Package 'mvst'

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Type Package

Title Bayesian Inference for the Multivariate Skew-t Model

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Description Estimates the multivariate skew-t and nested models, as described in the articles Liseo, B., Parisi, A. (2013). Bayesian inference for the multivariate skew-normal model: a population Monte Carlo approach. Comput. Statist. Data Anal. <doi:10.1016/j.csda.2013.02.007> and in Parisi, A., Liseo, B. (2017). Objective Bayesian analysis for the multivariate skew-t model. Statistical Methods & Applications <doi:10.1007/s10260-017-0404-0>.

SystemRequirements GNU Scientific Library

License GPL-3

Imports MCMCpack, mvtnorm, mnormt

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References

Parisi A, Liseo B (2017). Objective Bayesian Analysis for the Multivariate Skew-t Model. Statistical Methods & Applications. ISSN 1613-981X. doi:10.1007/s10260-017-0404-0 Parisi, A., Liseo, B. (2018). Statistical Inference with Skew-t Distributions: the MVST R Package. Annali del Dipartimento di Metodi e Modelli per l'Economia il Territorio e la Finanza. ISSN 2385-0825. Liseo, B., Parisi, A. (2013). Bayesian inference for the multivariate skew-normal model: a population Monte Carlo approach. Comput. Statist. Data Anal. <doi:10.1016/j.csda.2013.02.007>

`bivPlot` *Marginal and joint plots for bivariate data.*

Description

Scatterplot and marginal histograms for bivariate data. If theta is provided, the joint and marginal densities will be superimposed.

Usage

```
bivPlot(y, modelType=NULL, theta=NULL)
```

Arguments

`y`	Data matrix or vector.
`modelType`	(optional) model specification. Already implemented modelTypes are 'N' (Normal), 'SN' (skew-normal), 'T' (Student T), and 'ST' (skew-t).
`theta`	(optional) list of parameters. The list should contain elements named 'xi' (a numeric vector) or 'B' (a kxp matrix), 'G' (a pxp matrix), 'psi' (a numeric vetor, optional) and 'nu' (a scalar, optional). See Details.

Value

The function draws a plot for bivariate data.

Examples

```
# Define the parameters' list
pars = list(xi=c(5,2), G=diag(2), psi=rep(1,2), nu=4)
# Generate data
values = rmvSE(200, 2, NULL, 'ST', theta=pars)
y = values$y
# Draw the data points.
bivPlot(y)
# Draw the data points and the density function.
bivPlot(y, modelType='ST', theta=pars)
```

cmlSE *CML for the parameters of a p-variate Skew-Elliptical model.*

Description

Complete Maximum Likelihood for the parameters of a p-variate Skew-Elliptical model.

Usage

```
cmlSE(modelType, y, z=NULL, v=NULL, X=NULL)
```

Arguments

modelType	character indicating the model. Possible values are "N", "SN", "T", "ST"
y	data matrix.
z	(optional) numeric vector.
v	(optional) numeric vector.
X	(optional) design matrix.

Value

Given the value of the latent variables z and v, the function returns a list containing the estimates for the required model. Where available, a design matrix with the value of the covariates can be provided. In this case, the parameters of a regression model with skewed errors are estimated.

References

Parisi, A. and Liseo, B. (2017) "Objective Bayesian Analysis for the Multivariate Skew-t Model" *Statistical Methods & Applications*

See Also

mcSE, rmvSE.

Examples

```
## Generate artificial data
pars = list(xi=c(3,5), psi=c(2,4), G=diag(2), nu=6)
values = rmvSE(n=20, p=2, modelType='ST', theta=pars)
## CML estimates for pars
thetaHat = cmlSE(modelType='ST', y=values$y, z=values$z, v=values$v)
```

coef.mcSEsummary *Extract mcSE Model Coefficients.*

Description

The point estimates for the model parameters are obtained from mcSE summary objects.

Usage

```
## S3 method for class 'mcSEsummary'
coef(object, ...)
```

Arguments

object	an object of class mcSEsummary.
...	further arguments passed to or from other methods.

Value

A list containing the point estimates for the estimated model.

See Also

mcSE, summary.mcSE.

Examples

```
# Generate ST-distributed data (including the value of the latent variables)
pars = list(xi=c(2,2), G=diag(2), psi=c(0.3,0.5), nu=5)
values = rmvSE(n=100, p=2, modelType='ST', theta=pars)
# Estimate a Skew-t model (not run)
# fit = mcSE(y=values$y, X=NULL, N=20000, Ti=3, modelType='ST', warmUp=TRUE)
# stats = summary(fit)
# coef(stats)
```

dmvSE *Density function for the SE distributions.*

Description

This function computes the density function for p-variate Skew-Elliptical variables.

