

NAG C Library Function Document

nag_tsa_multi_auto_corr_part (g13dbc)

1 Purpose

nag_tsa_multi_auto_corr_part (g13dbc) calculates the multivariate partial autocorrelation function of a multivariate time series.

2 Specification

```
void nag_tsa_multi_auto_corr_part (const double c0[], const double c[], Integer ns,
    Integer nl, Integer nk, double p[], double *v0, double v[], double d[],
    double db[], double w[], double wb[], Integer *nvp, NagError *fail)
```

3 Description

The input is a set of lagged autocovariance matrices $C_0, C_1, C_2, \dots, C_m$. These will generally be sample values such as are obtained from a multivariate time series using nag_tsa_multi_cross_corr (g13dmc).

The main calculation is the recursive determination of the coefficients in the finite lag (forward) prediction equation

$$x_t = \Phi_{l,1}x_{t-1} + \dots + \Phi_{l,l}x_{t-l} + e_{l,t}$$

and the associated backward prediction equation

$$x_{t-l-1} = \Psi_{l,1}x_{t-l} + \dots + \Psi_{l,l}x_{t-1} + f_{l,t}$$

together with the covariance matrices D_l of $e_{l,t}$ and G_l of $f_{l,t}$.

The recursive cycle, by which the order of the prediction equation is extended from l to $l+1$, is to calculate

$$M_{l+1} = C'_{l+1} - \Phi_{l,1}C'_l - \dots - \Phi_{l,l}C'_1 \quad (1)$$

then $\Phi_{l+1,l+1} = M_{l+1}D_l^{-1}$, $\Psi_{l+1,l+1} = M'_{l+1}G_l^{-1}$

from which

$$\Phi_{l+1,j} = \Phi_{l,j} - \Phi_{l+1,l+1}\Psi_{l,l+1-j}, \quad j = 1, 2, \dots, l \quad (2)$$

and

$$\Psi_{l+1,j} = \Psi_{l,j} - \Psi_{l+1,l+1}\Phi_{l,l+1-j}, \quad j = 1, 2, \dots, l. \quad (3)$$

Finally, $D_{l+1} = D_l - M_{l+1}\Phi'_{l+1,l+1}$, and $G_{l+1} = G_l - M'_{l+1}\Psi'_{l+1,l+1}$.

(Here ' denotes the transpose of a matrix.)

The cycle is initialised by taking (for $l = 0$)

$$D_0 = G_0 = C_0.$$

In the step from $l = 0$ to 1, the above equations contain redundant terms and simplify. Thus (1) becomes $M_1 = C'_1$ and neither (2) or (3) are needed.

Quantities useful in assessing the effectiveness of the prediction equation are generalized variance ratios

$$v_l = \det D_l / \det C_0, \quad l = 1, 2, \dots$$

and multiple squared partial autocorrelations

$$p_l^2 = 1 - v_l/v_{l-1}.$$

4 References

Akaike H (1971) Autoregressive model fitting for control *Ann. Inst. Statist. Math.* **23** 163–180

Whittle P (1963) On the fitting of multivariate autoregressions and the approximate canonical factorization of a spectral density matrix *Biometrika* **50** 129–134

