Package ‘MultiRNG’

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Title Multivariate Pseudo-Random Number Generation

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Description Pseudo-random number generation for 11 multivariate distributions: Normal, t, Uniform, Bernoulli, Hypergeometric, Beta (Dirichlet), Multinomial, Dirichlet-Multinomial, Laplace, Wishart, and Inverted Wishart. The details of the method are explained in Demirtas (2004) <DOI:10.22237/jmasm/1099268340>.

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MultiRNG-package *Multivariate Pseudo-Random Number Generation*

Description

This package implements the algorithms described in Demirtas (2004) for pseudo-random number generation of 11 multivariate distributions. The following multivariate distributions are available: Normal, t, Uniform, Bernoulli, Hypergeometric, Beta (Dirichlet), Multinomial, Dirichlet-Multinomial, Laplace, Wishart, and Inverted Wishart.

This package contains 11 main functions and 2 auxiliary functions. The methodology for each random-number generation procedure varies and each distribution has its own function. For multivariate normal, `draw.d.variate.normal` employs the Cholesky decomposition and a vector of univariate normal draws and for multivariate t, `draw.d.variate.t` employs the Cholesky decomposition and a vector of univariate normal and chi-squared draws. `draw.d.variate.uniform` is based on cdf of multivariate normal deviates (Falk, 1999) and `draw.correlated.binary` generates correlated binary variables using an algorithm developed by Park, Park and Shin (1996) and makes use of the auxiliary function `loc.min`. `draw.multivariate.hypergeometric` employs sequential generation of succeeding conditionals which are univariate hypergeometric. Furthermore, `draw.dirichlet` uses the ratios of gamma variates with a common scale parameter and `draw.multinomial` generates data via sequential generation of marginals which are binomials. `draw.dirichlet.multinomial` is a mixture distribution of a multinomial that is a realization of a random variable having a Dirichlet distribution. `draw.multivariate.laplace` is based on generation of a point s on the d-dimensional sphere and utilizes the auxiliary function `generate.point.in.sphere`. `draw.wishart` and `draw.inv.wishart` employs Wishart variates that follow d-variate normal distribution.

Details

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Author(s)

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References

Demirtas, H. (2004). Pseudo-random number generation in R for commonly used multivariate distributions. *Journal of Modern Applied Statistical Methods*, **3(2)**, 485-497.

Falk, M. (1999). A simple approach to the generation of uniformly distributed random variables with prescribed correlations. *Communications in Statistics, Simulation and Computation*, **28(3)**, 785-791.

Park, C. G., Park, T., & Shin D. W. (1996). A simple method for generating correlated binary variates. *The American Statistician*, **50(4)**, 306-310.

`draw.correlated.binary` *Generation of Correlated Binary Data*

Description

This function implements pseudo-random number generation for a multivariate Bernoulli distribution (correlated binary data).

Usage

```
draw.correlated.binary(no.row,d,prop.vec,corr.mat)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`prop.vec`	Vector of means.
`corr.mat`	Correlation matrix.

Value

A $no.row \times d$ matrix of generated data.

References

Park, C. G., Park, T., & Shin D. W. (1996). A simple method for generating correlated binary variates. *The American Statistician*, **50(4)**, 306-310.

See Also

`loc.min`

Examples

```
cmat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
propvec=c(0.3,0.5,0.7)

mydata=draw.correlated.binary(no.row=1e5,d=3,prop.vec=propvec,corr.mat=cmat)
apply(mydata,2,mean)-propvec
cor(mydata)-cmat
```

draw.d.variate.normal *Pseudo-Random Number Generation under Multivariate Normal Distribution*

Description

This function implements pseudo-random number generation for a multivariate normal distribution with pdf

$$f(x|\mu, \Sigma) = c \exp{(-\frac{1}{2}(x-\mu)^T \Sigma^{-1}(x-\mu))}$$

for $-\infty < x < \infty$ and $c = (2\pi)^{-d/2}|\Sigma|^{-1/2}$, Σ is symmetric and positive definite, where μ and Σ are the mean vector and the variance-covariance matrix, respectively.

Usage

