Skew t-Distributions</i>
---------	---

Description

Computes maximum likelihood estimators (MLE) for finite mixtures of canonical fundamental multivariate skew t (FM-CFUST) model via the EM algorithm.

Usage

```
fmcfust(g=1, dat, q, initial=NULL, known=NULL, clust=NULL, itmax=100, eps=1e-6,
        nkmeans=20, verbose=T, method=c("moments","transformation","EMMIXskew","EMMIXuskew"),
        convergence=c("Aitken","likelihood","parameters"))
## S3 method for class 'fmcfust'
summary(object, ...)
## S3 method for class 'fmcfust'
print(x, ...)
```

Arguments

object, x	an object class of class "fmcfust", i.e. a fitted model.
g	a scalar specifying the number of components in the mixture model
dat	the data matrix giving the coordinates of the point(s) where the density is evaluated. This is either a vector of length p or a matrix with p columns.
q	a scalar specifying how many number of columns the skewness matrix delta has.

initial	(optional) a list containing the initial parameters of the mixture model. See the 'Details' section. The default is NULL.
known	(optional) a list containing parameters of the mixture model that are known and not required to be estimated. See the 'Details' section. The default is NULL.
itmax	(optional) a positive integer specifying the maximum number of EM iterations to perform. The default is 100.
eps	(optional) a numeric value used to control the termination criteria for the EM loops. It is the maximum tolerance for the absolute difference between the log-likelihood value and the asymptotic log likelihood value. The default is 1e-6.
clust	(optional) a numeric value of length nrow(dat) containing the initial labels for each data point in dat. The default is NULL, indicating no initial clustering is known.
nkmeans	(optional) a numeric value indicating how many k-means trials to be used when searching for initial values. The default is 20.
verbose	(optional) a logical value. If TRUE, output for each iteration will be printed out. if FALSE, no output is printed. The default is TRUE. See the 'Details' section.
method	(optional) a string indicating which method to use to generate initial values. See init.cfust .
convergence	(optional) a string indicating which convergence criterion to use to terminate the iterations. The default "Aitken" uses Aitken accelation, whereas "likelihood" uses the relative difference in log likleihood value, and "parameters" checks the changes in parameter estimates.
...	not used.

Details

The arguments `init` and `known`, if specified, is a list structure containing at least one of `mu`, `sigma`, `delta`, `dof`, `pro` (See [dfmcfust](#) for the structure of each of these elements). If `init=FALSE` (default), the program uses an automatic approach based on moments estimate and k-means clustering to generate an initial value for the model parameters. Note that this may not provide the best results.

As the EM algorithm is sensitive to the starting value, it is highly recommended to apply a wide range different initializations. Some strategies are implemented in [init.cfust](#).

Value

<code>mu</code>	a list of <code>g</code> numeric matrices containing the location parameter for each component.
<code>sigma</code>	a list of <code>g</code> numeric matrices containing the scale parameter for each component.
<code>delta</code>	a list of <code>g</code> numeric matrices containing the skewness parameter for each component.
<code>dof</code>	a numeric vector of length <code>g</code> representing the degrees of freedom for each component.
<code>pro</code>	a vector of length of <code>g</code> specifying the mixing proportions for each component.
<code>tau</code>	an <code>g</code> by <code>n</code> matrix of posterior probability of component membership.

clusters	a vector of length n of final partition.
loglik	the final log likelihood value.
lk	a vector of log likelihood values at each EM iteration.
iter	number of iterations performed.
eps	the final absolute difference between the log likelihood value and the asymptotic log likelihood value.
aic, bic	Akaike Information Criterion (AIC), Bayes Information Criterion (BIC)

References

Lee S.X. and McLachlan, G.J. (2016). Finite mixtures of canonical fundamental skew t-distributions: the unification of the restricted and unrestricted skew t-mixture models. *Statistics and Computing* 26, 573-589

Lee S.X. and McLachlan, G.J. (2017). EMMIXcskew: An R Package for the Fitting of a Mixture of Canonical Fundamental Skew t-Distributions. *Journal of Statistical Software* 83(3), 1-32. URL [10.18637/jss.v083.i03](https://doi.org/10.18637/jss.v083.i03).

See Also

[init.cfust](#), [rfmcfust](#), [dfmcfust](#), [fmcfust.contour.2d](#)

Examples

```
#a short demo using geysers data
library(MASS)
Fit <- fmcfust(3, geysers)
summary(Fit)
print(Fit)
```

fmcfust.contour.2d *2D and 3D Visualisation of Fitted Contours*

Description

Create 2D or 3D contour plot.