Usage

```
dmvSE(y, X=NULL, modelType, theta, LOG=FALSE)
```

Arguments

y	vector of quantiles. If y is a matrix, each row is considered as a quantile.
X	(optional) a design matrix.
modelType	Model specification. Already implemented modelTypes are 'N' (Normal), 'SN' (skew-normal), 'T' (Student T), and 'ST' (skew-t).
theta	list of parameters. The list should contain elements named 'xi' (a numeric vector) or 'B' (a kxp matrix), 'G' (a pxp matrix), 'psi' (a numeric vetor, optional) and 'nu' (a scalar, optional). See Details.
LOG	logical; if TRUE, log-densities are returned.

Value

A numeric vector with n values of the density function, one for each row in y.

References

Azzalini, A. and Capitanio, A. (2003) "Distributions generated by perturbation of symmetry with emphasis on a multivariate skew t distribution", *JRSSB*.

See Also

rmvSE.

Examples

```
# Define the parameters' list
pars = list(xi=c(5,2), G=diag(2), psi=rep(1,2), nu=4)
# Generate data
value = rmvSE(1, 2, NULL, 'ST', theta=pars)
# Compute the density function in the point y
dmvSE(y=value$y, X=NULL, modelType='ST', theta=pars, LOG=FALSE)
```

---

mcSE *MC sampler for a p-variate Skew-Elliptical model.*

Description

MonteCarlo sampler for a p-variate Skew-Elliptical model.

Usage

```
mcSE(y, X=NULL, N, Ti, modelType='ST', warmUp=FALSE, control=list())
```

Arguments

y	data matrix.
X	design matrix. (default: NULL)
N	number of particles per iteration.
Ti	number of iterations.
modelType	model to be estimated (default: ST). See 'Details'.
warmUp	logical flag (default: FALSE). See 'Deatils'
control	(optional) a list of control parameters. See 'Details'.

Details

Already implemented modelTypes are 'N' (Normal), 'SN' (skew-normal), 'T' (Student T), and 'ST' (skew-t, the default). To estimate a regression model, an 'X' should be added: for example, 'STX' stands for a regression model with ST errors. For these models, the argument parTypes in the control list is overridden. It is however possible to implement other models; in this case, parType is required and should contain the names of the parameters of the model. The argument warmUp allows to run preliminary iterations with a smaller number of particles, in order to speed up the algorithm. The number of these iterations, and the number of particles can be controlled using the Nwu argument in the control list.

To estimate regression models with skewed errors, it is sufficient to specify the argument X, which should contain the design matrix.

The (optional) argument control can provide a list with the following elements

seed if different from NULL, sets the random seed for replicability purposes.

parInfo data.frame containing the informations about the model parameters. Each row of the data.frame should contain the names of the parameters, the type (u: 'univariate', m: 'multivariate', M: 'matrix-variate', SM: 'symmetric matrix-variate'), the number nCols of elements, or columns, of the parameter and the number nRows of rows (eventually 1). Required if the modelType is not already implemented.

propFuncs named character vector with the names of the functions for the proposal distributions. The names of the elements of propFuncs should be the relevant elements of the set ('z', 'v', 'xi', 'psi', 'G', 'nu'). Custom proposal functions should require at least four arguments: y, the data matrix, X, the covariates (NULL if not relevant), particles, that is the list of current values of the parameters, for each particle, and priorList, a list containing the hyperparameters of the prior distributions. It should return two objects: values (the proposed values for the parameter, for each particle) and log.dq (vector with the N (log-)values of the proposal density).

logPriorFunc name of the file containing the function to compute the value (in logarithms) of the posterior density for all the particles. It should depend on the objects y, particles and priorList, while it should return N values of the posterior density, in logarithms.

Nwu numeric vector with the number of particles for each warm-up iteration. Default value is rep(2000, 3). It is however overridden if warmUp is FALSE.

priorList list of hyperparameters.

saveParticles logical flag (default: FALSE) indicating whether the value of the particles proposed in each iteration should be saved. If TRUE, the folder 'Iterations' is created in the current directory.

`outFolder` the folder in which the outputs are saved (if saveParticles is TRUE). The default folder is '/Output/Iterations'.

`verbose` logical flag (default: TRUE). If TRUE, details about the progress of the algorithm are printed.

Value

The function returns

`particles`	a list with the resampled particles of the last iteration,
`log.py`	the vector of the estimates of the marginal likelihood (one value per iteration),
`nResampled`	the vector of the number of resampled particles (one value per iteration).

