NAG Library Function Document

nag_zhbmv (f16sdc)

1 Purpose

nag_zhbmv (f16sdc) performs matrix-vector multiplication for a complex Hermitian band matrix.

2 Specification

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

```
void nag_zhbmv (Nag_OrderType order, Nag_UploType uplo, Integer n, Integer k,
     Complex alpha, const Complex ab[], Integer pdab, const Complex x[],
     Integer incx, Complex beta, Complex y[], Integer incy, NagError *fail)
```

3 Description

nag_zhbmv (f16sdc) performs the matrix-vector operation

$$y \leftarrow \alpha A x + \beta y,$$

where A is an n by n complex Hermitian band matrix with k subdiagonals and k superdiagonals, x and y are n-element complex vectors, and α and β are complex scalars.

4 References

Basic Linear Algebra Subprograms Technical (BLAST) Forum (2001) *Basic Linear Algebra Subprograms Technical (BLAST) Forum Standard* University of Tennessee, Knoxville, Tennessee http://www.netlib.org/blas/blast-forum/blas-report.pdf

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 3.2.1.3 in the Essential Introduction for a more detailed explanation of the use of this argument.

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

2: **uplo** – Nag_UploType *Input*

On entry: specifies whether the upper or lower triangular part of A is stored.

uplo = Nag_Upper
The upper triangular part of A is stored.

uplo = Nag_Lower
The lower triangular part of A is stored.

Constraint: **uplo** = Nag_Upper or Nag_Lower.

3: **n** – Integer *Input*

On entry: n, the order of the matrix A.

Constraint: **n** ≥ 0.

4: **k** – Integer *Input*

On entry: k, the number of subdiagonals or superdiagonals of the matrix A.

Constraint: $\mathbf{k} \geq 0$.

5: **alpha** – Complex *Input*

On entry: the scalar α.

6: **ab**[*dim*] – const Complex *Input*

Note: the dimension, *dim*, of the array **ab** must be at least $\max(1, \mathbf{pdab} \times \mathbf{n})$.

On entry: the n by n Hermitian band matrix A.

This is stored as a notional two-dimensional array with row elements or column elements stored contiguously. The storage of elements of A_{ij}, depends on the **order** and **uplo** arguments as follows:

if **order** = Nag_ColMajor and **uplo** = Nag_Upper,
A_{ij} is stored in $\mathbf{ab}[k+i-j+(j-1)\times\mathbf{pdab}]$, for $j=1,\dots,n$ and $i=\max(1,j-k),\dots,j$;
if **order** = Nag_ColMajor and **uplo** = Nag_Lower,
A_{ij} is stored in $\mathbf{ab}[i-j+(j-1)\times\mathbf{pdab}]$, for $j=1,\dots,n$ and $i=j,\dots,\min(n,j+k)$;
if **order** = Nag_RowMajor and **uplo** = Nag_Upper,
A_{ij} is stored in $\mathbf{ab}[j-i+(i-1)\times\mathbf{pdab}]$, for $i=1,\dots,n$ and $j=i,\dots,\min(n,i+k)$;
if **order** = Nag_RowMajor and **uplo** = Nag_Lower,
A_{ij} is stored in $\mathbf{ab}[k+j-i+(i-1)\times\mathbf{pdab}]$, for $i=1,\dots,n$ and $j=\max(1,i-k),\dots,i$.

7: **pdab** – Integer *Input*

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

Constraint: $\mathbf{pdab} \geq \mathbf{k}+1$.

8: **x**[*dim*] – const Complex *Input*

Note: the dimension, *dim*, of the array **x** must be at least $\max(1, 1+(\mathbf{n}-1)|\mathbf{incx}|)$.

On entry: the vector x.

9: **incx** – Integer *Input*

On entry: the increment in the subscripts of **x** between successive elements of x.

Constraint: $\mathbf{incx} \neq 0$.

10: **beta** – Complex *Input*

On entry: the scalar β.

11: **y**[*dim*] – Complex *Input/Output*

Note: the dimension, *dim*, of the array **y** must be at least $\max(1, 1+(\mathbf{n}-1)|\mathbf{incy}|)$.

On entry: the vector y.

If $\mathbf{beta} = 0$, **y** need not be set.

On exit: the updated vector y.

12: **incy** – Integer *Input*

On entry: the increment in the subscripts of **y** between successive elements of y.

Constraint: **incy** $\neq 0$.

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

The NAG error argument (see Section 3.6 in the Essential Introduction).

6 Error Indicators and Warnings

NE_ALLOC_FAIL

Dynamic memory allocation failed.
See Section 3.2.1.2 in the Essential Introduction for further information.

NE_BAD_PARAM

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

NE_INT

On entry, **incx** $= \langle value\rangle$.
Constraint: **incx** $\neq 0$.