Usage

```
fmcfust.contour.2d(dat, model, grid=50, drawpoints=TRUE, clusters=NULL,
  nlevels=10, map=c("scatter", "heat", "cluster"),
  component=NULL, xlim, ylim, xlab, ylab, main, pcol=NULL, ccol=NULL, ...)
fmcfust.contour.3d(dat, model, grid=20, drawpoints=TRUE, levels=0.9,
  clusters=NULL, xlim, ylim, zlim, xlab, ylab, zlab, main, component=NULL,
  pcol=NULL, ccol=NULL, ...)
```

Arguments

<code>dat</code>	the data matrix giving the coordinates of the point(s) where the density is evaluated. This must be a matrix with at least 2 columns for <code>fmcfust.contour.2d</code> or 3 columns for <code>fmcfust.contour.3d</code> . If <code>dat</code> is not provided, then <code>xlim</code> , <code>ylim</code> and <code>zlim</code> must be provided, and <code>drawpoints</code> must be set to <code>FALSE</code> .
<code>model</code>	a list containing the parameters of the model and also a vector of cluster labels for <code>dat</code> . This is typically an output from <code>fmcfust</code> , containing <code>mu</code> , <code>sigma</code> , <code>delta</code> , <code>dof</code> , <code>pro</code> and <code>clusters</code> ; see <code>fmcfust</code> for structure of <code>model</code> .
<code>grid</code>	a positive integer specifying the grid size used to calculate the density map.
<code>drawpoints</code>	logical. Points are plotted if <code>TRUE</code> .
<code>clusters</code>	a vector of cluster labels to be applied when colouring the points. This only applies when <code>drawpoints</code> is <code>TRUE</code> .
<code>nlevels</code>	a positive integer specifying the number of contour levels
<code>levels</code>	either a positive integer or a numeric vector specifying the contour levels to be drawn for each component
<code>map</code>	character string specifying how to plot the points if <code>drawpoints=TRUE</code> . Possible values are "scatter" (default), "heat" and "cluster". See the 'Details' section.
<code>component</code>	the index of the components to be plotted. See the 'Details' section.
<code>xlim, ylim, zlim</code>	x-, y- and z- limits for the plot
<code>xlab, ylab, zlab</code>	labels for x-, y- and z- axis
<code>main</code>	title of the plot
<code>pcol</code>	the color(s) to be used for plotted points
<code>ccol</code>	the color(s) to be used for plotted contours
<code>...</code>	additional arguments to <code>plot.default</code>

Details

`fmcfust.contour.2d` draw contour plots for bivariate densities. The argument `dat` must be provided and must contain at least 2 columns. Note that only the first two columns of `dat` will be used if `dat` have more than 2 columns. For bivariate dataset, the data points can be drawn as a scatter plot by specifying `map="scatter"` (default), or as an intensity plot (`map="heat"`). Alternatively, a cluster map can be drawn instead (`map="cluster"`). Note that if an intensity plot is used, the data points will not be drawn, that is, `drawpoints` will be set to `FALSE`.

The argument `component` specifies which individual component is drawn. When `component=FALSE`, the mixture contour is drawn. If specified, `component` is a integer vector of the index of the components to be drawn. It can only take values between 1 and `g` inclusive. For example, `component=c(1, 3)` will draw the first and third component contours.

If the argument `model` contains the cluster labels (`model$clusters`), the data point will be coloured according to their cluster.

See Also

[fmcfust](#), [contour](#)

Examples

```
#2D plots
data(iris)
iris.versicolor <- iris[iris$Species=="versicolor",2:3]
Fit.versicolor <- fmcfust(1, iris.versicolor)
fmcfust.contour.2d(iris.versicolor, Fit.versicolor, drawpoints=FALSE, main="versicolor")

#3D plot
obj <- list()
obj$mu <- list(matrix(c(0,0,0),3), matrix(c(5,5,5),3))
obj$sigma <- list(matrix(c(5,2,1,2,5,1,1,1,1),3,3), 2*diag(3))
obj$delta <- list(matrix(c(1,0,0,1,0,0,1,0,0),3,3), matrix(c(5,0,0,0,10,0,0,0,15),3,3))
obj$dof <- c(3,3)
obj$pro <- c(0.2, 0.8)
fmcfust.contour.3d(model=obj, level=0.98, drawpoints=FALSE, xlab="X", ylab="Y", zlab="Z",
  xlim = c(-20, 50), ylim = c(-20, 50), zlim = c(-20, 80), ccol = "green")
```

fmmst

Fitting Finite Mixtures of Unrestricted Multivariate Skew t Distributions

Description

Computes maximum likelihood estimators (MLE) for finite mixtures of unrestricted multivariate skew t (FM-MST) model via the EM algorithm.

