NAG Library Function Document

nag_zgbmv (f16sbc)

1 Purpose

nag_zgbmv (f16sbc) performs matrix-vector multiplication for a complex band matrix.

2 Specification

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

```
void nag_zgbmv (Nag_OrderType order, Nag_TransType trans, Integer m,
     Integer n, Integer kl, Integer ku, Complex alpha, const Complex ab[],
     Integer pdab, const Complex x[], Integer incx, Complex beta,
     Complex y[], Integer incy, NagError *fail)
```

3 Description

nag_zgbmv (f16sbc) performs one of the matrix-vector operations

$$y \leftarrow \alpha Ax + \beta y, \quad y \leftarrow \alpha A^{\mathrm{T}}x + \beta y \quad \text{or} \quad y \leftarrow \alpha A^{\mathrm{H}}x + \beta y$$

where A is an m by n complex band matrix with k_l subdiagonals and k_u superdiagonals, x and y are complex vectors, and α and β are complex scalars.

If $m = 0$ or $n = 0$, no operation is performed.

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 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: **trans** – Nag_TransType *Input*

On entry: specifies the operation to be performed.

trans = Nag_NoTrans
$y \leftarrow \alpha Ax + \beta y$.

trans = Nag_Trans
$y \leftarrow \alpha A^{\mathrm{T}}x + \beta y$.

trans = Nag_ConjTrans
$y \leftarrow \alpha A^{\mathrm{H}}x + \beta y$.

Constraint: **trans** = Nag_NoTrans, Nag_Trans or Nag_ConjTrans.

3: **m** – Integer *Input*

On entry: m, the number of rows of the matrix A.

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

4: **n** – Integer *Input*

On entry: n, the number of columns of the matrix A.

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

5: **kl** – Integer *Input*

On entry: k_l, the number of subdiagonals within the band of A.

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

6: **ku** – Integer *Input*

On entry: k_u, the number of superdiagonals within the band of A.

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

7: **alpha** – Complex *Input*

On entry: the scalar α.

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

Note: the dimension, *dim*, of the array **ab** must be at least

$\max(1, \mathbf{pdab} \times \mathbf{n})$ when **order** = Nag_ColMajor;
$\max(1, \mathbf{m} \times \mathbf{pdab})$ when **order** = Nag_RowMajor.

On entry: the m by n band matrix A.

This is stored as a notional two-dimensional array with row elements or column elements stored contiguously. The storage of elements A_{ij}, for row $i = 1, \ldots, m$ and column $j = \max(1, i - k_l), \ldots, \min(n, i + k_u)$, depends on the **order** argument as follows:

if **order** = Nag_ColMajor, A_{ij} is stored as $\mathbf{ab}[(j-1) \times \mathbf{pdab} + \mathbf{ku} + i - j]$;

if **order** = Nag_RowMajor, A_{ij} is stored as $\mathbf{ab}[(i-1) \times \mathbf{pdab} + \mathbf{kl} + j - i]$.

9: **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: $\mathbf{pdab} \geq \mathbf{kl} + \mathbf{ku} + 1$.

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

Note: the dimension, *dim*, of the array **x** must be at least

$\max(1, 1 + (\mathbf{n} - 1)|\mathbf{incx}|)$ when **trans** = Nag_NoTrans;
$\max(1, 1 + (\mathbf{m} - 1)|\mathbf{incx}|)$ when **trans** = Nag_Trans or Nag_ConjTrans.

On entry: the vector x.

If **trans** = Nag_NoTrans, then x is an n-element vector.

If $\mathbf{incx} > 0$, x_i must be stored in $\mathbf{x}[(i-1) \times \mathbf{incx}]$, for $i = 1, 2, \ldots, \mathbf{n}$.

If $\mathbf{incx} < 0$, x_i must be stored in $\mathbf{x}[(\mathbf{n} - i) \times |\mathbf{incx}|]$, for $i = 1, 2, \ldots, \mathbf{n}$.

