

# NAG Library Routine Document

## G02BNF

**Note:** before using this routine, please read the Users' Note for your implementation to check the interpretation of *bold italicised* terms and other implementation-dependent details.

### 1 Purpose

G02BNF computes Kendall and/or Spearman nonparametric rank correlation coefficients for a set of data; the data array is overwritten with the ranks of the observations.

### 2 Specification

SUBROUTINE G02BNF (N, M, X, LDX, ITYPE, RR, LDRR, KWORKA, KWORKB, WORK1, &  
WORK2, IFAIL)

INTEGER N, M, LDX, ITYPE, LDRR, KWORKA(N), KWORKB(N), IFAIL  
REAL (KIND=nag\_wp) X(LDX,M), RR(LDRR,M), WORK1(M), WORK2(M)

### 3 Description

The input data consists of  $n$  observations for each of  $m$  variables, given as an array

$$[x_{ij}], \quad i = 1, 2, \dots, n (n \geq 2), j = 1, 2, \dots, m (m \geq 2),$$

where  $x_{ij}$  is the  $i$ th observation of the  $j$ th variable.

The quantities calculated are:

#### (a) Ranks

For a given variable,  $j$  say, each of the  $n$  observations,  $x_{1j}, x_{2j}, \dots, x_{nj}$ , has associated with it an additional number, the 'rank' of the observation, which indicates the magnitude of that observation relative to the magnitudes of the other  $n - 1$  observations on that same variable.

The smallest observation for variable  $j$  is assigned the rank 1, the second smallest observation for variable  $j$  the rank 2, the third smallest the rank 3, and so on until the largest observation for variable  $j$  is given the rank  $n$ .

If a number of cases all have the same value for the given variable,  $j$ , then they are each given an 'average' rank, e.g., if in attempting to assign the rank  $h + 1$ ,  $k$  observations were found to have the same value, then instead of giving them the ranks

$$h + 1, h + 2, \dots, h + k,$$

all  $k$  observations would be assigned the rank

$$\frac{2h + k + 1}{2}$$

and the next value in ascending order would be assigned the rank

$$h + k + 1.$$

The process is repeated for each of the  $m$  variables.

Let  $y_{ij}$  be the rank assigned to the observation  $x_{ij}$  when the  $j$ th variable is being ranked. The actual observations  $x_{ij}$  are replaced by the ranks  $y_{ij}$ .

## (b) Nonparametric rank correlation coefficients

## (i) Kendall's tau:

$$R_{jk} = \frac{\sum_{h=1}^n \sum_{i=1}^n \text{sign}(y_{hj} - y_{ij}) \text{sign}(y_{hk} - y_{ik})}{\sqrt{[n(n-1) - T_j][n(n-1) - T_k]}}, \quad j, k = 1, 2, \dots, m,$$

where  $\text{sign } u = 1$  if  $u > 0$ ,

$\text{sign } u = 0$  if  $u = 0$ ,

$\text{sign } u = -1$  if  $u < 0$ ,

and  $T_j = \sum t_j(t_j - 1)$ , where  $t_j$  is the number of ties of a particular value of variable  $j$ , and the summation is over all tied values of variable  $j$ .

## (ii) Spearman's:

$$R_{jk}^* = \frac{n(n^2 - 1) - 6 \sum_{i=1}^n (y_{ij} - y_{ik})^2 - \frac{1}{2}(T_j^* + T_k^*)}{\sqrt{[n(n^2 - 1) - T_j^*][n(n^2 - 1) - T_k^*]}}, \quad j, k = 1, 2, \dots, m,$$

where  $T_j^* = \sum t_j(t_j^2 - 1)$ ,  $t_j$  being the number of ties of a particular value of variable  $j$ , and the summation being over all tied values of variable  $j$ .

## 4 References

Siegel S (1956) *Non-parametric Statistics for the Behavioral Sciences* McGraw-Hill

## 5 Parameters

- 1: N – INTEGER *Input*  
*On entry:*  $n$ , the number of observations or cases.  
*Constraint:*  $N \geq 2$ .
- 2: M – INTEGER *Input*  
*On entry:*  $m$ , the number of variables.  
*Constraint:*  $M \geq 2$ .
- 3: X(LDX, M) – REAL (KIND=nag\_wp) array *Input/Output*  
*On entry:*  $X(i, j)$  must be set to  $x_{ij}$ , the value of the  $i$ th observation on the  $j$ th variable, for  $i = 1, 2, \dots, n$  and  $j = 1, 2, \dots, m$ .  
*On exit:*  $X(i, j)$  contains the rank  $y_{ij}$  of the observation  $x_{ij}$ , for  $i = 1, 2, \dots, n$  and  $j = 1, 2, \dots, m$ .
- 4: LDX – INTEGER *Input*  
*On entry:* the first dimension of the array X as declared in the (sub)program from which G02BNF is called.  
*Constraint:*  $LDX \geq N$ .

