Package ‘MomTrunc’

January 20, 2025

Type Package

Title Moments of Folded and Doubly Truncated Multivariate Distributions

Version 6.1

Date 2024-10-17

Author Christian E. Galarza [aut, cre, trl] (<https://orcid.org/0000-0002-4818-6006>), Raymond Kan [ctb] (<https://orcid.org/0000-0002-0578-9974>), Victor H. Lachos [aut, ths] (<https://orcid.org/0000-0002-7239-2459>)

Maintainer Christian E. Galarza <cgalarza88@gmail.com>

Description It computes arbitrary products moments (mean vector and variance-covariance matrix), for some double truncated (and folded) multivariate distributions. These distributions belong to the family of selection elliptical distributions, which includes well known skewed distributions as the unified skew-t distribution (SUT) and its particular cases as the extended skew-t (EST), skew-t (ST) and the symmetric student-t (T) distribution. Analogous normal cases unified skew-normal (SUN), extended skew-normal (ESN), skew-normal (SN), and symmetric normal (N) are also included. Density, probabilities and random deviates are also offered for these members.

License GPL (>= 2)

Depends R (>= 3.6.0)

Imports Rcpp (>= 1.0.1), mvtnorm (>= 1.0.11), tlrmvnmvt (>= 1.1.0), hypergeo

LinkingTo Rcpp (>= 1.0.1), RcppArmadillo, mvtnorm

Suggests tmvtnorm

NeedsCompilation yes

Repository CRAN

Date/Publication 2024-10-28 21:40:02 UTC

Contents

`MomTrunc-package` *Moments of Folded and Doubly Truncated Multivariate Distributions*

Description

It computes arbitrary products moments (mean vector and variance-covariance matrix), for some double truncated (and folded) multivariate distributions. These distributions belong to the family of selection elliptical distributions, which includes well known skewed distributions as the unified skew-t distribution (SUT) and its particular cases as the extended skew-t (EST), skew-t (ST) and the symmetric student-t (T) distribution. Analogous normal cases unified skew-normal (SUN), extended skew-normal (ESN), skew-normal (SN), and symmetric normal (N) are also included. Density, probabilities and random deviates are also offered for these members.

Details

Probabilities can be computed using the functions `pmvSN` and `pmvESN` for the normal cases SN and ESN and, `pmvST` and `pmvEST` for the t cases ST and EST respectively, which offer the option to return the logarithm in base 2 of the probability, useful when the true probability is too small for the machine precision. These functions above use methods in Genz (1992) through the `mvtnorm` package (linked direclty to our `C++` functions) and Cao et.al. (2019) through the package `tlrmvnmvt`. For the double truncated Student-t cases SUT, EST, ST and T, decimal degrees of freedom are supported. Computation of arbitrary moments are based in the works of Kan & Robotti (2017) and Galarza et.al. (2021,2022a,2022b). Reference for the family of selection-elliptical distributions in this package can be found in Arellano-Valle & Genton (2005).

Author(s)

Christian E. Galarza [aut, cre, trl] (<https://orcid.org/0000-0002-4818-6006>), Raymond Kan [ctb] (<https://orcid.org/0000-0002-0578-9974>), Victor H. Lachos [aut, ths] (<https://orcid.org/0000-0002-7239-2459>)

Maintainer: Christian E. Galarza <cgalarza88@gmail.com>

References

Arellano-Valle, R. B. & Genton, M. G. (2005). On fundamental skew distributions. Journal of Multivariate Analysis, 96, 93-116.

Cao, J., Genton, M. G., Keyes, D. E., & Turkiyyah, G. M. (2019) "Exploiting Low Rank Covariance Structures for Computing High-Dimensional Normal and Student-t Probabilities" <https://marcgenton.github.io/2019.CGKT.manuscript.pdf>.

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

Genz, A., "Numerical computation of multivariate normal probabilities," Journal of Computational and Graphical Statistics, 1, 141-149 (1992) <doi:10.1080/10618600.1992.10477010>.

Kan, R., & Robotti, C. (2017). On moments of folded and truncated multivariate normal distributions. Journal of Computational and Graphical Statistics, 26(4), 930-934.

See Also

onlymeanTMD,meanvarTMD,momentsTMD,dmvSN,pmvSN,rmvSN,dmvST,pmvST,rmvST

Examples

```
a = c(-0.8,-0.7,-0.6)
b = c(0.5,0.6,0.7)
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)

meanvarTMD(a,b,mu,Sigma,dist="normal") #normal case
meanvarTMD(mu = mu,Sigma = Sigma,lambda = c(-2,0,1),dist="SN") #skew normal with NO truncation
meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),nu = 4.87,dist = "ST") #skew t
momentsTMD(3,a,b,mu,Sigma,nu = 4,dist = "t") #t case, all moments or order <=3
```

---

cdfFMD *Cumulative distribution function for folded multivariate distributions*

Description

It computes the cumulative distribution function on x for a folded p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Student's t-distribution.

Usage

```
cdfFMD(x,mu,Sigma,lambda = NULL,tau = NULL,dist,nu = NULL)
```

Arguments

x	vector of length p where the cdf is evaluated.
mu	a numeric vector of length p representing the location parameter.
Sigma	a numeric positive definite matrix with dimension pxp representing the scale parameter.
lambda	a numeric vector of length p representing the skewness parameter for SN and ESN cases. If `lambda == 0`, the ESN/SN reduces to a normal (symmetric) distribution.
tau	It represents the extension parameter for the ESN distribution. If `tau == 0`, the ESN reduces to a SN distribution.
dist	represents the folded distribution to be computed. The values are `normal`, `SN` , `ESN` and `t` for the doubly truncated Normal, Skew-normal, Extended Skew-normal and Student's t-distribution respectively.
nu	It represents the degrees of freedom for the Student's t-distribution.

