

NAG Library Function Document

nag_rand_bivariate_copula_frank (g05rfc)

1 Purpose

nag_rand_bivariate_copula_frank (g05rfc) generates pseudorandom uniform bivariate with joint distribution of a Frank Archimedean copula.

2 Specification

```
#include <nag.h>
#include <nagg05.h>

void nag_rand_bivariate_copula_frank (Nag_OrderType order, Integer state[],
    double theta, Integer n, double x[], Integer pdx, Integer sdx,
    NagError *fail)
```

3 Description

Generates pseudorandom uniform bivariate $\{u_1, u_2\} \in [0, 1]^2$ whose joint distribution is the Frank Archimedean copula C_θ with parameter θ , given by

$$C_\theta = -\frac{1}{\theta} \ln \left[1 + \frac{(e^{-\theta u_1} - 1)(e^{-\theta u_2} - 1)}{e^{-\theta} - 1} \right], \quad \theta \in (-\infty, \infty) \setminus \{0\}$$

with the special cases:

$C_{-\infty} = \max(u_1 + u_2 - 1, 0)$, the Fréchet–Hoeffding lower bound;

$C_0 = u_1 u_2$, the product copula;

$C_\infty = \min(u_1, u_2)$, the Fréchet–Hoeffding upper bound.

The generation method uses conditional sampling.

One of the initialization functions nag_rand_init_repeatable (g05kfc) (for a repeatable sequence if computed sequentially) or nag_rand_init_nonrepeatable (g05kgc) (for a non-repeatable sequence) must be called prior to the first call to nag_rand_bivariate_copula_frank (g05rfc).

4 References

Nelsen R B (2006) *An Introduction to Copulas* (2nd Edition) Springer Series in Statistics

5 Arguments

1: **order** – Nag_OrderType *Input*

On entry: the **order** argument specifies the two-dimensional storage scheme being used, i.e., row-major ordering or column-major ordering. C language defined storage is specified by **order** = Nag_RowMajor. See Section 2.3.1.3 in How to Use the NAG Library and its Documentation for a more detailed explanation of the use of this argument.

Constraint: **order** = Nag_RowMajor or Nag_ColMajor.

2: **state**[*dim*] – Integer *Communication Array*

Note: the dimension, *dim*, of this array is dictated by the requirements of associated functions that must have been previously called. This array **MUST** be the same array passed as argument

state in the previous call to nag_rand_init_repeatable (g05kfc) or nag_rand_init_nonrepeatable (g05kge).

On entry: contains information on the selected base generator and its current state.

On exit: contains updated information on the state of the generator.

3: **theta** – double *Input*

On entry: θ , the copula parameter.

4: **n** – Integer *Input*

On entry: n , the number of bivariate to generate.

Constraint: $n \geq 0$.

5: **x**[**pdx** × **sdx**] – double *Output*

Note: where $\mathbf{X}(i, j)$ appears in this document, it refers to the array element

$$\begin{aligned} & \mathbf{x}[(j-1) \times \mathbf{pdx} + i - 1] \text{ when } \mathbf{order} = \text{Nag_ColMajor}; \\ & \mathbf{x}[(i-1) \times \mathbf{pdx} + j - 1] \text{ when } \mathbf{order} = \text{Nag_RowMajor}. \end{aligned}$$

On exit: the n bivariate uniforms with joint distribution described by C_θ , with $\mathbf{X}(i, j)$ holding the i th value for the j th dimension if $\mathbf{order} = \text{Nag_ColMajor}$ and the j th value for the i th dimension if $\mathbf{order} = \text{Nag_RowMajor}$.

6: **pdx** – Integer *Input*

On entry: the stride separating row or column elements (depending on the value of **order**) in the array **x**.

Constraints:

$$\begin{aligned} & \text{if } \mathbf{order} = \text{Nag_ColMajor}, \mathbf{pdx} \geq \mathbf{n}; \\ & \text{if } \mathbf{order} = \text{Nag_RowMajor}, \mathbf{pdx} \geq 2. \end{aligned}$$

7: **sdx** – Integer *Input*

On entry: the secondary dimension of **x**.

Constraints:

$$\begin{aligned} & \text{if } \mathbf{order} = \text{Nag_ColMajor}, \mathbf{sdx} \geq 2; \\ & \text{if } \mathbf{order} = \text{Nag_RowMajor}, \mathbf{sdx} \geq \mathbf{n}. \end{aligned}$$

8: **fail** – NagError * *Input/Output*

The NAG error argument (see Section 2.7 in How to Use the NAG Library and its Documentation).

6 Error Indicators and Warnings

NE_ALLOC_FAIL

Dynamic memory allocation failed.

See Section 2.3.1.2 in How to Use the NAG Library and its Documentation for further information.

NE_BAD_PARAM

On entry, argument $\langle value \rangle$ had an illegal value.

NE_INT

On entry, **n** = $\langle value \rangle$.
 Constraint: **n** ≥ 0 .