Usage

```
fmmst(g = 1, dat, initial = NULL, known = NULL, itmax = 100,
  eps = 1e-03, clust=NULL, nkmeans=20, print = T)
## S3 method for class 'fmmst'
summary(object, ...)
## S3 method for class 'fmmst'
print(x, ...)
```

Arguments

`object`, `x` an object class of class "fmmst", i.e. a fitted model.

`g` a scalar specifying the number of components in the mixture model

`dat` the data matrix giving the coordinates of the point(s) where the density is evaluated. This is either a vector of length `p` or a matrix with `p` columns.

<code>initial</code>	(optional) a list containing the initial parameters of the mixture model. See the 'Details' section. The default is NULL.
<code>known</code>	(optional) a list containing parameters of the mixture model that are known and not required to be estimated. See the 'Details' section. The default is NULL.
<code>itmax</code>	(optional) a positive integer specifying the maximum number of EM iterations to perform. The default is 100.
<code>eps</code>	(optional) a numeric value used to control the termination criteria for the EM loops. It is the maximum tolerance for the absolute difference between the log-likelihood value and the asymptotic log likelihood value. The default is 1e-6.
<code>clust</code>	(optional) a numeric value of length <code>nrow(dat)</code> containing the initial labels for each data point in <code>dat</code> . The default is NULL, indicating no initial clustering is known.
<code>nkmeans</code>	(optional) a numeric value indicating how many k-means trials to be used when searching for initial values. The default is 20.
<code>print</code>	(optional) a logical value. If TRUE, output for each iteration will be printed out. if FALSE, no output is printed. The default is TRUE. See the 'Details' section.
<code>...</code>	not used.

Details

The arguments `init` and `known`, if specified, is a list structure containing at least one of `mu`, `sigma`, `delta`, `dof`, `pro`. If `init=FALSE` (default), the program uses an automatic approach based on k-means clustering to generate an initial value for the model parameters. Note that this may not provide the best results.

Value

<code>mu</code>	a list of <code>g</code> numeric matrices containing the location parameter for each component.
<code>sigma</code>	a list of <code>g</code> numeric matrices containing the scale parameter for each component.
<code>delta</code>	a list of <code>g</code> numeric matrices containing the skewness parameter for each component.
<code>dof</code>	a numeric vector of length <code>g</code> representing the degrees of freedom for each component.
<code>pro</code>	a vector of length of <code>g</code> specifying the mixing proportions for each component.
<code>tau</code>	an <code>g</code> by <code>n</code> matrix of posterior probability of component membership.
<code>clusters</code>	a vector of length <code>n</code> of final partition.
<code>loglik</code>	the final log likelihood value.
<code>lk</code>	a vector of log likelihood values at each EM iteration.
<code>iter</code>	number of iterations performed.
<code>eps</code>	the final absolute difference between the log likelihood value and the asymptotic log likelihood value.
<code>aic, bic</code>	Akaike Information Criterion (AIC), Bayes Information Criterion (BIC)

References

Lee S, McLachlan G (2011). On the fitting of mixtures of multivariate skew t-distributions via the EM algorithm. arXiv:1109.4706 [stat.ME]

Lee, S. and McLachlan, G.J. (2014) Finite mixtures of multivariate skew t-distributions: some recent and new results. *Statistics and Computing*, 24, 181-202.

Lee, S. and McLachlan, G.J. (2013) EMMIXuskew: An R package for fitting mixtures of multivariate skew t-distributions via the EM algorithm. *Journal of Statistical Software*, 55(12), 1-22. URL <http://www.jstatsoft.org/v55/i12/>.

See Also

[fmcfust](#)

Examples

```
#a short demo using geysers data
library(MASS)
Fit <- fmmst(3, geysers)
summary(Fit)
print(Fit)
```

init.cfust

Initialization for Fitting Finite Mixtures of Canonical Fundamental Skew t-Distributions

Description

Computes different sets of initial values for finite mixtures of canonical fundamental skew t (FM-CFUST) model based on an initial clustering, transformation approach, moment-based approach, or nested-model approach.