If saveParticles is TRUE, the lists of the sampled particles, the importance weights, and the indices of the resampled particles are saved in the folder specified in outFolder, or in the default folder '/Output'. If outFolder doesn't already exists, it will be created.

References

Parisi, A. and Liseo, B. (2017) "Objective Bayesian Analysis for the Multivariate Skew-t Model" *Statistical Methods & Applications*

Azzalini, A. and Arellano-Valle, R.B. (2013) "Maximum Penalized Likelihood Estimation for Skew-normal and Skew-t Distributions" *J. Statist. Plann. Inference*, **143 (2)**, 419–433.

See Also

`cmlSE`, `rmvSE`.

Examples

```
## Generate artificial data
pars = list(xi=c(3,5), psi=c(2,4), G=diag(2), nu=6)
values = rmvSE(n=60, p=2, modelType='ST', theta=pars)
## Estimate a Skew-t model (not run)
# fit = mcSE(y=values$y, N=20000, Ti=3, modelType='ST')
# stats = summary(fit)
# coef(stats)
```

`MNmargLike` *Marginal Likelihood for the Multivariate Normal Model.*

Description

This function computes the exact marginal likelihood for Normally distributed data, under the default priors.

Usage

```
MNmargLike(y, X=NULL, LOG=FALSE)
```

Arguments

y	data matrix.
X	(optional) a design matrix.
LOG	logical; if TRUE, the log-marginal likelihood is returned.

Value

A scalar representing the marginal likelihood of a (multivariate) Normal model under the default priors for data y. If the design matrix X is provided, the function returns the marginal likelihood of a (multivariate) regression model with Normally distributed errors.

References

Liseo B, Parisi A (2013). Bayesian Inference for the Multivariate Skew-Normal Model: A Population Monte Carlo approach. Comput. Statist. Data Anal., 63, 125-138. ISSN 0167-9473. doi:10.1016/j.csda.2013.02.007.

See Also

rmvSE, dmvSE.

Examples

```
# Generate Normally distributed data
require(mvtnorm)
y = rmvnorm(100, rep(2,2), diag(2))
# Marginal likelihood (exact value)
MNmargLike(y, X=NULL, LOG=TRUE)
```

---

rmvSE *Random generation from a SE distribution.*

Description

This function generates draws from a p-variate Skew-Elliptical distribution.

Usage

```
rmvSE(n, p, X=NULL, modelType, theta)
```

Arguments

n	number of draws.
p	dimension of the drawn vectors.
X	a design matrix.
modelType	generating distribution. Already implemented modelTypes are 'N' (Normal), 'SN' (skew-normal), 'T' (Student T), and 'ST' (skew-t).
theta	list of parameters. The list should contain elements named 'xi' (numeric), 'G' (pxp matrix), 'psi' (numeric, optional) and 'nu' (scalar, optional).

Value

A list with three elements

- y n x p matrix of the random draws from a p-variate SE distribution.
- z vector of the latent values z (NULL for symmetric models)
- v vector of the latent values v (NULL for the N and SN models)

References

Azzalini, A. and Capitanio, A. (2003) "Distributions generated by perturbation of symmetry with emphasis on a multivariate skew t distribution", *JRSSB* (see eq. 25).

See Also

cmlSE, mcSE.

Examples

```
## Generate artificial data
pars = list(xi=c(3,5), psi=c(2,4), G=diag(2), nu=6)
values = rmvSE(n=200, p=2, modelType='ST', theta=pars)
## X contains the data matrix and the vectors z and v of latent variables:
y = values$y
z = values$z
v = values$v
```

---

summary.mcSE *Summary function for mcSE objects.*

Description

summary method for class "mcSE".

Usage

```
## S3 method for class 'mcSE'
summary(object, ...)
```

Arguments

object	an object of class mcSE.
...	further arguments passed to or from other methods.

Value

A numeric vector with n values of the density function, one for each row in y.

References

Parisi A, Liseo B (2017). Objective Bayesian Analysis for the Multivariate Skew-t Model. Statistical Methods & Applications.

See Also

mcSE, coef.mcSEsummary.

Examples

```
# Generate Normally distributed data
pars = list(xi=c(2,2), G=diag(2), psi=c(0.3,0.5), nu=5)
values = rmvSE(n=100, p=2, modelType='N', theta=pars)
# Estimate a Skew-t model (not run)
# fit = mcSE(y=values$y, X=NULL, N=20000, Ti=3, modelType='ST', warmUp=FALSE)
# summary(fit)
```

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