Package 'MomTrunc'

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Title Moments of Folded and Doubly Truncated Multivariate Distributions

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Imports mvtnorm

Suggests TTmoment

Description It computes the raw moments for the truncated and folded multivariate normal, Skew-normal (SN), Extended skew normal (ESN) and Student's t-distribution. It also offers specific functions to compute the mean and variance-covariance matrix as well as the cumulative distribution function (cdf) for the folded normal, SN, ESN, and folded t-distribution. Density and random deviates are offered for the ESN (SN as particular case) distribution. Most algorithms are extensions based on Kan, R., & Robotti, C. (2017) <doi:10.1080/10618600.2017.1322092>.

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R topics documented:

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

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

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References

Chakraborty, A. K., & Chatterjee, M. (2013). On multivariate folded normal distribution. Sankhya B, 75(1), 1-15.

Kan R. & Robotti C. (2017) On Moments of Folded and Truncated Multivariate Normal Distributions, Journal of Computational and Graphical Statistics, 26:4, 930-934.

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

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")
```

---

drmvESN *Multivariate Extended-Skew Normal Density and Random Deviates*

Description

These functions provide the density function and a random number generator for the multivariate extended-skew normal (ESN) and skew-normal (SN, as particular case) 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)
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.
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.

Details

The rmvESN function is based on a rejection algorithm, so for small values of tau, that is, when $\tau \leq -2\sqrt{1+\sum \lambda_i^2}$, it is possible that the algorithm return less than the n observations and also take more time than usual, due to the high rejection rate.

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References

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

See Also

pmvESN, 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)
```

drmvSN *Multivariate Skew Normal Density 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)
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.
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.

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References

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

See Also

pmvESN, 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)
```

`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,dist,nu = NULL)
```

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.
`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 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."

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References

Kan R. & Robotti C. (2017) On Moments of Folded and Truncated Multivariate Normal Distributions, Journal of Computational and Graphical Statistics, 26:4, 930-934.

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

See Also

momentsFMD, meanvarFMD, meanvarTMD, cdfFMD,dmvESN,rmvESN

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,dist = "t",nu = 4)
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 the doubly truncated p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Student's t-distribution.

Usage

```
meanvarTMD(lower = NULL,upper = NULL,mu,Sigma,lambda = NULL,tau = NULL,dist,nu = NULL)
```

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.
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

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

The mean can only be provided when nu is larger than 2. By 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."

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References

Kan R. & Robotti C. (2017) On Moments of Folded and Truncated Multivariate Normal Distributions, Journal of Computational and Graphical Statistics, 26:4, 930-934.

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

Vaida, F. & Liu, L. (2009). Fast implementation for normal mixed effects models with censored response. Journal of Computational and Graphical Statistics, 18(4), 797-817.

See Also

momentsTMD, meanvarFMD, 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 = meanvarTMD(a,b,mu,Sigma,dist="normal")
value2 = meanvarTMD(a,b,mu,Sigma,dist = "t",nu = 4)
value3 = meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),dist = "SN")
value4 = meanvarTMD(a,b,mu,Sigma,lambda = c(-2,0,1),tau = 1,dist = "ESN")
```

---

momentsFMD *Moments for folded multivariate distributions*

Description

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

Usage

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

Arguments

kappa	moments vector of length p. All its elements must be integers greater or equal to 0.
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

A data frame containing $p + 1$ columns. The p first containing the set of moments involved in the recursive approach and the last column containing the expected value.

Normal cases (ESN, SN and normal) return prod(kappa)+1 moments while the Student's t-distribution case returns sum(kappa)+1. See example section.

Warning

For the Student-t case, the kappa-th moment can only be computed when sum(kappa) $\leq$ nu-2.

Note

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

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References

Kan, R., & Robotti, C. (2017). On Moments of Folded and Truncated Multivariate Normal Distributions. Journal of Computational and Graphical Statistics, (just-accepted).

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

See Also

meanvarFMD, meanvarFMD,momentsTMD,meanvarTMD,cdfFMD,dmvESN,rmvESN

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(c(0,2,0),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")
```

`momentsTMD` *Moments for doubly truncated multivariate distributions*

Description

It computes the kappa-th raw moment for the doubly truncated p-variate Normal, Skew-normal (SN), Extended Skew-normal (ESN) and Student's t-distribution. It also output some other lower moments (than `kappa`) involved in the recurrence approach.