Usage

```
init.cfust(g, dat, q=p, initial=NULL, known=NULL, clust=NULL, nkmeans=20,
  method=c("moments", "transformation", "EMMIXskew", "EMMIXuskew"))
init.fmcfust(g, dat, q=p, initial=NULL, known=NULL, clust=NULL, nkmeans=20,
  method=c("moments", "transformation", "EMMIXskew", "EMMIXuskew"))
```

Arguments

<code>g</code>	a scalar specifying the number of components in the mixture model
<code>dat</code>	the data matrix giving the coordinates of the point(s) where the density is evaluated. This is either a vector of length <code>p</code> or a matrix with <code>p</code> columns.
<code>q</code>	a scalar specifying how many number of columns the skewness matrix <code>delta</code> has.
<code>initial</code>	(optional) a list containing the initial parameters of the mixture model. See the 'Details' section. The default is <code>NULL</code> .
<code>known</code>	(optional) a list containing parameters of the mixture model that are known and not required to be estimated. See the 'Details' section. The default is <code>NULL</code> .
<code>clust</code>	(optional) a numeric value of length <code>nrow(dat)</code> containing the initial labels for each data point in <code>dat</code> . The default is <code>NULL</code> , indicating no initial clustering is known.
<code>nkmeans</code>	(optional) a numeric value indicating how many k-means trials to be used when searching for initial values. The default is <code>20</code> .
<code>method</code>	(optional) a string indicating which method to use to generate initial values. See Details.

Details

As the EM algorithm is sensitive to the starting value, it is highly recommended to apply a wide range different initializations. To obtain different sets of starting values using the strategy described in Section 5.1.3 of Lee and McLachlan (2014), `init.cfust()` can be used, which will return a list of objects with the same structure as `initial`. An example is given in the examples section below.

The argument `known`, if specified, is a list structure containing at least one of `mu`, `sigma`, `delta`, `dof`, `pro` (See [dfmcfust](#) for the structure of each of these elements). Note that although not all parameters need to be provided in `known`, the parameters that are provided must be fully specified. They cannot be partially specified, e.g. only some elements or some components are specified.

Value

a list object containing the following parameters:

<code>mu</code>	a list of <code>g</code> numeric matrices containing the location parameter for each component.
<code>sigma</code>	a list of <code>g</code> numeric matrices containing the scale parameter for each component.
<code>delta</code>	a list of <code>g</code> numeric matrices containing the skewness matrix for each component.
<code>dof</code>	a numeric vector of length <code>g</code> representing the degrees of freedom for each component.
<code>pro</code>	a vector of length of <code>g</code> specifying the mixing proportions for each component.
<code>tau</code>	an <code>g</code> by <code>n</code> matrix of initial probability of component membership.
<code>clusters</code>	a vector of length <code>n</code> of initial partition.
<code>loglik</code>	the initial log likelihood value.

References

Lee S.X. and McLachlan, G.J. (2016). Finite mixtures of canonical fundamental skew t-distributions: the unification of the restricted and unrestricted skew t-mixture models. *Statistics and Computing* 26, 573-589.

Lee S.X. and McLachlan, G.J. (2017). EMMIXcskew: An R Package for the Fitting of a Mixture of Canonical Fundamental Skew t-Distributions. *Journal of Statistical Software* 83(3), 1-32. URL [10.18637/jss.v083.i03](https://doi.org/10.18637/jss.v083.i03).

See Also

[rfmcfust](#), [dfmcfust](#), [fmcust.contour.2d](#)

Examples

```
#a short demo using geysers data
library(MASS)
data(geyser)
initial.transformation <- init.cfust(3, geysers, method="transformation")
initial.transformation$loglik
```

rfmcfust

Simulation of Mixture Data

Description

Generate random sample from a specified mixture of multivariate canonical fundamental skew t distribution

Usage

```
rfmcfust(g, n, mu, sigma, delta, dof=rep(10,g), pro=rep(1/g,g), known=NULL)
rcfust(n=1, mu = NULL, sigma=NULL, delta=NULL, dof=1, known=NULL)
```

Arguments

<code>g</code>	a scalar specifying the number of components in the mixture model
<code>n</code>	either a positive integer specifying the total number of points to be generated or a vector (of length <code>g</code>) of positive integers specifying the number of points to be generated in each component.
<code>mu</code>	for <code>rcfust</code> , this is a numeric vector of length <code>p</code> representing the location parameter; for <code>rfmcfust</code> , this is list of <code>g</code> numeric matrices each having <code>p</code> rows and 1 column containing the location parameter for each component.
<code>sigma</code>	for <code>rcfust</code> , this is a numeric positive definite matrix with dimension (p,p) representing the scale parameter; for <code>rfmcfust</code> , this is list of <code>g</code> numeric matrices containing the scale parameter for each component.