Details

Normal case by default, i.e., when `dist` is not provided. Univariate case is also considered, where `Sigma` will be the variance σ^2.

Value

It returns the distribution value for a single point `x`.

Note

Degrees of freedom must be a positive integer. If `nu >= 200`, Normal case is considered."

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

See Also

momentsFMD, meanvarFMD

Examples

```
mu = c(0.1,0.2,0.3,0.4)
Sigma = matrix(data = c(1,0.2,0.3,0.1,0.2,1,0.4,-0.1,0.3,0.4,1,0.2,0.1,-0.1,0.2,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
cdfFMD(x = c(0.5,0.2,1.0,1.3),mu,Sigma,dist="normal")
cdfFMD(x = c(0.5,0.2,1.0,1.3),mu,Sigma,dist = "t",nu = 4)
cdfFMD(x = c(0.5,0.2,1.0,1.3),mu,Sigma,lambda = c(-2,0,2,1),dist = "SN")
cdfFMD(x = c(0.5,0.2,1.0,1.3),mu,Sigma,lambda = c(-2,0,2,1),tau = 1,dist = "ESN")
```

---

dprmvESN — *Multivariate Extended-Skew Normal Density, Probablilities and Random Deviates Generator*

Description

These functions provide the density function, probabilities and a random number generator for the multivariate extended-skew normal (ESN) distribution with mean vector mu, scale matrix Sigma, skewness parameter lambda and extension parameter tau.

Usage

```
dmvESN(x,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda,tau=0)
pmvESN(lower = rep(-Inf,length(lambda)),upper=rep(Inf,length(lambda)),
        mu = rep(0,length(lambda)),Sigma,lambda,tau,log2 = FALSE)
rmvESN(n,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda,tau=0)
```

Arguments

x	vector or matrix of quantiles. If x is a matrix, each row is taken to be a quantile.
n	number of observations.
lower	the vector of lower limits of length p.
upper	the vector of upper limits of length p.
mu	a numeric vector of length p representing the location parameter.
Sigma	a numeric positive definite matrix with dimension pxp representing the scale parameter.
lambda	a numeric vector of length p representing the skewness parameter for SN and ESN cases. If lambda == 0, the ESN/SN reduces to a normal (symmetric) distribution.
tau	It represents the extension parameter for the ESN distribution. If tau == 0, the ESN reduces to a SN distribution.
log2	a boolean variable, indicating if the log2 result should be returned. This is useful when the true probability is too small for the machine precision.

Value

dmvESN gives the density, pmvESN gives the distribution function, and rmvESN generates random deviates for the Multivariate Extended-Skew Normal Distribution.

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

Galarza, C.E., Matos, L.A. and Lachos, V.H. (2022c). An EM algorithm for estimating the parameters of the multivariate skew-normal distribution with censored responses. Metron. <doi:10.1007/s40300-021-00227-4>.

Genz, A., (1992) "Numerical computation of multivariate normal probabilities," Journal of Computational and Graphical Statistics, 1, 141-149 <doi:10.1080/10618600.1992.10477010>.

See Also

dmvSN, pmvSN, rmvSN, meanvarFMD,meanvarTMD,momentsTMD

Examples

```
#Univariate case
dmvESN(x = -1,mu = 2,Sigma = 5,lambda = -2,tau = 0.5)
rmvESN(n = 100,mu = 2,Sigma = 5,lambda = -2,tau = 0.5)
#Multivariate case
mu = c(0.1,0.2,0.3,0.4)
Sigma = matrix(data = c(1,0.2,0.3,0.1,0.2,1,0.4,-0.1,0.3,0.4,1,0.2,0.1,-0.1,0.2,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
lambda = c(-2,0,1,2)
tau = 2
#One observation
dmvESN(x = c(-2,-1,0,1),mu,Sigma,lambda,tau)
rmvESN(n = 100,mu,Sigma,lambda,tau)
#Many observations as matrix
x = matrix(rnorm(4*10),ncol = 4,byrow = TRUE)
dmvESN(x = x,mu,Sigma,lambda,tau)

lower = rep(-Inf,4)
```

```
upper = c(-1,0,2,5)
pmvESN(lower,upper,mu,Sigma,lambda,tau)
```

---

dprmvEST *Multivariate Extended-Skew t Density, Probablilities and Random Deviates Generator*

Description

These functions provide the density function, probabilities and a random number generator for the multivariate extended-skew t (EST) distribution with mean vector `mu`, scale matrix `Sigma`, skewness parameter `lambda`, extension parameter `tau` and degrees of freedom `nu`.

Usage

```
dmvEST(x,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda,tau=0,nu)
pmvEST(lower = rep(-Inf,length(lambda)),upper=rep(Inf,length(lambda)),
        mu = rep(0,length(lambda)),Sigma,lambda,tau,nu,log2 = FALSE)
rmvEST(n,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda,tau,nu)
```

Arguments

`x`	vector or matrix of quantiles. If `x` is a matrix, each row is taken to be a quantile.
`n`	number of observations.
`lower`	the vector of lower limits of length p.
`upper`	the vector of upper limits of length p.
`mu`	a numeric vector of length p representing the location parameter.
`Sigma`	a numeric positive definite matrix with dimension pxp representing the scale parameter.
`lambda`	a numeric vector of length p representing the skewness parameter for ST and EST cases. If `lambda == 0`, the EST/ST reduces to a t (symmetric) distribution.
`tau`	It represents the extension parameter for the EST distribution. If `tau == 0`, the EST reduces to a ST distribution.
`nu`	It represents the degrees of freedom of the Student's t-distribution.
`log2`	a boolean variable, indicating if the log2 result should be returned. This is useful when the true probability is too small for the machine precision.

