

NAG Library Function Document

nag_zhfrk (f16zqc)

1 Purpose

nag_zhfrk (f16zqc) performs one of the Hermitian rank- k update operations

$$C \leftarrow \alpha AA^H + \beta C \quad \text{or} \quad C \leftarrow \alpha A^H A + \beta C,$$

where A is a complex matrix, C is an n by n complex Hermitian matrix stored in Rectangular Full Packed (RFP) format, and α and β are real scalars.

2 Specification

```
#include <nag.h>
#include <nagf16.h>

void nag_zhfrk (Nag_OrderType order, Nag_RFP_Store transr,
               Nag_UploType uplo, Nag_TransType trans, Integer n, Integer k,
               double alpha, const Complex a[], Integer pda, double beta, Complex cr[],
               NagError *fail)
```

3 Description

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$$C \leftarrow \alpha AA^H + \beta C \quad \text{or} \quad C \leftarrow \alpha A^H A + \beta C,$$

where A is a complex matrix, C is an n by n complex Hermitian matrix stored in Rectangular Full Packed (RFP) format, and α and β are real scalars. The RFP storage format is described in Section 3.3.3 in the f07 Chapter Introduction.

If $n = 0$ or if $\beta = 1.0$ and either $k = 0$ or $\alpha = 0.0$ then nag_zhfrk (f16zqc) returns immediately. If $\beta = 0.0$ and either $k = 0$ or $\alpha = 0.0$ then C is set to the zero matrix.

4 References

Gustavson F G, Waśniewski J, Dongarra J J and Langou J (2010) Rectangular full packed format for Cholesky's algorithm: factorization, solution, and inversion *ACM Trans. Math. Software* **37**, 2

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: **transr** – Nag_RFP_Store *Input*

On entry: specifies whether the normal RFP representation of C or its conjugate transpose is stored.

transr = Nag_RFP_Normal

The matrix C is stored in normal RFP format.

- transr** = Nag_RFP_ConjTrans
The conjugate transpose of the RFP representation of the matrix C is stored.
Constraint: **transr** = Nag_RFP_Normal or Nag_RFP_ConjTrans.
- 3: **uplo** – Nag_UploType *Input*
On entry: specifies whether the upper or lower triangular part of C is stored in RFP format.
uplo = Nag_Upper
The upper triangular part of C is stored in RFP format.
uplo = Nag_Lower
The lower triangular part of C is stored in RFP format.
Constraint: **uplo** = Nag_Upper or Nag_Lower.
- 4: **trans** – Nag_TransType *Input*
On entry: specifies the operation to be performed.
trans = Nag_NoTrans
 $C \leftarrow \alpha AA^H + \beta C.$
trans = Nag_ConjTrans
 $C \leftarrow \alpha A^H A + \beta C.$
Constraint: **trans** = Nag_NoTrans or Nag_ConjTrans.
- 5: **n** – Integer *Input*
On entry: n , the order of the matrix C .
Constraint: $n \geq 0$.
- 6: **k** – Integer *Input*
On entry: k , the number of columns of A if **trans** = Nag_NoTrans, or the number of rows of A if **trans** = Nag_ConjTrans.
Constraint: $k \geq 0$.
- 7: **alpha** – double *Input*
On entry: the scalar α .
- 8: **a**[*dim*] – const Complex *Input*
Note: the dimension, *dim*, of the array **a** must be at least
 $\max(1, \mathbf{pda} \times \mathbf{k})$ when **trans** = Nag_NoTrans and **order** = Nag_ColMajor;
 $\max(1, \mathbf{n} \times \mathbf{pda})$ when **trans** = Nag_NoTrans and **order** = Nag_RowMajor;
 $\max(1, \mathbf{pda} \times \mathbf{n})$ when **trans** = Nag_ConjTrans and **order** = Nag_ColMajor;
 $\max(1, \mathbf{k} \times \mathbf{pda})$ when **trans** = Nag_ConjTrans and **order** = Nag_RowMajor.
On entry: the matrix A ; A is n by k if **trans** = Nag_NoTrans, or k by n if **trans** = Nag_ConjTrans. If **alpha** = 0.0, **a** is not referenced.
- 9: **pda** – Integer *Input*
On entry: the stride separating row or column elements (depending on the value of **order**) in the array **a**.

Constraints:

```

if order = Nag_ColMajor,
    if trans = Nag_NoTrans, pda ≥ max(1, n);
    if trans = Nag_ConjTrans, pda ≥ max(1, k);
if order = Nag_RowMajor,
    if trans = Nag_NoTrans, pda ≥ max(1, k);
    if trans = Nag_ConjTrans, pda ≥ max(1, n)..