On entry, **incy** $= \langle value\rangle$.
Constraint: **incy** $\neq 0$.

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

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

NE_INT_2

On entry, **pdab** $= \langle value\rangle$, **k** $= \langle value\rangle$.
Constraint: **pdab** $\geq$ **k** $+ 1$.

NE_INTERNAL_ERROR

An unexpected error has been triggered by this function. Please contact NAG.
See Section 3.6.6 in the Essential Introduction for further information.

NE_NO_LICENCE

Your licence key may have expired or may not have been installed correctly.
See Section 3.6.5 in the Essential Introduction for further information.

7 Accuracy

The BLAS standard requires accurate implementations which avoid unnecessary over/underflow (see Section 2.7 of Basic Linear Algebra Subprograms Technical (BLAST) Forum (2001)).

8 Parallelism and Performance

Not applicable.

9 Further Comments

None.

10 Example

This example computes the matrix-vector product

$$y = \alpha Ax + \beta y$$

where

$$A = \begin{pmatrix} 1.0+0.0i & 2.0-1.0i & 3.0-1.0i & 0.0+0.0i & 0.0+0.0i \\ 2.0+1.0i & 2.0+0.0i & 3.0-2.0i & 4.0-2.0i & 0.0+0.0i \\ 3.0+1.0i & 3.0+2.0i & 3.0+0.0i & 4.0-3.0i & 5.0-3.0i \\ 0.0+0.0i & 4.0+2.0i & 4.0+3.0i & 4.0+0.0i & 5.0-4.0i \\ 0.0+0.0i & 0.0+0.0i & 5.0+3.0i & 5.0+4.0i & 5.0+0.0i \end{pmatrix},$$

$$x = \begin{pmatrix} -1.0+1.0i \\ 2.0+2.0i \\ -3.0-1.0i \\ 2.0+3.0i \\ -1.0+1.0i \end{pmatrix},$$

$$y = \begin{pmatrix} 3.0-0.5i \\ -0.5-6.0i \\ 0.5-8.5i \\ 2.5-6.0i \\ 14.0-2.0i \end{pmatrix},$$