5 Parameters

- 1: **c0**[*dim*] – const double *Input*
Note: the dimension, *dim*, of the array **c0** must be at least **ns** × **ns**.
On entry: contains the zero lag cross-covariances between the **ns** series as returned by nag_tsa_multi_cross_corr (g13dmc). (**c0** is assumed to be symmetric, upper triangle only is used.)
- 2: **c**[*dim*] – const double *Input*
Note: the dimension, *dim*, of the array **c** must be at least **ns** × **ns** × **nl**.
On entry: the *k* cross-covariances as returned by nag_tsa_multi_cross_corr (g13dmc).
- 3: **ns** – Integer *Input*
On entry: the number of time series, *k*, whose cross-covariances are supplied in **c** and **c0**.
Constraint: **ns** ≥ 1.
- 4: **nl** – Integer *Input*
On entry: the maximum lag, *m*, for which cross-covariances are supplied in **c**.
Constraint: **nl** ≥ 1.
- 5: **nk** – Integer *Input*
On entry: the number of lags to which partial auto-correlations are to be calculated.
Constraint: 1 ≤ **nk** ≤ **nl**.
- 6: **p**[**nk**] – double *Output*
On exit: the multiple squared partial autocorrelations from lags 1 to **nvp**; that is, **p**[*l* – 1] contains p_l^2 , for *l* = 1, 2, ..., **nvp**. For lags **nvp** + 1 to **nk** the elements of **p** are set to zero.
- 7: **v0** – double * *Output*
On exit: the lag zero prediction error variance (equal to the determinant of **c0**).
- 8: **v**[**nk**] – double *Output*
On exit: the prediction error variance ratios from lags 1 to **nvp**; that is, **v**[*l* – 1] contains v_l , for *l* = 1, 2, ..., **nvp**. For lags **nvp** + 1 to **nk** the elements of **v** are set to zero.
- 9: **d**[*dim*] – double *Output*
Note: the dimension, *dim*, of the array **d** must be at least **ns** × **ns** × **nk**.
On exit: the prediction error variance matrices at lags 1 to **nvp**, **d**[(*l* – 1) k^2 + (*j* – 1)*k* + *i* – 1] contains the (*i*, *j*)th prediction error covariance of series *i* and series *j* at lag *l*. Series *j* leads series *i*.
- 10: **db**[*dim*] – double *Output*
Note: the dimension, *dim*, of the array **db** must be at least **ns** × **ns**.

On exit: the backward prediction error variance matrix at lag **nvp**, **db** $[(j-1)k+i-1]$ contains the backward prediction error covariance of series i and series j .

11: **w** $[dim]$ – double *Output*

Note: the dimension, dim , of the array **w** must be at least $ns \times ns \times nk$.

On exit: the prediction coefficient matrices at lags 1 to **nvp**, **w** $[(l-1)k^2+(j-1)k+i-1]$ contains the j th prediction coefficient of series i at lag l (i.e., the (i,j) th element of $\Phi_{L,l}$).

12: **wb** $[dim]$ – double *Output*

Note: the dimension, dim , of the array **wb** must be at least $ns \times ns \times nk$.

On exit: the backward prediction coefficient matrices at lags 1 to **nvp**, **wb** $[(l-1)k^2+(j-1)k+i-1]$ contains the j th backward prediction coefficient of series i at lag l (i.e., the (i,j) th element of $\Psi_{L,l}$).

13: **nvp** – Integer * *Output*

On exit: the maximum lag, L , for which calculation of **p**, **v**, **d**, **db**, **w** and **wb** was successful. If the routine completes successfully **nvp** will equal **nk**.

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

The NAG error parameter (see the Essential Introduction).

6 Error Indicators and Warnings

NE_INT

On entry, **ns** = $\langle value \rangle$.

Constraint: **ns** ≥ 1 .

On entry, **nk** = $\langle value \rangle$.

Constraint: **nk** ≥ 1 .

On entry, **nl** = $\langle value \rangle$.

Constraint: **nl** ≥ 1 .

NE_INT_2

On entry, **nk** > **nl**: **nk** = $\langle value \rangle$, **nl** = $\langle value \rangle$.

NE_POS_DEF

At lag **nvp** + 1 $\leq nk$, **d** is not positive-definite, **nvp** = $\langle value \rangle$, **nk** = $\langle value \rangle$.

c0 is not positive-definite.

NE_ALLOC_FAIL

Memory allocation failed.

NE_BAD_PARAM

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

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 consult NAG for assistance.

7 Accuracy

The conditioning of the problem depends on the prediction error variance ratios. Very small values of these may indicate loss of accuracy in the computations.

8 Further Comments

The time taken by the routine is roughly proportional to $\mathbf{nk}^2 \times \mathbf{ns}^3$.