Intermediate elements of **x** are not referenced. If $\mathbf{n} = 0$, **x** is not referenced and may be **NULL**.

Otherwise, x is an m-element vector.

If **incx** > 0, x_i must be stored in $\mathbf{x}[(i-1) \times \mathbf{incx}]$, for $i = 1, 2, \ldots, \mathbf{m}$.

If **incx** < 0, x_i must be stored in $\mathbf{x}[(\mathbf{m} - i) \times |\mathbf{incx}|]$, for $i = 1, 2, \ldots, \mathbf{m}$.

Intermediate elements of **x** are not referenced. If **m** $= 0$, **x** is not referenced and may be **NULL**.

11: **incx** – Integer *Input*

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

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

12: **beta** – Complex *Input*

On entry: the scalar β.

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

Note: the dimension, *dim*, of the array **y** must be at least

$\max(1, 1 + (\mathbf{m} - 1)|\mathbf{incy}|)$ when **trans** = Nag_NoTrans;
$\max(1, 1 + (\mathbf{n} - 1)|\mathbf{incy}|)$ when **trans** = Nag_Trans or Nag_ConjTrans.

On entry: the vector y. See **x** for details of storage.

If **beta** $= 0$, **y** need not be set.

On exit: the updated vector y.

14: **incy** – Integer *Input*

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

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

15: **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 ⟨*value*⟩ had an illegal value.

NE_INT

On entry, **incx** = ⟨*value*⟩.
Constraint: **incx** $\neq 0$.

On entry, **incy** = ⟨*value*⟩.
Constraint: **incy** $\neq 0$.

On entry, **kl** = ⟨*value*⟩.
Constraint: **kl** ≥ 0.

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

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

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

NE_INT_3

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

NE_INTERNAL_ERROR

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

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

nag_zgbmv (f16sbc) is not threaded in any implementation.

9 Further Comments

None.

10 Example

This example computes the matrix-vector product

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

where

$$A = \begin{pmatrix} 1.0+1.0i & 1.0+2.0i & 0.0+0.0i & 0.0+0.0i \\ 2.0+1.0i & 2.0+2.0i & 2.0+3.0i & 0.0+0.0i \\ 3.0+1.0i & 3.0+2.0i & 3.0+3.0i & 3.0+4.0i \\ 0.0+0.0i & 4.0+2.0i & 4.0+3.0i & 4.0+4.0i \\ 0.0+0.0i & 0.0+0.0i & 5.0+3.0i & 5.0+4.0i \\ 0.0+0.0i & 0.0+0.0i & 0.0+0.0i & 6.0+4.0i \end{pmatrix},$$

$$x = \begin{pmatrix} 1.0-1.0i \\ 2.0-2.0i \\ 3.0-3.0i \\ 4.0-4.0i \end{pmatrix},$$

$$y = \begin{pmatrix} -3.5 + 0.0i \\ -11.5 + 1.0i \\ -27.5 + 3.0i \\ -29.0 + 7.5i \\ -25.5 + 10.0i \\ -14.5 + 10.0i \end{pmatrix},$$