```
draw.d.variate.normal(no.row,d,mean.vec,cov.mat)
```

Arguments

no.row	Number of rows to generate.
d	Number of variables to generate.
mean.vec	Vector of means.
cov.mat	Variance-covariance matrix.

Value

A $no.row \times d$ matrix of generated data.

Examples

```
cmat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
meanvec=c(0,3,7)
mydata=draw.d.variate.normal(no.row=1e5,d=3,mean.vec=meanvec,cov.mat=cmat)
apply(mydata,2,mean)-meanvec
cor(mydata)-cmat
```

draw.d.variate.t — *Pseudo-Random Number Generation under Multivariate t Distribution*

Description

This function implements pseudo-random number generation for a multivariate t distribution with pdf

$$f(x|\mu, \Sigma, \nu) = c \left(1 + \frac{1}{\nu}(x-\mu)^T \Sigma^{-1}(x-\mu)\right)^{-(\nu+d)/2}$$

for $-\infty < x < \infty$ and $c = \frac{\Gamma((\nu+d)/2)}{\Gamma(\nu/2)(\nu\pi)^{d/2}} |\Sigma|^{-1/2}$, Σ is symmetric and positive definite, $\nu > 0$, where μ, Σ, and ν are the mean vector, the variance-covariance matrix, and the degrees of freedom, respectively.

Usage

```
draw.d.variate.t(dof,no.row,d,mean.vec,cov.mat)
```

Arguments

`dof`	Degrees of freedom.
`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`mean.vec`	Vector of means.
`cov.mat`	Variance-covariance matrix.

Value

A $no.row \times d$ matrix of generated data.

Examples

```
cmat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
meanvec=c(0,3,7)
mydata=draw.d.variate.t(dof=5,no.row=1e5,d=3,mean.vec=meanvec,cov.mat=cmat)
apply(mydata,2,mean)-meanvec
cor(mydata)-cmat
```

draw.d.variate.uniform

Pseudo-Random Number Generation under Multivariate Uniform Distribution

Description

This function implements pseudo-random number generation for a multivariate uniform distribution with specified mean vector and covariance matrix.

Usage

```
draw.d.variate.uniform(no.row,d,cov.mat)
```

Arguments

no.row	Number of rows to generate.
d	Number of variables to generate.
cov.mat	Variance-covariance matrix.

Value

A $no.row \times d$ matrix of generated data.

References

Falk, M. (1999). A simple approach to the generation of uniformly distributed random variables with prescribed correlations. *Communications in Statistics, Simulation and Computation*, **28(3)**, 785-791.

Examples

```
cmat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
mydata=draw.d.variate.uniform(no.row=1e5,d=3,cov.mat=cmat)
apply(mydata,2,mean)-rep(0.5,3)
cor(mydata)-cmat
```

draw.dirichlet	*Pseudo-Random Number Generation under Multivariate Beta (Dirichlet) Distribution*

Description

This function implements pseudo-random number generation for a multivariate beta (Dirichlet) distribution with pdf

$$f(x|\alpha_1,...,\alpha_d) = \frac{\Gamma(\sum_{j=1}^{d}\alpha_j)}{\prod_{j=1}^{d}\Gamma(\alpha_j)}\prod_{j=1}^{d}x_j^{\alpha_j-1}$$

for $\alpha_j > 0$, $x_j \geq 0$, and $\sum_{j=1}^{d} x_j = 1$, where $\alpha_1,...,\alpha_d$ are the shape parameters and β is a common scale paramter.

Usage

```
draw.dirichlet(no.row,d,alpha,beta)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`alpha`	Vector of shape parameters.
`beta`	Scale parameter common to d variables.

Value

A $no.row \times d$ matrix of generated data.