If sample autocorrelation matrices are used as input, then the output will be relevant to the original series scaled by their standard deviations. If these autocorrelation matrices are produced by `nag_tsa_multi_cross_corr (g13dmc)`, the user must replace the diagonal elements of C_0 (otherwise used to hold the series variances) by 1.

9 Example

The example program reads the autocovariance matrices for four series from lag 0 to 5. It calls `nag_tsa_multi_auto_corr_part (g13dbc)` to calculate the multivariate partial autocorrelation function and other related matrices of statistics up to lag 3. It prints the results.

9.1 Program Text

```
/* nag_tsa_multi_auto_corr_part (g13dbc) Example Program.
 *
 * Copyright 2002 Numerical Algorithms Group.
 *
 * Mark 7, 2002.
 */

#include <stdio.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagg13.h>

int main(void)
{
    /* Scalars */
    double v0;
    Integer exit_status, il, i, j, j1, k, nk, nl, ns, nvp,
        pdc0, pddb;
    NagError fail;
    Nag_OrderType order;

    /* Arrays */
    double *c0 = 0, *c = 0, *d = 0, *db = 0, *p = 0, *v = 0, *w = 0,
        *wb = 0;

#define C(I,J,K) c[((K-1)*ns + (J-1))*ns + I - 1]
#define D(I,J,K) d[((K-1)*ns + (J-1))*ns + I - 1]
#define W(I,J,K) w[((K-1)*ns + (J-1))*ns + I - 1]
#define WB(I,J,K) wb[((K-1)*ns + (J-1))*ns + I - 1]

#ifdef NAG_COLUMN_MAJOR
#define C0(I,J) c0[(J-1)*pdc0 + I - 1]
#define DB(I,J) db[(J-1)*pddb + I - 1]
    order = Nag_ColMajor;
#else
#define C0(I,J) c0[(I-1)*pdc0 + J - 1]
#define DB(I,J) db[(I-1)*pddb + J - 1]
    order = Nag_RowMajor;
#endif

    INIT_FAIL(fail);
    exit_status = 0;

    Vprintf("g13dbc Example Program Results\n");
```

```

/* Skip heading in data file */
Vscanf("%*[\n] ");

/* Read series length, and numbers of lags */
Vscanf("%ld%ld%ld%*[\n] ", &ns, &nl, &nk);

if (ns > 0 && nl > 0 && nk > 0)
{
    /* Allocate arrays */
    if ( !(c0 = NAG_ALLOC(ns * ns, double)) ||
        !(c = NAG_ALLOC(ns * ns * nl, double)) ||
        !(d = NAG_ALLOC(ns * ns * nk, double)) ||
        !(db = NAG_ALLOC(ns * ns, double)) ||
        !(p = NAG_ALLOC(nk, double)) ||
        !(v = NAG_ALLOC(nk, double)) ||
        !(w = NAG_ALLOC(ns * ns * nk, double)) ||
        !(wb = NAG_ALLOC(ns * ns * nk, double)) )
    {
        Vprintf("Allocation failure\n");
        exit_status = -1;
        goto END;
    }

    pdc0 = ns;
    pddb = ns;

    /* Read autocovariances */
    for (i = 1; i <= ns; ++i)
    {
        for (j = 1; j <= ns; ++j)
            Vscanf("%lf", &c0(i,j));
    }
    Vscanf("%*[\n] ");

    for (k = 1; k <= nl; ++k)
    {
        for (i = 1; i <= ns; ++i)
        {
            for (j = 1; j <= ns; ++j)
                Vscanf("%lf", &c(i,j,k));
        }
    }
    Vscanf("%*[\n] ");

    /* Call routine to calculate multivariate partial
       autocorrelation function */

    g13dbc(c0, c, ns, nl, nk, p, &v0, v, d, db, w, wb,
           &nvp, &fail);
    if (fail.code != NE_NOERROR)
    {
        Vprintf("Error from g13dbc.\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }

    if (fail.code == NE_NOERROR || fail.code == NE_POS_DEF)
    {
        Vprintf("\n");
        Vprintf("Number of valid parameters =%10ld\n", nv);

        Vprintf("\n");
        Vprintf("Multivariate partial autocorrelations\n");

        for (i1 = 1; i1 <= nk; ++i1)
        {
            Vprintf("%13.5f", p[i1-1]);
            if (i1 % 5 == 0 || i1 == nk)
                Vprintf("\n");
        }
    }
}