Value

`dmvEST` gives the density, `pmvEST` gives the distribution function, and `rmvEST` generates random deviates for the Multivariate Extended-Skew-t Distribution.

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

Genz, A., (1992) "Numerical computation of multivariate normal probabilities," Journal of Computational and Graphical Statistics, 1, 141-149 <doi:10.1080/10618600.1992.10477010>.

See Also

dmvST, pmvST, rmvST, meanvarFMD,meanvarTMD,momentsTMD

Examples

```
#Univariate case
dmvEST(x = -1,mu = 2,Sigma = 5,lambda = -2,tau = 0.5,nu=4)
rmvEST(n = 100,mu = 2,Sigma = 5,lambda = -2,tau = 0.5,nu=4)
#Multivariate case
mu = c(0.1,0.2,0.3,0.4)
Sigma = matrix(data = c(1,0.2,0.3,0.1,0.2,1,0.4,-0.1,0.3,0.4,1,0.2,0.1,-0.1,0.2,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
lambda = c(-2,0,1,2)
tau = 2
#One observation
dmvEST(x = c(-2,-1,0,1),mu,Sigma,lambda,tau,nu=4)
rmvEST(n = 100,mu,Sigma,lambda,tau,nu=4)
#Many observations as matrix
x = matrix(rnorm(4*10),ncol = 4,byrow = TRUE)
dmvEST(x = x,mu,Sigma,lambda,tau,nu=4)

lower = rep(-Inf,4)
upper = c(-1,0,2,5)
pmvEST(lower,upper,mu,Sigma,lambda,tau,nu=4)
```

---

dprmvSN — *Multivariate Skew Normal Density and Probabilities and Random Deviates*

Description

These functions provide the density function and a random number generator for the multivariate skew normal (SN) distribution with mean vector `mu`, scale matrix `Sigma` and skewness parameter `lambda`.

Usage

```
dmvSN(x,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda)
pmvSN(lower = rep(-Inf,length(lambda)),upper=rep(Inf,length(lambda)),
        mu = rep(0,length(lambda)),Sigma,lambda,log2 = FALSE)
rmvSN(n,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda)
```

Arguments

`x`	vector or matrix of quantiles. If `x` is a matrix, each row is taken to be a quantile.
`n`	number of observations.
`lower`	the vector of lower limits of length p.
`upper`	the vector of upper limits of length p.
`mu`	a numeric vector of length p representing the location parameter.
`Sigma`	a numeric positive definite matrix with dimension pxp representing the scale parameter.
`lambda`	a numeric vector of length p representing the skewness parameter for SN and SN cases. If `lambda == 0`, the SN/SN reduces to a normal (symmetric) distribution.
`log2`	a boolean variable, indicating if the log2 result should be returned. This is useful when the true probability is too small for the machine precision.

Value

`dmvSN` gives the density, `pmvSN` gives the distribution function, and `rmvSN` generates random deviates for the Multivariate Skew-normal Distribution.

Author(s)

Christian E. Galarza <<`cgalarza88@gmail.com`>> and Victor H. Lachos <<`hlachos@uconn.edu`>>

Maintainer: Christian E. Galarza <<`cgalarza88@gmail.com`>>

References

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

Galarza, C.E., Matos, L.A. and Lachos, V.H. (2022c). An EM algorithm for estimating the parameters of the multivariate skew-normal distribution with censored responses. Metron. <doi:10.1007/s40300-021-00227-4>.

Genz, A., (1992) "Numerical computation of multivariate normal probabilities," Journal of Computational and Graphical Statistics, 1, 141-149 <doi:10.1080/10618600.1992.10477010>.

See Also

dmvESN, pmvESN, rmvESN, meanvarFMD,meanvarTMD,momentsTMD

Examples

```
#Univariate case
dmvSN(x = -1,mu = 2,Sigma = 5,lambda = -2)
rmvSN(n = 100,mu = 2,Sigma = 5,lambda = -2)
#Multivariate case
mu = c(0.1,0.2,0.3,0.4)
Sigma = matrix(data = c(1,0.2,0.3,0.1,0.2,1,0.4,-0.1,0.3,0.4,1,0.2,0.1,-0.1,0.2,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
lambda = c(-2,0,1,2)
#One observation
dmvSN(x = c(-2,-1,0,1),mu,Sigma,lambda)
rmvSN(n = 100,mu,Sigma,lambda)
#Many observations as matrix
x = matrix(rnorm(4*10),ncol = 4,byrow = TRUE)
dmvSN(x = x,mu,Sigma,lambda)

lower = rep(-Inf,4)
upper = c(-1,0,2,5)
pmvSN(lower,upper,mu,Sigma,lambda)
```

---

dprmvST *Multivariate Skew t Density, Probablilities and Random Deviates Generator*

Description

These functions provide the density function, probabilities and a random number generator for the multivariate skew t (EST) distribution with mean vector mu, scale matrix Sigma, skewness parameter lambda and degrees of freedom nu.

Usage

```
dmvST(x,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda,nu)
pmvST(lower = rep(-Inf,length(lambda)),upper=rep(Inf,length(lambda)),
        mu = rep(0,length(lambda)),Sigma,lambda,nu,log2 = FALSE)
rmvST(n,mu=rep(0,length(lambda)),Sigma=diag(length(lambda)),lambda,nu)
```

Arguments

x	vector or matrix of quantiles. If x is a matrix, each row is taken to be a quantile.
n	number of observations.
lower	the vector of lower limits of length p.
upper	the vector of upper limits of length p.

mu	a numeric vector of length p representing the location parameter.
Sigma	a numeric positive definite matrix with dimension pxp representing the scale parameter.
lambda	a numeric vector of length p representing the skewness parameter for ST and EST cases. If `lambda == 0`, the EST/ST reduces to a t (symmetric) distribution.
nu	It represents the degrees of freedom of the Student's t-distribution.
log2	a boolean variable, indicating if the log2 result should be returned. This is useful when the true probability is too small for the machine precision.