Examples

```
alpha.vec=c(1,3,4,4)
mydata=draw.dirichlet(no.row=1e5,d=4,alpha=alpha.vec,beta=2)
apply(mydata,2,mean)-alpha.vec/sum(alpha.vec)
```

draw.dirichlet.multinomial *Pseudo-Random Number Generation under Dirichlet-Multinomial Distribution*

Description

This function implements pseudo-random number generation for a Dirichlet-multinomial distribution. This is a mixture distribution that is multinomial with parameter θ that is a realization of a random variable having a Dirichlet distribution with shape vector α. N is the sample size and β is a common scale parameter.

Usage

```
draw.dirichlet.multinomial(no.row,d,alpha,beta,N)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`alpha`	Vector of shape parameters.
`beta`	Scale parameter common to d variables.
`N`	Sample size.

Value

A $no.row \times d$ matrix of generated data.

See Also

`draw.dirichlet`, `draw.multinomial`

Examples

```
alpha.vec=c(1,3,4,4) ; N=3
mydata=draw.dirichlet.multinomial(no.row=1e5,d=4,alpha=alpha.vec,beta=2, N=3)
apply(mydata,2,mean)-N*alpha.vec/sum(alpha.vec)
```

`draw.inv.wishart` *Pseudo-Random Number Generation under Inverted Wishart Distribution*

Description

This function implements pseudo-random number generation for an inverted Wishart distribution with pdf

$$f(x|\nu,\Sigma) = (2^{\nu d/2}\pi^{d(d-1)/4}\prod_{i=1}^{d}\Gamma((\nu+1-i)/2))^{-1}|\Sigma|^{\nu/2}|x|^{-(\nu+d+1)/2}\exp(-\frac{1}{2}tr(\Sigma x^{-1}))$$

x is positive definite, $\nu \geq d$, and Σ^{-1} is symmetric and positive definite, where ν and Σ^{-1} are the degrees of freedom and the inverse scale matrix, respectively.

Usage

```
draw.inv.wishart(no.row,d,nu,inv.sigma)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`nu`	Degrees of freedom.
`inv.sigma`	Inverse scale matrix.

Value

A $no.row \times d^2$ matrix ofcontaining Wishart deviates in the form of rows. To obtain the Inverted-Wishart matrix, convert each row to a matrix where rows are filled first.

See Also

`draw.wishart`

Examples

```
mymat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
draw.inv.wishart(no.row=1e5,d=3,nu=5,inv.sigma=mymat)
```

`draw.multinomial` *Pseudo-Random Number Generation under Multivariate Multinomial Distribution*

Description

This function implements pseudo-random number generation for a multivariate multinomial distribution with pdf

$$f(x|\theta_1, ..., \theta_d) = \frac{N!}{\prod x_j!} \prod_{j=1}^{d} \theta_j^{x_j}$$

for $0 < \theta_j < 1$, $x_j \geq 0$, and $\sum_{j=1}^{d} x_j = N$, where $\theta_1, ..., \theta_d$ are cell probabilities and N is the size.

Usage

```
draw.multinomial(no.row,d,theta,N)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`theta`	Vector of cell probabilities.
`N`	Sample Size. Must be at least 2.

Value

A $no.row \times d$ matrix of generated data.

Examples

```
theta.vec=c(0.3,0.3,0.25,0.15) ; N=4
mydata=draw.multinomial(no.row=1e5,d=4,theta=c(0.3,0.3,0.25,0.15),N=4)
apply(mydata,2,mean)-N*theta.vec
```

draw.multivariate.hypergeometric

Pseudo-Random Number Generation under Multivariate Hypergeometric Distribution

Description

This function implements pseudo-random number generation for a multivariate hypergeometric distribution.

Usage

```
draw.multivariate.hypergeometric(no.row,d,mean.vec,k)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`mean.vec`	Number of items in each category.
`k`	Number of items to be sampled. Must be a positive integer.

Value

A $no.row \times d$ matrix of generated data.

References

Demirtas, H. (2004). Pseudo-random number generation in R for commonly used multivariate distributions. *Journal of Modern Applied Statistical Methods*, **3(2)**, 485-497.