```

10: **beta** – double *Input*

On entry: the scalar β .

11: **cr**[$\mathbf{n} \times (\mathbf{n} + 1)/2$] – Complex *Input/Output*

On entry: the upper or lower triangular part (as specified by **uplo**) of the n by n Hermitian matrix C , stored in RFP format (as specified by **transr**). The storage format is described in detail in Section 3.3.3 in the f07 Chapter Introduction. If $\beta = 0.0$, **cr** need not be set on entry.

On exit: the updated matrix C , that is its upper or lower triangular part stored in RFP format.

12: **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_ENUM_INT_2

On entry, **trans** = $\langle value \rangle$, **k** = $\langle value \rangle$, **pda** = $\langle value \rangle$.

Constraint: if **trans** = Nag_ConjTrans, **pda** ≥ max(1, **k**).

On entry, **trans** = $\langle value \rangle$, **k** = $\langle value \rangle$, **pda** = $\langle value \rangle$.

Constraint: if **trans** = Nag_NoTrans, **pda** ≥ max(1, **k**).

On entry, **trans** = $\langle value \rangle$, **n** = $\langle value \rangle$, **pda** = $\langle value \rangle$.

Constraint: if **trans** = Nag_ConjTrans, **pda** ≥ max(1, **n**).

On entry, **trans** = $\langle value \rangle$, **n** = $\langle value \rangle$, **pda** = $\langle value \rangle$.

Constraint: if **trans** = Nag_NoTrans, **pda** ≥ max(1, **n**).

NE_INT

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

Constraint: **k** ≥ 0.

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

Constraint: **n** ≥ 0.

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_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_zhfrk (f16zqc) makes calls to BLAS and/or LAPACK routines, which may be threaded within the vendor library used by this implementation. Consult the documentation for the vendor library for further information.

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

None.

10 Example

This example reads in the lower triangular part of a symmetric matrix C which it converts to RFP format. It also reads in α , β and a 4 by 3 matrix A and then performs the Hermitian rank-3 update $C \leftarrow \alpha AA^H + \beta C$.

10.1 Program Text

```
/* nag_zhfrk (f16zqc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */

#include <nag.h>
#include <nag_stdlib.h>
#include <nagf01.h>
#include <nagf16.h>
#include <nagx04.h>

int main(void)
{
    /* Scalars */
    Integer exit_status = 0;
    double alpha, beta;
    Integer i, j, k, n, pda, pdc;
    /* Arrays */
    Complex *a = 0, *c = 0, *cr = 0;
    char nag_enum_arg[40];
    /* Nag Types */
    Nag_OrderType order;
    Nag_RFP_Store transr;
    Nag_UploType uplo;
    Nag_MatrixType matrix;
    Nag_TransType trans;
```

```

NagError fail;

INIT_FAIL(fail);

printf("nag_zhfrk (f16zqc) Example Program Results\n");
/* Skip heading in data file */
#ifdef _WIN32
scanf_s("%*[\n] ");
#else
scanf("%*[\n] ");
#endif
#ifdef _WIN32
scanf_s("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &n, &k);
#else
scanf("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &n, &k);
#endif
pdc = n;

#ifdef NAG_COLUMN_MAJOR
order = Nag_ColMajor;
pda = n;
#define C(I, J) c[(J-1)*pdc + I-1]
#define A(I, J) a[(J-1)*pda + I-1]
#else
order = Nag_RowMajor;
pda = k;
#define C(I, J) c[(I-1)*pdc + J-1]
#define A(I, J) a[(I-1)*pda + J-1]
#endif

if (!(c = NAG_ALLOC(pdc * n, Complex)) ||
    !(cr = NAG_ALLOC((n * (n + 1)) / 2, Complex)) ||
    !(a = NAG_ALLOC(n * k, Complex)))
{
printf("Allocation failure\n");
exit_status = -1;
goto END;
}
/* Nag_RFP_Store */
#ifdef _WIN32
scanf_s("%39s ", nag_enum_arg, (unsigned)_countof(nag_enum_arg));
#else
scanf("%39s ", nag_enum_arg);
#endif
transr = (Nag_RFP_Store) nag_enum_name_to_value(nag_enum_arg);
/* Nag_UploType */
#ifdef _WIN32
scanf_s("%39s ", nag_enum_arg, (unsigned)_countof(nag_enum_arg));
#else
scanf("%39s ", nag_enum_arg);
#endif
uplo = (Nag_UploType) nag_enum_name_to_value(nag_enum_arg);
/* Nag_TransType */
#ifdef _WIN32
scanf_s("%39s %*[\n] ", nag_enum_arg, (unsigned)_countof(nag_enum_arg));
#else
scanf("%39s %*[\n] ", nag_enum_arg);
#endif
trans = (Nag_TransType) nag_enum_name_to_value(nag_enum_arg);
#ifdef _WIN32
scanf_s("%lf%lf%*[\n] ", &alpha, &beta);
#else
scanf("%lf%lf%*[\n] ", &alpha, &beta);
#endif
/* Read upper or lower triangle of matrix C from data file */
if (uplo == Nag_Lower) {
for (i = 1; i <= n; i++) {
for (j = 1; j <= i; j++) {
#ifdef _WIN32
scanf_s(" ( %lf , %lf ) ", &C(i, j).re, &C(i, j).im);
#else