Value

`dmvST` gives the density, `pmvST` gives the distribution function, and `rmvST` generates random deviates for the Multivariate Skew-t Distribution.

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

Genz, A., (1992) "Numerical computation of multivariate normal probabilities," Journal of Computational and Graphical Statistics, 1, 141-149 <doi:10.1080/10618600.1992.10477010>.

See Also

`dmvST`, `pmvST`, `rmvST`, `meanvarFMD`,`meanvarTMD`,`momentsTMD`

Examples

```
#Univariate case
dmvST(x = -1,mu = 2,Sigma = 5,lambda = -2,nu=4)
rmvST(n = 100,mu = 2,Sigma = 5,lambda = -2,nu=4)
#Multivariate case
mu = c(0.1,0.2,0.3,0.4)
Sigma = matrix(data = c(1,0.2,0.3,0.1,0.2,1,0.4,-0.1,0.3,0.4,1,0.2,0.1,-0.1,0.2,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
lambda = c(-2,0,1,2)
#One observation
```

```
dmvST(x = c(-2,-1,0,1),mu,Sigma,lambda,nu=4)
rmvST(n = 100,mu,Sigma,lambda,nu=4)
#Many observations as matrix
x = matrix(rnorm(4*10),ncol = 4,byrow = TRUE)
dmvST(x = x,mu,Sigma,lambda,nu=4)

lower = rep(-Inf,4)
upper = c(-1,0,2,5)
pmvST(lower,upper,mu,Sigma,lambda,nu=4)
```

MCmeanvarTMD *Monte Carlo Mean and variance for doubly truncated multivariate distributions*

Description

It computes the Monte Carlo mean vector and variance-covariance matrix for some doubly truncated skew-elliptical distributions. Monte Carlo simulations are performed via slice Sampling. It supports the p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Unified Skew-normal (SUN) as well as the Student's-t, Skew-t (ST), Extended Skew-t (EST) and Unified Skew-t (SUT) distribution.

Usage

```
MCmeanvarTMD(lower = rep(-Inf,length(mu)),upper = rep(Inf,length(mu)),mu,Sigma
,lambda = NULL,tau = NULL,Gamma = NULL,nu = NULL,dist,n = 10000)
```

Arguments

- `lower` the vector of lower limits of length p.
- `upper` the vector of upper limits of length p.
- `mu` a numeric vector of length p representing the location parameter.
- `Sigma` a numeric positive definite matrix with dimension pxp representing the scale parameter.
- `lambda` a numeric matrix of dimension pxq representing the skewness/shape matrix parameter for the SUN and SUT distribution. For the ESN and EST distributions ($q = 1$), `lambda` is a numeric vector of dimension p (see examples at the end of this help). If `all(lambda == 0)`, the SUN/ESN/SN (SUT/EST/ST) reduces to a normal (t) symmetric distribution.
- `tau` a numeric vector of length q representing the extension parameter for the SUN and SUT distribution. For the ESN and EST distributions, `tau` is a positive scalar ($q = 1$). Furthermore, if `tau == 0`, the ESN (EST) reduces to a SN (ST) distribution.
- `Gamma` a correlation matrix with dimension qxq. It must be provided only for the SUN and SUT cases. For particular cases SN, ESN, ST and EST, we have that `Gamma == 1` (see examples at the end of this help).

nu	It represents the degrees of freedom for the Student's t-distribution being a positive real number.
dist	represents the truncated distribution to be used. The values are `normal`, `SN` , `ESN` and `SUN` for the doubly truncated Normal, Skew-normal, Extended Skew-normal and Unified-skew normal distributions and, `t`, `ST` , `EST` and `SUT` for the for the doubly truncated Student-t, Skew-t, Extended Skew-t and Unified skew-t distributions.
n	number of Monte Carlo samples to be generated.

Value

It returns a list with three elements:

mean	the estimate for the mean vector of length p
EYY	the estimate for the second moment matrix of dimensions pxp
varcov	the estimate for the variance-covariance matrix of dimensions pxp

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Arellano-Valle, R. B. & Genton, M. G. (2005). On fundamental skew distributions. Journal of Multivariate Analysis, 96, 93-116.

Ho, H. J., Lin, T. I., Chen, H. Y., & Wang, W. L. (2012). Some results on the truncated multivariate t distribution. Journal of Statistical Planning and Inference, 142(1), 25-40.

See Also

meanvarTMD, rmvSN,rmvESN,rmvST, rmvEST

Examples

```
a = c(-0.8,-0.7,-0.6)
b = c(0.5,0.6,0.7)
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)


## Normal case

# Theoretical value
value1 = meanvarTMD(a,b,mu,Sigma,dist="normal")

#MC estimate
MC11 = MCmeanvarTMD(a,b,mu,Sigma,dist="normal") #by defalut n = 10000
```

```
MC12 = MCmeanvarTMD(a,b,mu,Sigma,dist="normal",n = 10^5) #more precision

## Skew-t case

# Theoretical value
value2 = meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),nu = 4,dist = "ST")

#MC estimate
MC21 = MCmeanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),nu = 4,dist = "ST")

## More...

MC5 = MCmeanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,dist = "ESN")
MC6 = MCmeanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,nu = 4,dist = "EST")


#Skew-unified Normal (SUN) and Skew-unified t (SUT) distributions

Lambda = matrix(c(1,0,2,-3,0,-1),3,2) #A skewness matrix p times q
Gamma  = matrix(c(1,-0.5,-0.5,1),2,2) #A correlation matrix q times q
tau    = c(-1,2)                      #A vector of extension parameters of dim q

MC7 = MCmeanvarTMD(a,b,mu,Sigma,lambda = Lambda,tau = c(-1,2),Gamma = Gamma,dist = "SUN")
MC8 = MCmeanvarTMD(a,b,mu,Sigma,lambda = Lambda,tau = c(-1,2),Gamma = Gamma,nu = 1,dist = "SUT")
```

meanvarFMD — *Mean and variance for folded multivariate distributions*

Description

It computes the mean vector and variance-covariance matrix for the folded p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Student's t-distribution.