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

10.1 Program Text

```
/* nag_zgbmv (f16sbc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */

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

int main(void)
{

  /* Scalars */
  Complex alpha, beta;
  Integer ab_size, exit_status, i, incx, incy, j, kl, ku;
  Integer m, 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_TransType trans;

#ifdef NAG_COLUMN_MAJOR
#define AB(I, J) ab[(J-1)*pdab + ku + I - J]
  order = Nag_ColMajor;
#else
#define AB(I, J) ab[(I-1)*pdab + kl + J - I]
  order = Nag_RowMajor;
#endif

  exit_status = 0;
  INIT_FAIL(fail);

  printf("nag_zgbmv (f16sbc) Example Program Results\n\n");

  /* Skip heading in data file */
#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif

  /* Read the problem dimensions */
#ifdef _WIN32
  scanf_s("%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%*[^\n] ",
          &m, &n, &kl, &ku);
#else
  scanf("%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%*[^\n] ",
```

```
        &m, &n, &kl, &ku);
#endif
  /* Read the transpose parameter */
#ifdef _WIN32
  scanf_s("%39s%*[^\n] ", nag_enum_arg, (unsigned)_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
   */
  trans = (Nag_TransType) 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 = kl + ku + 1;
#ifdef NAG_COLUMN_MAJOR
  ab_size = pdab * n;
#else
  ab_size = pdab * m;
#endif

  if (trans == Nag_NoTrans) {
    xlen = MAX(1, 1 + (n - 1) * ABS(incx));
    ylen = MAX(1, 1 + (m - 1) * ABS(incy));
  }
  else {
    xlen = MAX(1, 1 + (m - 1) * ABS(incx));
    ylen = MAX(1, 1 + (n - 1) * ABS(incy));
  }

  if (m > 0 && n > 0) {
    /* Allocate memory */
    if (!(ab = NAG_ALLOC(ab_size, Complex)) ||
        !(x = NAG_ALLOC(xlen, Complex)) || !(y = NAG_ALLOC(ylen, Complex)))
    {
      printf("Allocation failure\n");
      exit_status = -1;
      goto END;
    }
  }
  else {
    printf("Invalid m or n\n");
    exit_status = 1;
    return exit_status;
  }

  /* Input matrix A and vectors x and y */

  for (i = 1; i <= m; ++i) {
    for (j = MAX(1, i - kl); j <= MIN(n, i + ku); ++j)
#ifdef _WIN32
      scanf_s(" ( %lf , %lf )", &AB(i, j).re, &AB(i, j).im);
#else
      scanf(" ( %lf , %lf )", &AB(i, j).re, &AB(i, j).im);
#endif
#ifdef _WIN32
    scanf_s("%*[^\n] ");
#else
```

```
    scanf("%*[^\n] ");
#endif
  }
  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_zgbmv (f16sbc).
   * Complex valued band matrix-vector multiply.
   *
   */
  nag_zgbmv(order, trans, m, n, kl, ku, alpha, ab, pdab, x,
            incx, beta, y, incy, &fail);
  if (fail.code != NE_NOERROR) {
    printf("Error from nag_zgbmv.\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_zgbmv (f16sbc) Example Program Data
  6 4 2 1                                   :Values of m, n, kl, ku
  Nag_NoTrans                               : trans
  ( 1.0, 0.0) ( 2.0, 0.0)                   : alpha, beta
  1 1                                       : incx, incy
  ( 1.0, 1.0) ( 1.0, 2.0)
  ( 2.0, 1.0) ( 2.0, 2.0) ( 2.0, 3.0)
  ( 3.0, 1.0) ( 3.0, 2.0) ( 3.0, 3.0) ( 3.0, 4.0)
              ( 4.0, 2.0) ( 4.0, 3.0) ( 4.0, 4.0)
                          ( 5.0, 3.0) ( 5.0, 4.0)
                                      ( 6.0, 4.0)  : the end of matrix A
  ( 1.0,-1.0)
  ( 2.0,-2.0)
  ( 3.0,-3.0)
  ( 4.0,-4.0)               : the end of vector x
  (-3.5, 0.0)
  (-11.5, 1.0)
  (-27.5, 3.0)
  (-29.0, 7.5)
  (-25.5, 10.0)
  (-14.5, 10.0)               : the end of vector y
```

10.3 Program Results

```
nag_zgbmv (f16sbc) Example Program Results

  y
(   1.000000,   2.000000)
(   3.000000,   4.000000)
(   5.000000,   6.000000)
(   7.000000,   8.000000)
(   9.000000,  10.000000)
(  11.000000,  12.000000)
```