```

```

Vprintf("\n");
Vprintf("Zero lag predictor error variance determinant\n");
Vprintf("followed by error variance ratios\n");
Vprintf("%12.5f", v0);

for (i1 = 1; i1 <= nk; ++i1)
{
    Vprintf("%13.5f", v[i1-1]);
    if (i1 % 5 == 0 || i1 == nk)
        Vprintf("\n");
}

Vprintf("\n");
Vprintf("Prediction error variances\n");
Vprintf("\n");

for (k = 1; k <= nk; ++k)
{
    Vprintf("Lag =%5ld\n", k);
    for (i = 1; i <= ns; ++i)
    {
        for (j1 = 1; j1 <= ns; ++j1)
        {
            Vprintf("%13.5f", D(i,j1,k));
            if (j1 % 5 == 0 || j1 == ns)
                Vprintf("\n");
        }
    }
    Vprintf("\n");
}

Vprintf("Last backward prediction error variances\n");
Vprintf("\n");
Vprintf("Lag =%5ld\n", nvp);

for (i = 1; i <= ns; ++i)
{
    for (j1 = 1; j1 <= ns; ++j1)
    {
        Vprintf("%13.5f", DB(i,j1));
        if (j1 % 5 == 0 || j1 == ns)
            Vprintf("\n");
    }
}

Vprintf("\n");
Vprintf("Prediction coefficients\n");
Vprintf("\n");

for (k = 1; k <= nk; ++k)
{
    Vprintf("Lag =%5ld\n", k);
    for (i = 1; i <= ns; ++i)
    {
        for (j1 = 1; j1 <= ns; ++j1)
        {
            Vprintf("%13.5f", W(i,j1,k));
            if (j1 % 5 == 0 || j1 == ns)
                Vprintf("\n");
        }
    }
    Vprintf("\n");
}

Vprintf("Backward prediction coefficients\n");
Vprintf("\n");

for (k = 1; k <= nk; ++k)
{
    Vprintf("Lag =%5ld\n", k);
    for (i = 1; i <= ns; ++i)

```

```

        {
            for (j1 = 1; j1 <= ns; ++j1)
            {
                Vprintf("%13.5f", WB(i,j1, k));
                if (j1 % 5 == 0 || j1 == ns)
                    Vprintf("\n");
            }
        }
        Vprintf("\n");
    }
}

END:
if (c0) NAG_FREE(c0);
if (c) NAG_FREE(c);
if (d) NAG_FREE(d);
if (db) NAG_FREE(db);
if (p) NAG_FREE(p);
if (v) NAG_FREE(v);
if (w) NAG_FREE(w);
if (wb) NAG_FREE(wb);

return exit_status;
}