Usage

```
meanvarFMD(mu,Sigma,lambda = NULL,tau = NULL,nu = NULL,dist)
```

Arguments

`mu`	a numeric vector of length p representing the location parameter.
`Sigma`	a numeric positive definite matrix with dimension pxp representing the scale parameter.
`lambda`	a numeric vector of length p representing the skewness parameter for SN and ESN cases. If `lambda == 0`, the ESN/SN reduces to a normal (symmetric) distribution.
`tau`	It represents the extension parameter for the ESN distribution. If `tau == 0`, the ESN reduces to a SN distribution.

nu	It represents the degrees of freedom for the Student's t-distribution. Must be an integer greater than 1.
dist	represents the folded distribution to be computed. The values are normal, SN , ESN and t for the doubly truncated Normal, Skew-normal, Extended Skew-normal and Student's t-distribution respectively.

Details

Normal case by default, i.e., when dist is not provided. Univariate case is also considered, where Sigma will be the variance σ^2.

Value

It returns a list with three elements:

mean	the mean vector of length p
EYY	the second moment matrix of dimensions pxp
varcov	the variance-covariance matrix of dimensions pxp

Warning

The mean can only be provided when nu is larger than 2. On the other hand, the varcov matrix can only be provided when nu is larger than 3.

Note

Degree of freedom must be a positive integer. If nu >= 200, Normal case is considered."

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

See Also

momentsFMD, onlymeanTMD,meanvarTMD,momentsTMD, dmvSN,pmvSN,rmvSN, dmvESN,pmvESN,rmvESN, dmvST,pmvST,rmvST, dmvEST,pmvEST,rmvEST

Examples

```
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
value1 = meanvarFMD(mu,Sigma,dist="normal")
value2 = meanvarFMD(mu,Sigma,nu = 4,dist = "t")
value3 = meanvarFMD(mu,Sigma,lambda = c(-2,0,1),dist = "SN")
value4 = meanvarFMD(mu,Sigma,lambda = c(-2,0,1),tau = 1,dist = "ESN")
```

`meanvarTMD` *Mean and variance for doubly truncated multivariate distributions*

Description

It computes the mean vector and variance-covariance matrix for some doubly truncated skew-elliptical distributions. It supports the p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Unified Skew-normal (SUN) as well as the Student's-t, Skew-t (ST), Extended Skew-t (EST) and Unified Skew-t (SUT) distribution.

Usage

```
meanvarTMD(lower = rep(-Inf,length(mu)),upper = rep(Inf,length(mu)),mu,Sigma
,lambda = NULL,tau = NULL,Gamma = NULL,nu = NULL,dist)
```

Arguments

`lower`	the vector of lower limits of length p.
`upper`	the vector of upper limits of length p.
`mu`	a numeric vector of length p representing the location parameter.
`Sigma`	a numeric positive definite matrix with dimension pxp representing the scale parameter.
`lambda`	a numeric matrix of dimension pxq representing the skewness/shape matrix parameter for the SUN and SUT distribution. For the ESN and EST distributions ($q = 1$), `lambda` is a numeric vector of dimension p (see examples at the end of this help). If `all(lambda == 0)`, the SUN/ESN/SN (SUT/EST/ST) reduces to a normal (t) symmetric distribution.
`tau`	a numeric vector of length q representing the extension parameter for the SUN and SUT distribution. For the ESN and EST distributions, `tau` is a positive scalar ($q = 1$). Furthermore, if `tau == 0`, the ESN (EST) reduces to a SN (ST) distribution.
`Gamma`	a correlation matrix with dimension qxq. It must be provided only for the SUN and SUT cases. For particular cases SN, ESN, ST and EST, we have that `Gamma == 1` (see examples at the end of this help).
`nu`	It represents the degrees of freedom for the Student's t-distribution being a positive real number.

`dist`	represents the truncated distribution to be used. The values are `normal`, `SN` , `ESN` and `SUN` for the doubly truncated Normal, Skew-normal, Extended Skew-normal and Unified-skew normal distributions and, `t`, `ST` , `EST` and `SUT` for the for the doubly truncated Student-t, Skew-t, Extended Skew-t and Unified skew-t distributions.

Details

Univariate case is also considered, where `Sigma` will be the variance σ^2. Normal case code is an R adaptation of the Matlab available function `dtmvnmom.m` from Kan & Robotti (2017) and it is used for `p<=3`. For higher dimensions we use an extension of the algorithm in Vaida (2009).

Value

It returns a list with three elements:

`mean`	the mean vector of length p
`EYY`	the second moment matrix of dimensions pxp
`varcov`	the variance-covariance matrix of dimensions pxp

Warning

For the t cases, the algorithm supports degrees of freedom `nu <= 2`.

Note

If `nu >= 300`, Normal case is considered."

