NAG Library Function Document

nag_ztrsv (f16sjc)

1 Purpose

nag_ztrsv (f16sjc) solves a system of equations given as a complex triangular matrix.

2 Specification

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

```
void nag_ztrsv (Nag_OrderType order, Nag_UploType uplo, Nag_TransType trans,
     Nag_DiagType diag, Integer n, Complex alpha, const Complex a[],
     Integer pda, Complex x[], Integer incx, NagError *fail)
```

3 Description

nag_ztrsv (f16sjc) performs one of the matrix-vector operations

$$x \leftarrow \alpha A^{-1}x, \quad x \leftarrow \alpha A^{-\mathrm{T}}x \quad \text{or} \quad x \leftarrow A^{-\mathrm{H}}x,$$

where A is an n by n complex triangular matrix, x is an n-element complex vector and α is a complex scalar. $A^{-\mathrm{T}}$ denotes $A^{-\mathrm{T}}$ or equivalently $A^{-\mathrm{T}}$; $A^{-\mathrm{H}}$ denotes $\left(A^{\mathrm{H}}\right)^{-1}$ or equivalently $\left(A^{-1}\right)^{\mathrm{H}}$.

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: **uplo** – Nag_UploType *Input*

On entry: specifies whether A is upper or lower triangular.

uplo = Nag_Upper
A is upper triangular.

uplo = Nag_Lower
A is lower triangular.

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

3: **trans** – Nag_TransType *Input*

On entry: specifies the operation to be performed.

trans = Nag_NoTrans
$x \leftarrow A^{-1}x$.

trans = Nag_Trans
$x \leftarrow A^{-\mathrm{T}}x$.

trans = Nag_ConjTrans
$x \leftarrow A^{-\mathrm{H}}x$.

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

4: **diag** – Nag_DiagType *Input*

On entry: specifies whether A has nonunit or unit diagonal elements.

diag = Nag_NonUnitDiag
The diagonal elements are stored explicitly.

diag = Nag_UnitDiag
The diagonal elements are assumed to be 1 and are not referenced.

Constraint: **diag** = Nag_NonUnitDiag or Nag_UnitDiag.

5: **n** – Integer *Input*

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

Constraint: **n** ≥ 0.

6: **alpha** – Complex *Input*

On entry: the scalar α.

7: **a**[*dim*] – const Complex *Input*

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

On entry: the n by n triangular matrix A.

If **order** = Nag_ColMajor, A_{ij} is stored in $\mathbf{a}[(j-1) \times \mathbf{pda} + i - 1]$.

If **order** = Nag_RowMajor, A_{ij} is stored in $\mathbf{a}[(i-1) \times \mathbf{pda} + j - 1]$.

If **uplo** = Nag_Upper, the upper triangular part of A must be stored and the elements of the array below the diagonal are not referenced.

If **uplo** = Nag_Lower, the lower triangular part of A must be stored and the elements of the array above the diagonal are not referenced.

If **diag** = Nag_UnitDiag, the diagonal elements of A are assumed to be 1, and are not referenced.

8: **pda** – Integer *Input*

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

Constraint: **pda** $\geq \max(1, \mathbf{n})$.

9: **x**[*dim*] – Complex *Input/Output*

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.

On exit: the solution vector x.

10: **incx** – Integer *Input*

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

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

11: **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, **n** = ⟨*value*⟩.
Constraint: **n** ≥ 0.

NE_INT_2

On entry, **pda** = ⟨*value*⟩, **n** = ⟨*value*⟩.
Constraint: **pda** $\geq \max(1, \mathbf{n})$.

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_ztrsv (f16sjc) is not threaded in any implementation.

9 Further Comments

No test for singularity or near-singularity of A is included in nag_ztrsv (f16sjc). Such tests must be performed before calling this function.

10 Example

Solves complex triangular system of linear equations, $Ax = y$, where A is a complex triangular 4 by 4 matrix given by

$$A = \begin{pmatrix} 4.78 + 4.56i & & & \\ 2.00 - 0.30i & -4.11 + 1.25i & & \\ 2.89 - 1.34i & 2.36 - 4.25i & 4.15 + 0.80i & \\ -1.89 + 1.15i & 0.04 - 3.69i & -0.02 + 0.46i & 0.33 - 0.26i \end{pmatrix},$$

and

$$y = \begin{pmatrix} -14.78 - 32.36i \\ 2.98 - 2.14i \\ -20.96 + 17.06i \\ 9.54 + 9.91i \end{pmatrix}.$$