```

```

        scanf(" ( %lf , %lf ) ", &C(i, j).re, &C(i, j).im);
#endif
    }
}
else {
    for (i = 1; i <= n; i++) {
        for (j = i; j <= n; j++) {
#ifdef _WIN32
            scanf_s(" ( %lf , %lf ) ", &C(i, j).re, &C(i, j).im);
#else
            scanf(" ( %lf , %lf ) ", &C(i, j).re, &C(i, j).im);
#endif
        }
    }
#ifdef _WIN32
    scanf_s("%*[^\\n] ");
#else
    scanf("%*[^\\n] ");
#endif

    /* Read matrix A from data file */
    for (i = 1; i <= n; i++) {
        for (j = 1; j <= k; j++) {
#ifdef _WIN32
            scanf_s(" ( %lf , %lf ) ", &A(i, j).re, &A(i, j).im);
#else
            scanf(" ( %lf , %lf ) ", &A(i, j).re, &A(i, j).im);
#endif
        }
    }

    /* Convert Hermitian matrix C from full triangular storage to rectangular full
     * packed storage (in cr) using nag_ztrttf (f01vfc).
     */
    nag_ztrttf(order, transr, uplo, n, c, pdc, cr, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_ztrttf (f01vfc).\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }

    printf("\\n");
    /* Perform the rank-k update of Hermitian matrix C by complex matrix A
     * using nag_zhfrk (f16zqc).
     */
    nag_zhfrk(order, transr, uplo, trans, n, k, alpha, a, pda, beta, cr, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_zhfrk (f16zqc).\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }

    /* Convert C back from rectangular full packed (cr) to standard triangular
     * storage format (c) using nag_zftttr (f01vhc).
     */
    nag_zftttr(order, transr, uplo, n, cr, c, pdc, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_zftttr (f01vhc).\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }

    matrix = (uplo == Nag_Upper ? Nag_UpperMatrix : Nag_LowerMatrix);

    /* Print out the result, stored in the lower triangle of matrix C using
     * the easy-to-use print routine nag_gen_cmplx_mat_print (x04dac).
     */
    fflush(stdout);
    nag_gen_cmplx_mat_print(order, matrix, Nag_NonUnitDiag, n, n, c, pdc,

```

```

                                "The Solution", 0, &fail);
if (fail.code != NE_NOERROR) {
    printf("Error from nag_gen_complx_mat_print (x04dac).\n%s\n",
          fail.message);
    exit_status = 1;
}
END:
NAG_FREE(a);
NAG_FREE(c);
NAG_FREE(cr);
return exit_status;
}

```

10.2 Program Data

```

nag_zhfrk (f16zqc) Example Program Data
4 3                                : n, k
Nag_RFP_Normal Nag_Lower Nag_NoTrans : transr, uplo, trans
2.21 2.89                          : alpha, beta

(1.0,3.0)
(2.0,2.0) (3.0,3.0)
(4.0,4.0) (4.0,4.0) (5.0,5.0)
(5.0,5.0) (5.0,6.0) (6.0,6.0) (6.0,6.0) : matrix C

( 3.21, 1.32) ( 2.31, 0.25) ( 1.65, 1.87)
( 0.32,-1.55) ( 1.80, 1.88) ( 2.05,-0.89)
( 5.25,-2.95) (-1.95,-3.80) ( 1.58,-2.69)
(-2.90,-3.04) (-1.11,-0.66) (-0.59, 0.80) : matrix A

```

10.3 Program Results

```

nag_zhfrk (f16zqc) Example Program Results

The Solution
      1          2          3          4
1    55.1885
    0.0000

2    17.5536    40.2153
   -9.2637     0.0000

3    22.7883    14.2818    156.4204
   -59.3437    11.3638     -0.0000

4   -19.8678    11.4084     7.0222    62.2194
     3.9432     9.7064   -44.0297    -0.0000

```