Author(s)

Christian E. Galarza <<`cgalarza88@gmail.com`>> and Victor H. Lachos <<`hlachos@uconn.edu`>>

Maintainer: Christian E. Galarza <<`cgalarza88@gmail.com`>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

See Also

`MCmeanvarTMD`, `momentsTMD`, `meanvarFMD`, `meanvarFMD`,`momentsFMD`, `dmvSN`,`pmvSN`,`rmvSN`, `dmvESN`,`pmvESN`,`rmvESN`, `dmvST`,`pmvST`,`rmvST`, `dmvEST`,`pmvEST`,`rmvEST`

Examples

```
a = c(-0.8,-0.7,-0.6)
b = c(0.5,0.6,0.7)
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)

# Theoretical value
value1 = meanvarTMD(a,b,mu,Sigma,dist="normal")

#MC estimate
MC11 = MCmeanvarTMD(a,b,mu,Sigma,dist="normal") #by defalut n = 10000
MC12 = MCmeanvarTMD(a,b,mu,Sigma,dist="normal",n = 10^5) #more precision

# Now works for for any nu>0
value2 = meanvarTMD(a,b,mu,Sigma,dist = "t",nu = 0.87)

value3 = meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),dist = "SN")
value4 = meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),nu = 4,dist = "ST")
value5 = meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,dist = "ESN")
value6 = meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,nu = 4,dist = "EST")


#Skew-unified Normal (SUN) and Skew-unified t (SUT) distributions

Lambda = matrix(c(1,0,2,-3,0,-1),3,2) #A skewness matrix p times q
Gamma  = matrix(c(1,-0.5,-0.5,1),2,2) #A correlation matrix q times q
tau    = c(-1,2)                      #A vector of extension parameters of dim q

value7 = meanvarTMD(a,b,mu,Sigma,lambda = Lambda,tau = c(-1,2),Gamma = Gamma,dist = "SUN")
value8 = meanvarTMD(a,b,mu,Sigma,lambda = Lambda,tau = c(-1,2),Gamma = Gamma,nu = 4,dist = "SUT")


#The ESN and EST as particular cases of the SUN and SUT for q=1

Lambda = matrix(c(-2,0,1),3,1)
Gamma  = 1
value9 = meanvarTMD(a,b,mu,Sigma,lambda = Lambda,tau = 1,Gamma = Gamma,dist = "SUN")
value10 = meanvarTMD(a,b,mu,Sigma,lambda = Lambda,tau = 1,Gamma = Gamma,nu = 4,dist = "SUT")

round(value5$varcov,2) == round(value9$varcov,2)
round(value6$varcov,2) == round(value10$varcov,2)
```

`momentsFMD` *Moments for folded multivariate distributions*

Description

It computes the kappa-th order moments for the folded p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Student's t-distribution. It also output other lower moments involved in the recurrence approach.

Usage

```
momentsFMD(kappa,mu,Sigma,lambda = NULL,tau = NULL,nu = NULL,dist)
```

Arguments

kappa	moments vector of length p. All its elements must be integers greater or equal to 0. For the Student's-t case, kappa can be a scalar representing the order of the moment.
mu	a numeric vector of length p representing the location parameter.
Sigma	a numeric positive definite matrix with dimension pxp representing the scale parameter.
lambda	a numeric vector of length p representing the skewness parameter for SN and ESN cases. If lambda == 0, the ESN/SN reduces to a normal (symmetric) distribution.
tau	It represents the extension parameter for the ESN distribution. If tau == 0, the ESN reduces to a SN distribution.
nu	It represents the degrees of freedom for the Student's t-distribution. Must be an integer greater than 1.
dist	represents the folded distribution to be computed. The values are normal, SN , ESN and t for the doubly truncated Normal, Skew-normal, Extended Skew-normal and Student's t-distribution respectively.

Details

Univariate case is also considered, where Sigma will be the variance σ^2.

Value

A data frame containing $p+1$ columns. The p first containing the set of combinations of exponents summing up to kappa and the last column containing the the expected value. Normal cases (ESN, SN and normal) return prod(kappa)+1 moments while the Student's t-distribution case returns all moments of order up to kappa. See example section.

Warning

For the Student-t cases, including ST and EST, kappa-th order moments exist only for kappa < nu.

Note

Degrees of freedom must be a positive integer. If nu >= 300, Normal case is considered."

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850 <doi:10.1007/s00184-020-00802-1>.

Galarza, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

See Also

`meanvarFMD`, `onlymeanTMD`,`meanvarTMD`,`momentsTMD`, `dmvSN`,`pmvSN`,`rmvSN`, `dmvESN`,`pmvESN`,`rmvESN`, `dmvST`,`pmvST`,`rmvST`, `dmvEST`,`pmvEST`,`rmvEST`

Examples

```
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
value1 = momentsFMD(c(2,0,1),mu,Sigma,dist="normal")
value2 = momentsFMD(3,mu,Sigma,dist = "t",nu = 7)
value3 = momentsFMD(c(2,0,1),mu,Sigma,lambda = c(-2,0,1),dist = "SN")
value4 = momentsFMD(c(2,0,1),mu,Sigma,lambda = c(-2,0,1),tau = 1,dist = "ESN")

#T case with kappa vector input
value5 = momentsFMD(c(2,0,1),mu,Sigma,dist = "t",nu = 7)
```

`momentsTMD` *Moments for doubly truncated multivariate distributions*

Description

It computes kappa-th order moments for for some doubly truncated skew-elliptical distributions. It supports the p-variate Normal, Skew-normal (SN) and Extended Skew-normal (ESN), as well as the Student's-t, Skew-t (ST) and the Extended Skew-t (EST) distribution.