Usage

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

Arguments

`kappa`	moments vector of length p. All its elements must be integers greater or equal to 0.
`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.
`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

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

Value

A data frame containing $p + 2$ columns. The p first containing the set of moments involved in the recursive approach and the last two columns containing the F function value (see Galarza and Lachos, 2018) and the expected value. Normal cases (ESN, SN and normal) return `prod(kappa)+1` moments while the Student's t-distribution case returns `sum(kappa)+1`. See example section.

Henceforth, we HIGHLY recomend to check the pdf manual instead because of formulae.

The F function is simply

$$F_\kappa(\mathbf{a}, \mathbf{b}, \mu, \Sigma, \nu) = \int_{\mathbf{a}}^{\mathbf{b}} \mathbf{x}^\kappa f(\mathbf{x}) \mathrm{d}\mathbf{x},$$

where $\mathbf{a}$ and $\mathbf{b}$ are vectors of length p representing the lower and upper bounds. We have used the short notation $\mathbf{x}^\kappa = x_1^{\kappa_1} x_2^{\kappa_2} \dots x_p^{\kappa_p}$. It is easy to see that $P(\mathbf{a} \leq \mathbf{X} \leq \mathbf{b}) = F_{\mathbf{0}}(\mathbf{a}, \mathbf{b}, \mu, \Sigma, \nu)$, i.e., the normalizing constant for the doubly truncated density. Then the expected value will be given by $E[\mathbf{x}^\kappa] = F_\kappa(\mathbf{a}, \mathbf{b}, \mu, \Sigma, \nu)/F_{\mathbf{0}}(\mathbf{a}, \mathbf{b}, \mu, \Sigma, \nu)$.

Normal case returns `prod(kappa)+1` moments while the Student's t-distribution case returns `sum(kappa)+1`. See example section. For the extended skew-normal case, we recommend to the readers to check the reference.

Warning

For the Student-t case, the `kappa`-th moment can only be computed when `sum(kappa)` $\leq$ `nu`-2.

Note

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

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References

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C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

See Also

`meanvarTMD`, `meanvarFMD`,`momentsFMD`,`meanvarFMD`,`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 = 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")
```

`onlymeanTMD` *Mean for doubly truncated multivariate distributions*

Description

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

Usage

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

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.
`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

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 the mean vector of length p.

Warning

For now, he mean can only be provided when nu is larger than 2.

Note

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

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References

Kan R. & Robotti C. (2017) On Moments of Folded and Truncated Multivariate Normal Distributions, Journal of Computational and Graphical Statistics, 26:4, 930-934.

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

Vaida, F. & Liu, L. (2009). Fast implementation for normal mixed effects models with censored response. Journal of Computational and Graphical Statistics, 18(4), 797-817.

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")
value2 = onlymeanTMD(a,b,mu,Sigma,dist = "t",nu = 4)
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")
```

pmvESN *Multivariate Extended-Skew Normal Probabilities*

Description

Computes the distribution function of the multivariate extended-skew normal (ESN) and skew-normal (SN, as particular case) distribution for arbitrary limits, mean vector mu, scale matrix $sigma$, skewness parameter $lambda$ and extension parameter tau.

Usage

```
pmvESN(lower = rep(-Inf,length(lambda)),upper=rep(Inf,length(lambda)),
        mu = rep(0,length(lambda)),Sigma,lambda,tau, ...)
```

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.
...	Arguments passed to the pmvnorm fucntion from the mvtnorm, for instance, algorithm.

Details

This code uses the pmvnorm function from mvtnorm package. For the normal case (all lambda and tau equal to zero), it is better to use pmvnorm directly.

Value

The evaluated distribution function is returned.

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References

Genz, A. and Bretz, F. (2009), Computation of Multivariate Normal and t Probabilities. Lecture Notes in Statistics, Vol. 195. Springer-Verlag, Heidelberg.

C.E. Galarza, L.A. Matos, D.K. Dey & V.H. Lachos. (2019) On Moments of Folded and Truncated Multivariate Extended Skew-Normal Distributions. Technical report. ID 19-14. University of Connecticut.

See Also

dmvESN,rmvESN, meanvarFMD,meanvarTMD,momentsTMD

Examples

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

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