- 5: ITYPE – INTEGER *Input*  
*On entry:* the type of correlation coefficients which are to be calculated.  
 ITYPE = -1  
     Only Kendall's tau coefficients are calculated.  
 ITYPE = 0  
     Both Kendall's tau and Spearman's coefficients are calculated.  
 ITYPE = 1  
     Only Spearman's coefficients are calculated.  
*Constraint:* ITYPE = -1, 0 or 1.
- 6: RR(LDRR, M) – REAL (KIND=nag\_wp) array *Output*  
*On exit:* the requested correlation coefficients.  
 If only Kendall's tau coefficients are requested (ITYPE = -1), RR(*j*, *k*) contains Kendall's tau for the *j*th and *k*th variables.  
 If only Spearman's coefficients are requested (ITYPE = 1), RR(*j*, *k*) contains Spearman's rank correlation coefficient for the *j*th and *k*th variables.  
 If both Kendall's tau and Spearman's coefficients are requested (ITYPE = 0), the upper triangle of RR contains the Spearman coefficients and the lower triangle the Kendall coefficients. That is, for the *j*th and *k*th variables, where *j* is less than *k*, RR(*j*, *k*) contains the Spearman rank correlation coefficient, and RR(*k*, *j*) contains Kendall's tau, for *j* = 1, 2, ..., *m* and *k* = 1, 2, ..., *m*.  
 (Diagonal terms, RR(*j*, *j*), are unity for all three values of ITYPE.)
- 7: LDRR – INTEGER *Input*  
*On entry:* the first dimension of the array RR as declared in the (sub)program from which G02BNF is called.  
*Constraint:* LDRR ≥ M.
- 8: KWORKA(N) – INTEGER array *Workspace*  
 9: KWORKB(N) – INTEGER array *Workspace*  
 10: WORK1(M) – REAL (KIND=nag\_wp) array *Workspace*  
 11: WORK2(M) – REAL (KIND=nag\_wp) array *Workspace*
- 12: IFAIL – INTEGER *Input/Output*  
*On entry:* IFAIL must be set to 0, -1 or 1. If you are unfamiliar with this parameter you should refer to Section 3.3 in the Essential Introduction for details.  
 For environments where it might be inappropriate to halt program execution when an error is detected, the value -1 or 1 is recommended. If the output of error messages is undesirable, then the value 1 is recommended. Otherwise, if you are not familiar with this parameter, the recommended value is 0. **When the value -1 or 1 is used it is essential to test the value of IFAIL on exit.**  
*On exit:* IFAIL = 0 unless the routine detects an error or a warning has been flagged (see Section 6).

## 6 Error Indicators and Warnings

If on entry  $IFAIL = 0$  or  $-1$ , explanatory error messages are output on the current error message unit (as defined by X04AAF).

Errors or warnings detected by the routine:

$IFAIL = 1$

On entry,  $N < 2$ .

$IFAIL = 2$

On entry,  $M < 2$ .

$IFAIL = 3$

On entry,  $LDX < N$ ,  
or  $LDRR < M$ .

$IFAIL = 4$

On entry,  $ITYPE < -1$ ,  
or  $ITYPE > 1$ .

$IFAIL = -99$

An unexpected error has been triggered by this routine. Please contact NAG.  
See Section 3.8 in the Essential Introduction for further information.

$IFAIL = -399$

Your licence key may have expired or may not have been installed correctly.  
See Section 3.7 in the Essential Introduction for further information.

$IFAIL = -999$

Dynamic memory allocation failed.  
See Section 3.6 in the Essential Introduction for further information.

## 7 Accuracy

The method used is believed to be stable.

## 8 Parallelism and Performance

G02BNF 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 routine. Please also consult the Users' Note for your implementation for any additional implementation-specific information.