Usage

```
momentsTMD(kappa,lower = rep(-Inf,length(mu)),upper = rep(Inf,length(mu)),mu,Sigma,
lambda = NULL,tau = NULL,nu = NULL,dist)
```

Arguments

- `kappa` moments vector of length p. All its elements must be integers greater or equal to 0. For the Student's-t case, `kappa` can be a scalar representing the order of the moment.
- `lower` the vector of lower limits of length p.
- `upper` the vector of upper limits of length p.
- `mu` a numeric vector of length p representing the location parameter.
- `Sigma` a numeric positive definite matrix with dimension pxp representing the scale parameter.
- `lambda` a numeric vector of length p representing the skewness parameter for SN and ESN cases. If `lambda == 0`, the ESN/SN reduces to a normal (symmetric) distribution.
- `tau` It represents the extension parameter for the ESN distribution. If `tau == 0`, the ESN reduces to a SN distribution.
- `nu` It represents the degrees of freedom for the Student's t-distribution being a positive real number.
- `dist` represents the truncated distribution to be used. The values are `normal`, `SN` and `ESN` for the doubly truncated Normal, Skew-normal and Extended Skew-normal distributions and, `t`, `ST` and `EST` for the for the doubly truncated Student-t, Skew-t and Extended Skew-t distributions.

Details

Univariate case is also considered, where `Sigma` will be the variance σ^2.

Value

A data frame containing $p+1$ columns. The p first containing the set of combinations of exponents summing up to `kappa` and the last column containing the the expected value. Normal cases (ESN, SN and normal) return `prod(kappa)+1` moments while the Student's t-distribution case returns all moments of order up to `kappa`. See example section.

Note

If `nu >= 300`, Normal case is considered."

Author(s)

Christian E. Galarza <<`cgalarza88@gmail.com`>> and Victor H. Lachos <<`hlachos@uconn.edu`>>

Maintainer: Christian E. Galarza <<`cgalarza88@gmail.com`>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850.

Galarza-Morales, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

Kan, R., & Robotti, C. (2017). On moments of folded and truncated multivariate normal distributions. Journal of Computational and Graphical Statistics, 26(4), 930-934.

See Also

onlymeanTMD,meanvarTMD,momentsFMD,meanvarFMD,dmvSN,pmvSN,rmvSN, dmvESN,pmvESN,rmvESN, dmvST,pmvST,rmvST, dmvEST,pmvEST,rmvEST

Examples

```
a = c(-0.8,-0.7,-0.6)
b = c(0.5,0.6,0.7)
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
value1 = momentsTMD(c(2,0,1),a,b,mu,Sigma,dist="normal")
value2 = momentsTMD(c(2,0,1),a,b,mu,Sigma,dist = "t",nu = 7)
value3 = momentsTMD(c(2,0,1),a,b,mu,Sigma,lambda = c(-2,0,1),dist = "SN")
value4 = momentsTMD(c(2,0,1),a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,dist = "ESN")


#T cases with kappa scalar (all moments up to 3)
value5 = momentsTMD(3,a,b,mu,Sigma,nu = 7,dist = "t")
value6 = momentsTMD(3,a,b,mu,Sigma,lambda = c(-2,0,1),nu = 7,dist = "ST")
value7 = momentsTMD(3,a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,nu = 7,dist = "EST")
```

---

onlymeanTMD *Mean for doubly truncated multivariate distributions*

Description

It computes the mean vector for some doubly truncated skew-elliptical distributions. It supports the p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Unified Skew-normal (SUN) as well as the Student's-t, Skew-t (ST), Extended Skew-t (EST) and Unified Skew-t (SUT) distribution.

Usage

```
onlymeanTMD(lower = rep(-Inf, length(mu)),upper = rep(Inf,length(mu)),mu,Sigma,
              lambda = NULL,tau = NULL,Gamma = NULL,nu = NULL,dist)
```

Arguments

- `lower` — the vector of lower limits of length p.
- `upper` — the vector of upper limits of length p.
- `mu` — a numeric vector of length p representing the location parameter.
- `Sigma` — a numeric positive definite matrix with dimension pxp representing the scale parameter.
- `lambda` — a numeric vector of length p representing the skewness parameter for SN and ESN cases. If `lambda == 0`, the ESN/SN reduces to a normal (symmetric) distribution.
- `tau` — It represents the extension parameter for the ESN distribution. If `tau == 0`, the ESN reduces to a SN distribution.
- `Gamma` — a correlation matrix with dimension qxq. It must be provided only for the SUN and SUT cases. For particular cases SN, ESN, ST and EST, we have that `Gamma == 1` (see examples at the end of this help).
- `nu` — It represents the degrees of freedom for the Student's t-distribution.
- `dist` — represents the truncated distribution to be used. The values are `normal`, `SN` , `ESN` and `SUN` for the doubly truncated Normal, Skew-normal, Extended Skew-normal and Unified-skew normal distributions and, `t`, `ST` , `EST` and `SUT` for the for the doubly truncated Student-t, Skew-t, Extended Skew-t and Unified skew-t distributions.

Details

Univariate case is also considered, where `Sigma` will be the variance σ^2. Normal case code is an R adaptation of the Matlab available function `dtmvnmom.m` from Kan & Robotti (2017) and it is used for `p<=3`. For higher dimensions we use proposal in Galarza (2022b).

Value

It returns the mean vector of length p.

Note

Degrees of freedom must be a positive integer. If `nu >= 300`, Normal case is considered."

Author(s)

Christian E. Galarza <<cgalarza88@gmail.com>> and Victor H. Lachos <<hlachos@uconn.edu>>

Maintainer: Christian E. Galarza <<cgalarza88@gmail.com>>

References

Galarza, C. E., Lin, T. I., Wang, W. L., & Lachos, V. H. (2021). On moments of folded and truncated multivariate Student-t distributions based on recurrence relations. Metrika, 84(6), 825-850.