NE_INT_2

On entry, **pdx** must be at least $\langle value \rangle$: **pdx** = $\langle value \rangle$.
 On entry, **sdx** must be at least $\langle value \rangle$: **sdx** = $\langle value \rangle$.

NE_INTERNAL_ERROR

An internal error has occurred in this function. Check the function call and any array sizes. If the call is correct then please contact NAG for assistance.

An unexpected error has been triggered by this function. Please contact NAG.
 See Section 2.7.6 in How to Use the NAG Library and its Documentation for further information.

NE_INVALID_STATE

On entry, corrupt **state** argument.

NE_NO_LICENCE

Your licence key may have expired or may not have been installed correctly.
 See Section 2.7.5 in How to Use the NAG Library and its Documentation for further information.

7 Accuracy

Not applicable.

8 Parallelism and Performance

nag_rand_bivariate_copula_frank (g05rfe) is threaded by NAG for parallel execution in multithreaded implementations of the NAG Library.

Please consult the x06 Chapter Introduction for information on how to control and interrogate the OpenMP environment used within this function. Please also consult the Users' Note for your implementation for any additional implementation-specific information.

9 Further Comments

In practice, the need for numerical stability restricts the range of θ such that:

if $\theta < \ln \epsilon_s$, the function returns pseudorandom uniform variates with $C_{-\infty}$ joint distribution;

if $|\theta| < 1.0 \times 10^{-6}$, the function returns pseudorandom uniform variates with C_0 joint distribution;

if $\theta > \ln \epsilon$, the function returns pseudorandom uniform variates with C_{∞} joint distribution;

where ϵ_s is the safe-range parameter, the value of which is returned by nag_real_safe_small_number (X02AMC); and ϵ is the *machine precision* returned by nag_machine_precision (X02AJC).

10 Example

This example generates thirteen variates for copula $C_{-12.0}$.

10.1 Program Text

```

/* nag_rand_bivariate_copula_frank (g05rfc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */
/* Pre-processor includes */
#include <stdio.h>
#include <math.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagg05.h>

#define X(I, J) x[order == Nag_ColMajor?((J-1)*pdx + I-1):((I-1)*pdx + J-1)]

int main(void)
{
    /* Integer scalar and array declarations */
    Integer exit_status = 0;
    Integer i, lstate, pdx, sdx;
    Integer *state = 0;

    /* Double scalar and array declarations */
    double *x = 0;

    /* NAG structures */
    NagError fail;

    /* Use row major order */
    Nag_OrderType order = Nag_RowMajor;

    /* Set the number of variates */
    Integer n = 13;

    /* Choose the base generator */
    Nag_BaseRNG genid = Nag_Basic;
    Integer subid = 0;

    /* Set the seed */
    Integer seed[] = { 1762543 };
    Integer lseed = 1;

    /* Set the theta parameter value */
    double theta = -12.0e0;

    /* Initialize the error structure */
    INIT_FAIL(fail);

    printf("nag_rand_bivariate_copula_frank (g05rfc) "
           "Example Program Results\n\n");

    /* Get the length of the state array */
    lstate = -1;
    nag_rand_init_repeatabl(genid, subid, seed, lseed, state, &lstate, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_rand_init_repeatabl (g05kfc).\n%s\n",
              fail.message);
        exit_status = 1;
        goto END;
    }

    /* Set matrix size and principal dimension according to storage order */
    pdx = (order == Nag_ColMajor) ? n : 2;
    sdx = (order == Nag_ColMajor) ? 2 : n;

    /* Allocate arrays */
    if (!(x = NAG_ALLOC((pdx * sdx), double)) ||

```

```

        !(state = NAG_ALLOC(lstate, Integer))
    {
        printf("Allocation failure\n");
        exit_status = -1;
        goto END;
    }

    /* Initialize the generator to a repeatable sequence */
    nag_rand_init_repeatable(genid, subid, seed, lseed, state, &lstate, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_rand_init_repeatable (g05kfc).\n%s\n",
            fail.message);
        exit_status = 1;
        goto END;
    }

    /* Generate variates */
    nag_rand_bivariate_copula_frank(order, state, theta, n, x, pdx, sdx, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_rand_bivariate_copula_frank (g05rfc).\n"
            "%s\n", fail.message);
        exit_status = 1;
        goto END;
    }

    /* Display the results */
    printf("Uniform variates with copula joint distribution\n");
    for (i = 1; i <= n; i++) {
        printf(" %9.6f   %9.6f\n", X(i, 1), X(i, 2));
    }

END:
    NAG_FREE(x);
    NAG_FREE(state);

    return exit_status;
}

```

10.2 Program Data

None.

10.3 Program Results

nag_rand_bivariate_copula_frank (g05rfc) Example Program Results

Uniform variates with copula joint distribution

0.636373	0.141124
0.106480	0.896697
0.746035	0.184315
0.798270	0.125439
0.104592	0.998172
0.492451	0.690103
0.384260	0.625047
0.787070	0.165409
0.498187	0.529766
0.671703	0.290232
0.050537	0.955405
0.258030	0.818964
0.623806	0.301387