delta	for rcfust, this is a numeric matrix of size p by q representing the skewness matrix; for rfmcfust, this is list of g numeric matrices each having p rows and q column containing the skewness parameter for each component.
dof	for rcfust, this is a positive integer specifying the degrees of freedom; for rfmcfust, this is numeric vector of length g representing the degrees of freedom for each component.
pro	the mixing proportions; for rcfust, this is equal to 1; for rfmcfust, this is vector of length of g specifying the mixing proportions for each component.
known	a list containing the parameters of the model. If specified, it overwrites the values of mu, sigma, delta, dof and pro.

Details

rcfust generates a sample n multivariate CFUST observations. rfmcfust generates a mixture of CFUST observation. Note that model parameters can be passed to rcfust and rfmcfust through the argument known or listed as individual arguments. If both methods of input were used, the parameters specified in known will be used.

Value

rcfust returns an n by p numeric matrix of generated data. rfmcfust returns an n by p+1 numeric matrix of generated data. The first p gives the coordinates of the generated data. The last column specifies which component each data point is generated from.

References

Lee S.X. and McLachlan, G.J. (2016). Finite mixtures of canonical fundamental skew t-distributions: the unification of the restricted and unrestricted skew t-mixture models. *Statistics and Computing* 26, 573-589.

Lee S.X. and McLachlan, G.J. (2017). EMMIXcskew: An R Package for the Fitting of a Mixture of Canonical Fundamental Skew t-Distributions. *Journal of Statistical Software* 83(3), 1-32. URL [10.18637/jss.v083.i03](https://doi.org/10.18637/jss.v083.i03).

See Also

[dcfust](#), [dfmcfust](#)

Examples

```
##---- Should be DIRECTLY executable !! ----
##-- ==> Define data, use random,
##--or do help(data=index) for the standard data sets.
rcfust(10,c(1,2),diag(2),matrix(c(2,1,1,2),2,2),4)

obj <- list()
obj$mu <- list(c(17,19), c(5,22), c(6,10))
obj$sigma <- list(diag(2), matrix(c(2,0,0,1),2), matrix(c(3,7,7,24),2))
obj$delta <- list(matrix(c(3,0,2,1.5),2,2), matrix(c(5,0,0,10),2,2), matrix(c(2,0,5,0),2,2))
obj$dof <- c(1, 2, 3)
```

```
obj$pro <- c(0.25, 0.25, 0.5)  
rfmcfust(3, 100, known=obj)
```

Index

- *Topic **3d**
 - fmcfust.contour.2d, 6
 - *Topic **EM algorithm**
 - fmcfust, 4
 - fmmst, 8
 - init.cfust, 10
 - *Topic **contour**
 - fmcfust.contour.2d, 6
 - *Topic **maximum likelihood estimation**
 - fmcfust, 4
 - fmmst, 8
 - init.cfust, 10
 - *Topic **mixture density**
 - dfmcfust, 2
 - *Topic **multivariate distribution**
 - dfmcfust, 2
 - rfmcfust, 12
 - *Topic **multivariate skew t distribution**
 - dfmcfust, 2
 - fmcfust, 4
 - init.cfust, 10
 - rfmcfust, 12
 - *Topic **multivariate skew t**
 - fmmst, 8
 - *Topic **package**
 - EMMIXcskew-package, 2
 - *Topic **random number**
 - rfmcfust, 12
- contour, 8
- dcfust, 13
- dcfust (dfmcfust), 2
- dfmcfust, 2, 2, 5, 6, 11–13
- EMMIXcskew (EMMIXcskew-package), 2
- EMMIXcskew-package, 2
- fmcfust, 2, 4, 7, 8, 10
- fmcfust.contour.2d, 6, 6, 12
- fmcfust.contour.3d, 2
- fmcfust.contour.3d
(fmcfust.contour.2d), 6
- fmmst, 8
- init.cfust, 5, 6, 10
- init.fmcfust (init.cfust), 10
- plot.default, 7
- print.fmcfust (fmcfust), 4
- print.fmmst (fmmst), 8
- rcfust, 4
- rcfust (rfmcfust), 12
- rfmcfust, 2, 4, 6, 12, 12
- summary.fmcfust (fmcfust), 4
- summary.fmmst (fmmst), 8