## 9 Further Comments

The time taken by G02BNF depends on  $n$  and  $m$ .

## 10 Example

This example reads in a set of data consisting of nine observations on each of three variables. The program then calculates and prints the rank of each observation, and both Kendall's tau and Spearman's rank correlation coefficients for all three variables.

### 10.1 Program Text

```

Program g02bnfe

!      G02BNF Example Program Text

!      Mark 25 Release. NAG Copyright 2014.

!      .. Use Statements ..
Use nag_library, Only: g02bnf, nag_wp
!      .. Implicit None Statement ..
Implicit None
!      .. Parameters ..
Integer, Parameter          :: nin = 5, nout = 6
!      .. Local Scalars ..
Integer                    :: i, ifail, itype, ldr, ldx, m, n
!      .. Local Arrays ..
Real (Kind=nag_wp), Allocatable :: rr(:,,:), work1(:), work2(:), x(:,,:)
Integer, Allocatable       :: kworka(:), kworkb(:)
!      .. Executable Statements ..
Write (nout,*) 'G02BNF Example Program Results'
Write (nout,*)

!      Skip heading in data file
Read (nin,*)

!      Read in the problem size
Read (nin,*) n, m, itype

      ldr = m
      ldx = n
      Allocate (rr(ldr,m),work1(m),work2(m),x(ldx,m),kworka(n),kworkb(n))

!      Read in data
Read (nin,*)(x(i,1:m),i=1,n)

!      Display data
Write (nout,99999) 'Number of variables (columns) =', m
Write (nout,99999) 'Number of cases      (rows)   =', n
Write (nout,*)
Write (nout,*) 'Data matrix is:-'
Write (nout,*)
Write (nout,99998)(i,i=1,m)
Write (nout,99997)(i,x(i,1:m),i=1,n)
Write (nout,*)

!      Calculate correlation coefficients
ifail = 0
Call g02bnf(n,m,x,ldx,itype,rr,ldr,kworka,kworkb,work1,work2,ifail)

!      Display results
Write (nout,*) 'Matrix of ranks:-'
Write (nout,99998)(i,i=1,m)
Write (nout,99997)(i,x(i,1:m),i=1,n)
Write (nout,*)
Write (nout,*) 'Matrix of rank correlation coefficients:'
Write (nout,*) 'Upper triangle -- Spearman''s'
Write (nout,*) 'Lower triangle -- Kendall''s tau'
Write (nout,*)
Write (nout,99998)(i,i=1,m)
Write (nout,99997)(i,rr(i,1:m),i=1,m)

```

```

99999 Format (1X,A,I5)
99998 Format (1X,3I12)
99997 Format (1X,I3,3F12.4)
      End Program g02bnfe

```

## 10.2 Program Data

```

G02BNF Example Program Data
9  3  0      :: N, M, ITYPE
 1.70  1.00  0.50
 2.80  4.00  3.00
 0.60  6.00  2.50
 1.80  9.00  6.00
 0.99  4.00  2.50
 1.40  2.00  5.50
 1.80  9.00  7.50
 2.50  7.00  0.00
 0.99  5.00  3.00      :: End of X

```

## 10.3 Program Results

G02BNF Example Program Results

```

Number of variables (columns) = 3
Number of cases (rows) = 9

```

Data matrix is:-

	1	2	3
1	1.7000	1.0000	0.5000
2	2.8000	4.0000	3.0000
3	0.6000	6.0000	2.5000
4	1.8000	9.0000	6.0000
5	0.9900	4.0000	2.5000
6	1.4000	2.0000	5.5000
7	1.8000	9.0000	7.5000
8	2.5000	7.0000	0.0000
9	0.9900	5.0000	3.0000

Matrix of ranks:-

	1	2	3
1	5.0000	1.0000	2.0000
2	9.0000	3.5000	5.5000
3	1.0000	6.0000	3.5000
4	6.5000	8.5000	8.0000
5	2.5000	3.5000	3.5000
6	4.0000	2.0000	7.0000
7	6.5000	8.5000	9.0000
8	8.0000	7.0000	1.0000
9	2.5000	5.0000	5.5000

Matrix of rank correlation coefficients:

Upper triangle -- Spearman's  
 Lower triangle -- Kendall's tau

	1	2	3
1	1.0000	0.2246	0.1186
2	0.0294	1.0000	0.3814
3	0.1176	0.2353	1.0000