NAG Toolbox for MATLAB

g05ra

1 Purpose

g05ra sets up a reference vector and generates an array of pseudo-random numbers from a Normal (Gaussian) copula with covariance matrix C.

2 Syntax

```
[x, iseed, r, ifail] = g05ra(mode, c, n, igen, iseed, r, 'm', m, 'lr', lr)
```

3 Description

The Gaussian copula, c, is defined by

$$c(u_1, u_2, \cdots, u_m; C) = \Phi_C\left(\phi^{-1}_{C_{11}}(u_1), \phi^{-1}_{C_{22}}(u_2), \cdots, \phi^{-1}_{C_{mm}}(u_m)\right)$$

where m is the number of dimensions, Φ_C is the multivariate Normal density function with mean zero and covariance matrix C and $\phi^{-1}_{C_{ii}}$ is the inverse of the univariate Normal density function with mean zero and variance C_{ii}.

Routine g05ly is used to generate a vector from a multivariate Normal distribution and function g01ea is used to convert each element of that vector into a uniformly distributed value between zero and one.

One of the initialization functions g05kb (for a repeatable sequence if computed sequentially) or g05kc (for a non-repeatable sequence) must be called prior to the first call to g05ra.

4 References

Nelsen R B 1998 *An Introduction to Copulas. Lecture Notes in Statistics 139* Springer

Sklar A 1973 Random Variables: Joint Distribution Functions and Copulas *Kybernetika* **9** 499–460

5 Parameters

5.1 Compulsory Input Parameters

1: **mode – int32 scalar**

Selects the operation to be performed:

mode $= 0$

Initialize and generate random numbers.

mode $= 1$

Initialize only (i.e., set up reference vector).

mode $= 2$

Generate random numbers using previously set up reference vector.

Constraint: $0 \leq$ **mode** ≤ 2.

2: **c(ldc,m) – double array**

ldc, the first dimension of the array, must be at least **m**.

The covariance matrix of the distribution. Only the upper triangle need be set.

Constraint: **c** must be positive semi-definite to ***machine precision***

3: **n – int32 scalar**

n, the number of random variates required.

Constraint: $\mathbf{n} \geq 1$.

4: **igen – int32 scalar**

Must contain the identification number for the generator to be used to return a pseudo-random number and should remain unchanged following initialization by a prior call to g05kb or g05kc.

5: **iseed**$(\mathbf{4})$ **– int32 array**

Contains values which define the current state of the selected generator.

6: **r**$(\mathbf{lr})$ **– double array**

If **mode** $= 2$, the reference vector as set up by g05ra in a previous call with **mode** $= 0$ or 1.

5.2 Optional Input Parameters

1: **m – int32 scalar**

Default: The dimension of the arrays **c**, **x**. (An error is raised if these dimensions are not equal.)

m, the number of dimensions of the distribution.

Constraint: $\mathbf{m} > 0$.

2: **lr – int32 scalar**

Default: The dimension of the array **r**.

If **mode** $= 2$, it must be the same as the value of **lr** specified in the prior call to g05ra with **mode** $= 0$ or 1.

Constraint: $\mathbf{lr} > \mathbf{m}(\mathbf{m}+1)$.

5.3 Input Parameters Omitted from the MATLAB Interface

ldc, ldx

5.4 Output Parameters

1: **x**$(\mathbf{ldx},\mathbf{m})$ **– double array**

The array of pseudo-random multivariate Normal vectors generated by the function.

2: **iseed**$(\mathbf{4})$ **– int32 array**

Contains updated values defining the new state of the selected generator.

3: **r**$(\mathbf{lr})$ **– double array**

If **mode** $= 0$ or 1, the reference vector that can be used in subsequent calls to g05ra with **mode** $= 2$.

4: **ifail – int32 scalar**

0 unless the function detects an error (see Section 6).

6 Error Indicators and Warnings

Errors or warnings detected by the function:

ifail $= 1$

On entry, **mode** $\neq 0$, 1 or 2.

ifail $= 2$

On entry, **m** < 1.

ifail $= 3$

The covariance matrix **c** is not positive semi-definite to ***machine precision***.

ifail $= 4$

On entry, **ldc** $<$ **m**.

ifail $= 5$

On entry, **n** < 1.

ifail $= 7$

On entry, **ldx** $<$ **n**.

ifail $= 8$

On entry, invalid value for **igen**. **igen** must be the same as the value as specified in the prior call to g05ra with **mode** $= 0$ or 1.

ifail $= 10$

The reference vector **r** has been corrupted or **m** has changed since **r** was set up in a previous call with **mode** $= 0$ or 1.

ifail $= 11$

On entry, **lr** $<$ **m**$(\mathbf{m}+1)$.

7 Accuracy

See Section 7 of the document for g05ly for an indication of the accuracy of the underlying multivariate Normal distribution.

8 Further Comments

None.

9 Example

```
mode = int32(0);
c = [1.69, 0.39, -1.86, 0.07000000000000001;
     0, 98.01000000000001, -7.07, -0.71;
     0, 0, 11.56, 0.03;
     0, 0, 0, 0.01];
n = int32(10);
igen = int32(1);
iseed = [int32(1762543);
     int32(9324783);
```

```
     int32(42344);
     int32(742355)];
r = zeros(31, 1);
[x, iseedOut, rOut, ifail] = g05ra(mode, c, n, igen, iseed, r)
```

```
x =
    0.9819    0.1689    0.0712    0.9428
    0.2525    0.7025    0.5261    0.1134
    0.4771    0.8504    0.8684    0.4064
    0.0900    0.4690    0.7162    0.2592
    0.3835    0.0400    0.8975    0.7915
    0.5492    0.9685    0.4275    0.1749
    0.2064    0.3430    0.9595    0.5140
    0.7369    0.6728    0.0191    0.3639
    0.8970    0.0732    0.5617    0.9151
    0.2198    0.0157    0.8901    0.8911
iseedOut =
    12448879
    13032530
    13959882
     2589587
rOut =
    4.5000
    1.3000
    0.3000
   -1.4308
    0.0538
         0
    9.8955
   -0.6711
   -0.0734
         0
         0
    3.0104
    0.0192
         0
         0
         0
    0.0367
    1.3000
    9.9000
    3.4000
    0.1000
         0
         0
         0
         0
         0
         0
         0
         0
         0
         0
ifail =
          0
```