10.1 Program Text

```
/* nag_ztrsv (f16sjc) 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;
  Integer exit_status, i, incx, j, n, pda, xlen;

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

  /* Nag Types */
  NagError fail;
  Nag_OrderType order;
  Nag_TransType trans;
  Nag_UploType uplo;
  Nag_DiagType diag;

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

  exit_status = 0;
  INIT_FAIL(fail);

  printf("nag_ztrsv (f16sjc) 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 "%*[^\n] ", &n);
#else
  scanf("%" NAG_IFMT "%*[^\n] ", &n);
#endif

  /* Read the uplo storage 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
   */
  uplo = (Nag_UploType) nag_enum_name_to_value(nag_enum_arg);
  /* 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), see above. */
  trans = (Nag_TransType) nag_enum_name_to_value(nag_enum_arg);
  /* Read the unit-diagonal 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), see above. */
  diag = (Nag_DiagType) nag_enum_name_to_value(nag_enum_arg);

  /* Read scalar parameters */
#ifdef _WIN32
  scanf_s(" ( %lf , %lf )%*[^\n] ", &alpha.re, &alpha.im);
#else
  scanf(" ( %lf , %lf )%*[^\n] ", &alpha.re, &alpha.im);
#endif
  /* Read increment parameter */
#ifdef _WIN32
  scanf_s("%" NAG_IFMT "%*[^\n] ", &incx);
#else
  scanf("%" NAG_IFMT "%*[^\n] ", &incx);
#endif

  pda = n;
  xlen = MAX(1, 1 + (n - 1) * ABS(incx));

  if (n > 0) {
    /* Allocate memory */
    if (!(a = NAG_ALLOC(pda * n, Complex)) || !(x = NAG_ALLOC(xlen, Complex)))
    {
      printf("Allocation failure\n");
      exit_status = -1;
      goto END;
    }
  }
  else {
    printf("Invalid n\n");
    exit_status = 1;
    return exit_status;
  }

  /* Input matrix A and vector x */

  if (uplo == Nag_Upper) {
    for (i = 1; i <= n; ++i) {
      if (diag == Nag_NonUnitDiag)
#ifdef _WIN32
        scanf_s(" ( %lf , %lf )", &A(i, i).re, &A(i, i).im);
#else
        scanf(" ( %lf , %lf )", &A(i, i).re, &A(i, i).im);
#endif
      for (j = i + 1; j <= n; ++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
    }
#ifdef _WIN32
    scanf_s("%*[^\n] ");
#else
    scanf("%*[^\n] ");
#endif
  }
  else {
    for (i = 1; i <= n; ++i) {
      for (j = 1; j < i; ++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
      if (diag == Nag_NonUnitDiag)
#ifdef _WIN32
        scanf_s(" ( %lf , %lf )", &A(i, i).re, &A(i, i).im);
#else
        scanf(" ( %lf , %lf )", &A(i, i).re, &A(i, i).im);
#endif
    }
#ifdef _WIN32
    scanf_s("%*[^\n] ");
#else
    scanf("%*[^\n] ");
#endif
  }
  for (i = 0; i < xlen; ++i)
#ifdef _WIN32
    scanf_s(" ( %lf , %lf )%*[^\n] ", &x[i].re, &x[i].im);
#else
    scanf(" ( %lf , %lf )%*[^\n] ", &x[i].re, &x[i].im);
#endif

  /* nag_ztrsv (f16sjc).
   * Solution of complex triangular system of linear equations.
   *
   */
  nag_ztrsv(order, uplo, trans, diag, n, alpha, a, pda, x, incx, &fail);
  if (fail.code != NE_NOERROR) {
    printf("Error from nag_ztrsv (f16sjc).\n%s\n", fail.message);
    exit_status = 1;
    goto END;
  }

  /* Print output vector x */
  printf("%s\n", " Solution x:");
  for (i = 0; i < xlen; ++i) {
    printf("( %11f , %11f )\n", x[i].re, x[i].im);
  }

END:
  NAG_FREE(a);
  NAG_FREE(x);

  return exit_status;
}
```

10.2 Program Data

```
nag_ztrsv (f16sjc) Example Program Data
  4                           :Value of n
  Nag_Lower                   :Storage of A
  Nag_NoTrans                 :Transpose A?
  Nag_NonUnitDiag             :Unit diagonal elements?
  ( 1.0, 0.0)                 :Value of alpha
  1                           :Value of incx
 ( 4.78, 4.56)
 ( 2.00,-0.30) (-4.11, 1.25)
 ( 2.89,-1.34) ( 2.36,-4.25) ( 4.15, 0.80)
 (-1.89, 1.15) ( 0.04,-3.69) (-0.02, 0.46) ( 0.33,-0.26)  :End of matrix A
 (-14.78,-32.36)
 (  2.98, -2.14)
 (-20.96, 17.06)
 (  9.54,  9.91)                                          :End of vector x
```

10.3 Program Results

```
nag_ztrsv (f16sjc) Example Program Results

 Solution x:
(   -5.000000 ,   -2.000000 )
(   -3.000000 ,   -1.000000 )
(    2.000000 ,    1.000000 )
(    4.000000 ,    3.000000 )
```