Examples

```
meanvec=c(10,10,12) ; myk=5
mydata=draw.multivariate.hypergeometric(no.row=1e5,d=3,mean.vec=meanvec,k=myk)
apply(mydata,2,mean)-myk*meanvec/sum(meanvec)
```

draw.multivariate.laplace *Pseudo-Random Number Generation under Multivariate Laplace Distribution*

Description

This function implements pseudo-random number generation for a multivariate Laplace (double exponential) distribution with pdf

$$f(x|\mu, \Sigma, \gamma) = c \exp(-((x-\mu)^T \Sigma^{-1} (x-\mu))^{\gamma/2})$$

for $-\infty < x < \infty$ and $c = \frac{\gamma \Gamma(d/2)}{2\pi^{d/2}\Gamma(d/\gamma)} |\Sigma|^{-1/2}$, Σ is symmetric and positive definite, where μ, Σ, and γ are the mean vector, the variance-covariance matrix, and the shape parameter, respectively.

Usage

```
draw.multivariate.laplace(no.row,d,gamma,mu,Sigma)
```

Arguments

no.row	Number of rows to generate.
d	Number of variables to generate.
gamma	Shape parameter.
mu	Vector of means.
Sigma	Variance-covariance matrix.

Value

A $no.row \times d$ matrix of generated data.

References

Ernst, M. D. (1998). A multivariate generalized Laplace distribution. *Computational Statistics*, **13**, 227-232.

See Also

generate.point.in.sphere

Examples

```
cmat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
mu.vec=c(0,3,7)
mydata=draw.multivariate.laplace(no.row=1e5,d=3,gamma=2,mu=mu.vec,Sigma=cmat)

apply(mydata,2,mean)-mu.vec
cor(mydata)-cmat
```

draw.wishart *Pseudo-Random Number Generation under Wishart Distribution*

Description

This function implements pseudo-random number generation for a Wishart distribution with pdf

$$f(x|\nu,\Sigma) = (2^{\nu d/2}\pi^{d(d-1)/4}\prod_{i=1}^{d}\Gamma((\nu+1-i)/2))^{-1}|\Sigma|^{-\nu/2}|x|^{(\nu-d-1)/2}\exp(-\frac{1}{2}tr(\Sigma^{-1}x))$$

x is positive definite, $\nu \geq d$, and Σ is symmetric and positive definite, where ν and Σ are positive definite and the scale matrix, respectively.

Usage

```
draw.wishart(no.row,d,nu,sigma)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.
`nu`	Degrees of freedom.
`sigma`	Scale matrix.

Value

A $no.row \times d^2$ matrix of Wishart deviates in the form of rows.To obtain the Wishart matrix, convert each row to a matrix where rows are filled first.

See Also

draw.d.variate.normal

Examples

```
mymat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
draw.wishart(no.row=1e5,d=3,nu=5,sigma=mymat)
```

generate.point.in.sphere *Point Generation for a Sphere*

Description

This function generates s points on a d-dimensional sphere.

Usage

```
generate.point.in.sphere(no.row,d)
```

Arguments

`no.row`	Number of rows to generate.
`d`	Number of variables to generate.

Value

A $no.row \times d$ matrix of coordinates of points in sphere.

References

Marsaglia, G. (1972). Choosing a point from the surface of a sphere. *Annals of Mathematical Statistics*, **43**, 645-646.

Examples

```
generate.point.in.sphere(no.row=1e5,d=3)
```

loc.min *Minimum Location Finder*

Description

This function identifies the location of the minimum value in a square matrix.

Usage

```
loc.min(my.mat,d)
```

Arguments

`my.mat`	A square matrix.
`d`	Dimensions of the matrix.

Value

A vector containing the row and column number of the minimum value.

Examples

```
cmat<-matrix(c(1,0.2,0.3,0.2,1,0.2,0.3,0.2,1), nrow=3, ncol=3)
loc.min(my.mat=cmat, d=3)
```

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