```

9.2 Program Data

g13dbc Example Program Data

4	5	3		
.10900E-01	-.77917E-02	.13004E-02	.12654E-02	
-.77917E-02	.57040E-01	.24180E-02	.14409E-01	
.13004E-02	.24180E-02	.43960E-01	-.21421E-01	
.12654E-02	.14409E-01	-.21421E-01	.72289E-01	
.45889E-02	.46510E-03	-.13275E-03	.77531E-02	
-.24419E-02	-.11667E-01	-.21956E-01	-.45803E-02	
.11080E-02	-.80479E-02	.13621E-01	-.85868E-02	
-.50614E-03	.14045E-01	-.10087E-02	.12269E-01	
.18652E-02	-.64389E-02	.88307E-02	-.24808E-02	
-.11865E-01	.72367E-02	-.19802E-01	.59069E-02	
-.80307E-02	.14306E-01	.14546E-01	.13510E-01	
-.21791E-02	-.29528E-01	-.15887E-01	.88308E-03	
-.80550E-04	-.37759E-02	.75463E-02	-.42276E-02	
.41447E-02	-.37987E-02	.19332E-02	-.17564E-01	
-.10582E-01	.67733E-02	.69832E-02	.61747E-02	
.41352E-02	-.16013E-01	.17043E-01	-.13412E-01	
.76079E-03	-.10134E-02	.11870E-01	-.41651E-02	
.36014E-02	-.36375E-02	-.25571E-01	.50218E-02	
-.13924E-01	.11718E-01	-.59088E-02	.59297E-02	
.10739E-01	-.14571E-01	.13816E-01	-.12588E-01	
-.64365E-03	-.44556E-02	.51334E-02	.71587E-03	
.63617E-02	.15217E-03	.27270E-02	-.22261E-02	
-.85855E-02	.14468E-02	-.28698E-02	.44384E-02	
.68339E-02	-.21790E-02	.13759E-01	.28217E-03	

9.3 Program Results

g13dbc Example Program Results

Number of valid parameters = 3

Multivariate partial autocorrelations
 0.64498 0.92669 0.84300

Zero lag predictor error variance determinant
 followed by error variance ratios
 0.00000 0.35502 0.02603 0.00409

Prediction error variances

```
Lag =      1
  0.00811    -0.00511    0.00159    -0.00029
 -0.00511    0.04089    0.00757    0.01843
  0.00159    0.00757    0.03834    -0.01894
 -0.00029    0.01843   -0.01894    0.06760
```

```
Lag =      2
  0.00354    -0.00087   -0.00075   -0.00105
 -0.00087    0.01946    0.00535    0.00566
 -0.00075    0.00535    0.01900   -0.01071
 -0.00105    0.00566   -0.01071    0.04058
```

```
Lag =      3
  0.00301    -0.00087   -0.00054    0.00065
 -0.00087    0.01824    0.00872    0.00247
 -0.00054    0.00872    0.00935   -0.00216
  0.00065    0.00247   -0.00216    0.02254
```

Last backward prediction error variances

```
Lag =      3
  0.00331    -0.00392   -0.00106    0.00592
 -0.00392    0.01890    0.00348   -0.00330
 -0.00106    0.00348    0.01003   -0.01054
  0.00592   -0.00330   -0.01054    0.03336
```

Prediction coefficients

```
Lag =      1
  0.81861    0.23399   -0.17097    0.09256
  0.06738   -0.48720   -0.14064    0.04295
  0.15036    0.11924   -0.36725   -0.42092
 -0.70971    0.02998    0.59779    0.34610
```

```
Lag =      2
 -0.34049   -0.13370    0.40610   -0.02183
 -1.27574   -0.13591   -0.65779   -0.11267
 -0.45439    0.19379    0.63420    0.33920
 -0.43237   -0.54848   -0.62897    0.16670
```

```
Lag =      3
  0.16437    0.13858    0.01290    0.03463
  0.39291    0.07407   -0.08802   -0.15361
 -1.29240   -0.24489    0.30235    0.39442
  0.89768   -0.39040    0.25151   -0.28304
```

Backward prediction coefficients

```
Lag =      1
  0.41541    0.06149    0.15319    0.05079
  0.12370   -0.26471   -0.22721    0.48503
 -0.86933   -0.47373    0.37924    0.13814
  1.30779   -0.09178   -1.45398   -0.21967
```

```
Lag =      2
 -0.06740   -0.12255   -0.13673   -0.09730
 -1.24801    0.03090    0.51706   -0.28925
  0.98045   -0.20194    0.16307   -0.10869
 -1.68389   -0.74589    0.52900    0.41580
```

```
Lag =      3
  0.03794    0.10491   -0.21635    0.08015
  0.75392    0.22603   -0.25661   -0.47450
 -0.00338    0.05636   -0.08818    0.12723
  0.55022   -0.41232    0.71649   -0.14565
```