Galarza-Morales, C. E., Matos, L. A., Dey, D. K., & Lachos, V. H. (2022a). "On moments of folded and doubly truncated multivariate extended skew-normal distributions." Journal of Computational and Graphical Statistics, 1-11 <doi:10.1080/10618600.2021.2000869>.

Galarza, C. E., Matos, L. A., Castro, L. M., & Lachos, V. H. (2022b). Moments of the doubly truncated selection elliptical distributions with emphasis on the unified multivariate skew-t distribution. Journal of Multivariate Analysis, 189, 104944 <doi:10.1016/j.jmva.2021.104944>.

Kan, R., & Robotti, C. (2017). On moments of folded and truncated multivariate normal distributions. Journal of Computational and Graphical Statistics, 26(4), 930-934.

See Also

momentsTMD, meanvarFMD, momentsFMD,dmvESN,rmvESN

Examples

```
a = c(-0.8,-0.7,-0.6)
b = c(0.5,0.6,0.7)
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)
value1 = onlymeanTMD(a,b,mu,Sigma,dist="normal")

# Now works for for any nu>0
value2 = onlymeanTMD(a,b,mu,Sigma,dist = "t",nu = 0.87)

value3 = onlymeanTMD(a,b,mu,Sigma,lambda = c(-2,0,1),dist = "SN")
value4 = onlymeanTMD(a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,dist = "ESN")
value5 = onlymeanTMD(a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,nu = 4,dist = "EST")

#Skew-unified Normal (SUN) and Skew-unified t (SUT) distributions

Lambda = matrix(c(1,0,2,-3,0,-1),3,2) #A skewness matrix p times q
Gamma  = matrix(c(1,-0.5,-0.5,1),2,2) #A correlation matrix q times q
tau    = c(-1,2)                      #A vector of extension parameters of dim q

value6 = onlymeanTMD(a,b,mu,Sigma,lambda = Lambda,tau = c(-1,2),Gamma = Gamma,dist = "SUN")
value7 = onlymeanTMD(a,b,mu,Sigma,lambda = Lambda,tau = c(-1,2),Gamma = Gamma,nu = 4,dist = "SUT")

#The ESN and EST as particular cases of the SUN and SUT for q=1

Lambda = matrix(c(-2,0,1),3,1)
Gamma  = 1
value8 = onlymeanTMD(a,b,mu,Sigma,lambda = Lambda,tau = 1,Gamma = Gamma,dist = "SUN")
value9 = onlymeanTMD(a,b,mu,Sigma,lambda = Lambda,tau = 1,Gamma = Gamma,nu = 4,dist = "SUT")

round(value4,2) == round(value8,2)
round(value5,2) == round(value9,2)
```

`pmvnormt` *Multivariate normal and Student-t probabilities*

Description

Computation of Multivariate normal and Student-t probabilities using the classic Genz method form packages `mvtnorm` and `tlrmvnmvt` packages. In order to save computational effort, it chooses whether to use the function `pmvtnorm` (`pmvt`) from `mvtnorm`, or functions `pmvn` (`pmvt`) from the `tlrmvnmvt` package, depending of the vector size `p`, real or integer degrees of freedom `nu`.

Usage

```
pmvnormt(lower = rep(-Inf,ncol(sigma)),upper = rep(Inf,ncol(sigma)),
mean = rep(0,ncol(sigma)),sigma,nu = NULL,uselog2 = FALSE)
```

Arguments

`lower`	lower integration limits, a numeric vector of length p
`upper`	upper integration limits, a numeric vector of length p
`mean`	the location parameter, a numeric vector of length p
`sigma`	the scale matrix, a square matrix that matches the length of ‘lower‘
`nu`	degrees of freedom, a positive real number. If `NULL`, normal case is considered
`uselog2`	a boolean variable, indicating if the log2 result should be returned. This is useful when the true probability is too small for the machine precision

Value

The estimated probability or its log2 if `uselog2 == TRUE`

Note

If `is.null(nu)`, normal case is considered.

Author(s)

Christian E. Galarza <<`cgalarza88@gmail.com`>> and Victor H. Lachos <<`hlachos@uconn.edu`>>

Maintainer: Christian E. Galarza <<`cgalarza88@gmail.com`>>

References

Genz, A. (1992), "Numerical computation of multivariate normal probabilities," Journal of Computational and Graphical Statistics, 1, 141-149.

Cao, J., Genton, M. G., Keyes, D. E., & Turkiyyah, G. M. "Exploiting Low Rank Covariance Structures for Computing High-Dimensional Normal and Student- t Probabilities" (2019) <https://marcgenton.github.io/2019.CGK

See Also

onlymeanTMD,meanvarTMD,momentsFMD,momentsTMD,meanvarFMD,dmvSN,pmvSN,rmvSN, dmvESN,pmvESN,rmvESN, dmvST,pmvST,rmvST, dmvEST,pmvEST,rmvEST

Examples

```
a = c(-0.8,-0.7,-0.6)
b = c(0.5,0.6,0.7)
mu = c(0.1,0.2,0.3)
Sigma = matrix(data = c(1,0.2,0.3,0.2,1,0.4,0.3,0.4,1),
               nrow = length(mu),ncol = length(mu),byrow = TRUE)

pmvnormt(lower = a,upper = b,mean = mu,sigma = Sigma) #normal case
pmvnormt(lower = a,upper = b,mean = mu,sigma = Sigma,nu = 4.23)  #t case
pmvnormt(lower = a,upper = b,mean = mu,sigma = Sigma,nu = 4.23,uselog2 = TRUE)
```

Index