$$\alpha = 1.0+0.0i \quad \text{and} \quad \beta = 2.0+0.0i.$$

10.1 Program Text

```
/* nag_zhbmv (f16sdc) Example Program.
 *
 * Copyright 2014 Numerical Algorithms Group.
 *
 * Mark 8, 2005.
 */

#include <stdio.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagf16.h>

int main(void)
{

  /* Scalars */
  Complex       alpha, beta;
  Integer       exit_status, i, incx, incy, j, k, kd, n, pdab, xlen, ylen;

  /* Arrays */
  Complex       *ab = 0, *x = 0, *y = 0;
  char          nag_enum_arg[40];

  /* Nag Types */
  NagError      fail;
  Nag_OrderType order;
  Nag_UploType  uplo;

#ifdef NAG_COLUMN_MAJOR
#define AB_UPPER(I, J) ab[(J-1)*pdab + k + I - J - 1]
#define AB_LOWER(I, J) ab[(J-1)*pdab + I - J]
  order = Nag_ColMajor;
```

```
#else
#define AB_UPPER(I, J) ab[(I-1)*pdab + J - I]
#define AB_LOWER(I, J) ab[(I-1)*pdab + k + J - I - 1]
  order = Nag_RowMajor;
#endif

  exit_status = 0;
  INIT_FAIL(fail);

  printf("nag_zhbmv (f16sdc) Example Program Results\n\n");

  /* Skip heading in data file */
#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif
  /* Read the problem dimension */
#ifdef _WIN32
  scanf_s("%"NAG_IFMT"%"NAG_IFMT"%*[^\n] ", &n, &kd);
#else
  scanf("%"NAG_IFMT"%"NAG_IFMT"%*[^\n] ", &n, &kd);
#endif
  /* Read uplo */
#ifdef _WIN32
  scanf_s("%39s%*[^\n] ", nag_enum_arg, _countof(nag_enum_arg));
#else
  scanf("%39s%*[^\n] ", nag_enum_arg);
#endif
  /* nag_enum_name_to_value (x04nac).
   * Converts NAG enum member name to value
   */
  uplo = (Nag_UploType) nag_enum_name_to_value(nag_enum_arg);
  /* Read scalar parameters */
#ifdef _WIN32
  scanf_s(" ( %lf , %lf ) ( %lf , %lf )%*[^\n] ",
         &alpha.re, &alpha.im, &beta.re, &beta.im);
#else
  scanf(" ( %lf , %lf ) ( %lf , %lf )%*[^\n] ",
         &alpha.re, &alpha.im, &beta.re, &beta.im);
#endif
  /* Read increment parameters */
#ifdef _WIN32
  scanf_s("%"NAG_IFMT"%"NAG_IFMT"%*[^\n] ", &incx, &incy);
#else
  scanf("%"NAG_IFMT"%"NAG_IFMT"%*[^\n] ", &incx, &incy);
#endif

  pdab = kd + 1;
  xlen = MAX(1, 1 + (n - 1)*ABS(incx));
  ylen = MAX(1, 1 + (n - 1)*ABS(incy));

  if (n > 0)
    {
      /* Allocate memory */
      if (!(ab = NAG_ALLOC(pdab*n, Complex)) ||
          !(x = NAG_ALLOC(xlen, Complex)) ||
          !(y = NAG_ALLOC(ylen, Complex)))
        {
          printf("Allocation failure\n");
          exit_status = -1;
          goto END;
        }
    }
  else
    {
      printf("Invalid n\n");
      exit_status = 1;
      return exit_status;
    }
  /* Read A from data file */
  k = kd + 1;
  if (uplo == Nag_Upper)
    {
      for (i = 1; i <= n; ++i)
        {
          for (j = i; j <= MIN(i+kd, n); ++j)
#ifdef _WIN32
            scanf_s(" ( %lf , %lf )", &AB_UPPER(i, j).re,
                    &AB_UPPER(i, j).im);
#else
            scanf(" ( %lf , %lf )", &AB_UPPER(i, j).re,
                    &AB_UPPER(i, j).im);
#endif
        }
#ifdef _WIN32
      scanf_s("%*[^\n] ");
#else
      scanf("%*[^\n] ");
#endif
    }
  else
    {
      for (i = 1; i <= n; ++i)
        {
          for (j = MAX(1, i-kd); j <= i; ++j)
#ifdef _WIN32
            scanf_s(" ( %lf , %lf )",
                    &AB_LOWER(i, j).re, &AB_LOWER(i, j).im);
#else
            scanf(" ( %lf , %lf )",
                    &AB_LOWER(i, j).re, &AB_LOWER(i, j).im);
#endif
        }
#ifdef _WIN32
      scanf_s("%*[^\n] ");
#else
      scanf("%*[^\n] ");
#endif
    }

  /* Input vectors x and y */

  for (i = 1; i <= xlen; ++i)
#ifdef _WIN32
    scanf_s(" ( %lf , %lf )%*[^\n] ", &x[i - 1].re, &x[i - 1].im);
#else
    scanf(" ( %lf , %lf )%*[^\n] ", &x[i - 1].re, &x[i - 1].im);
#endif
  for (i = 1; i <= ylen; ++i)
#ifdef _WIN32
    scanf_s(" ( %lf , %lf )%*[^\n] ", &y[i - 1].re, &y[i - 1].im);
#else
    scanf(" ( %lf , %lf )%*[^\n] ", &y[i - 1].re, &y[i - 1].im);
#endif

  /* nag_zhbmv (f16sdc).
   * Hermitian banded matrix-vector multiply.
   *
   */
  nag_zhbmv(order, uplo, n, kd, alpha, ab, pdab, x, incx,
            beta, y, incy, &fail);
  if (fail.code != NE_NOERROR)
    {
      printf("Error from nag_zhbmv.\n%s\n", fail.message);
      exit_status = 1;
      goto END;
    }

  /* Print output vector y */
  printf("%s\n", "  y");
  for (i = 1; i <= ylen; ++i)
    {
      printf("(%11f,%11f)\n", y[i-1].re, y[i-1].im);
    }

 END:
  NAG_FREE(ab);
  NAG_FREE(x);
  NAG_FREE(y);

  return exit_status;
}
```

10.2 Program Data

```
nag_zhbmv (f16sdc) Example Program Data
  5  2                     :Values of n and kd
  Nag_Lower                :Value of uplo
  ( 1.0, 0.0) ( 2.0, 0.0)        : alpha, beta
  1 1                 : incx, incy
  (1.0, 0.0)
  (2.0, 1.0) (2.0, 0.0)
  (3.0, 1.0) (3.0, 2.0) (3.0, 0.0)
             (4.0, 2.0) (4.0, 3.0) (4.0, 0.0)
                        (5.0, 3.0) (5.0, 4.0) (5.0, 0.0) :End of matrix A
  (-1.0, 1.0)
  ( 2.0, 2.0)
  (-3.0,-1.0)
  ( 2.0, 3.0)
  (-1.0, 1.0)               : the end of vector x
  ( 3.0,-0.5)
  (-0.5,-6.0)
  ( 0.5,-8.5)
  ( 2.5,-6.0)
  (14.0,-2.0)               : the end of vector y
```

10.3 Program Results

```
nag_zhbmv (f16sdc) Example Program Results

  y
(   1.000000,   2.000000)
(   3.000000,   4.000000)
(   5.000000,   6.000000)
(   7.000000,   8.000000)
(   9.000000,  10.000000)
```