NAG Library Function Document
nag_zgtcon (f07cuc)

1 Purpose
nag_zgtcon (f07cuc) estimates the reciprocal condition number of a complex $n$ by $n$ tridiagonal matrix $A$, using the $LU$ factorization returned by nag_zgttrf (f07crc).

2 Specification
#include <nag.h>
#include <nagf07.h>

void nag_zgtcon (Nag_NormType norm, Integer n, const Complex dl[],
const Complex d[], const Complex du[], const Complex du2[],
const Integer ipiv[], double anorm, double *rcond, NagError *fail)

3 Description
nag_zgtcon (f07cuc) should be preceded by a call to nag_zgttrf (f07crc), which uses Gaussian elimination with partial pivoting and row interchanges to factorize the matrix $A$ as

$$A = PLU,$$

where $P$ is a permutation matrix, $L$ is unit lower triangular with at most one nonzero subdiagonal element in each column, and $U$ is an upper triangular band matrix, with two superdiagonals. nag_zgtcon (f07cuc) then utilizes the factorization to estimate either $\|A^{-1}\|_1$ or $\|A^{-1}\|_\infty$, from which the estimate of the reciprocal of the condition number of $A$, $1/\kappa(A)$ is computed as either

$$1/\kappa_1(A) = 1/(\|A\|_1 \|A^{-1}\|_1)$$

or

$$1/\kappa_\infty(A) = 1/(\|A\|_\infty \|A^{-1}\|_\infty).$$

$1/\kappa(A)$ is returned, rather than $\kappa(A)$, since when $A$ is singular $\kappa(A)$ is infinite.

Note that $\kappa_\infty(A) = \kappa_1(A^T)$.

4 References

5 Arguments
1: norm – Nag_NormType

On entry: specifies the norm to be used to estimate $\kappa(A)$.

$\textbf{norm} = \text{Nag_OneNorm}$

Estimate $\kappa_1(A)$.

$\textbf{norm} = \text{Nag_InfNorm}$

Estimate $\kappa_\infty(A)$.

Constraint: norm = Nag_OneNorm or Nag_InfNorm.
2: n – Integer

*Input*

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

*Constraint:* $n \geq 0$.

3: dl[dim] – const Complex

*Input*

*Note:* the dimension, $dim$, of the array $dl$ must be at least $\max(1, n-1)$.

*On entry:* must contain the $(n-1)$ multipliers that define the matrix $L$ of the $LU$ factorization of $A$.

4: d[dim] – const Complex

*Input*

*Note:* the dimension, $dim$, of the array $d$ must be at least $\max(1, n)$.

*On entry:* must contain the $n$ diagonal elements of the upper triangular matrix $U$ from the $LU$ factorization of $A$.

5: du[dim] – const Complex

*Input*

*Note:* the dimension, $dim$, of the array $du$ must be at least $\max(1, n-1)$.

*On entry:* must contain the $(n-1)$ elements of the first superdiagonal of $U$.

6: du2[dim] – const Complex

*Input*

*Note:* the dimension, $dim$, of the array $du2$ must be at least $\max(1, n-2)$.

*On entry:* must contain the $(n-2)$ elements of the second superdiagonal of $U$.

7: ipiv[dim] – const Integer

*Input*

*Note:* the dimension, $dim$, of the array $ipiv$ must be at least $\max(1, n)$.

*On entry:* must contain the $n$ pivot indices that define the permutation matrix $P$. At the $i$th step, row $i$ of the matrix was interchanged with row $ipiv[i-1]$, and $ipiv[i-1]$ must always be either $i$ or $(i+1)$, $ipiv[i-1] = i$ indicating that a row interchange was not performed.

8: anorm – double

*Input*

*On entry:* if $\text{norm} = \text{Nag\_OneNorm}$, the 1-norm of the *original* matrix $A$.

If $\text{norm} = \text{Nag\_InfNorm}$, the $\infty$-norm of the *original* matrix $A$.

$\text{anorm}$ may be computed as demonstrated in Section 10 for the 1-norm. The $\infty$-norm may be similarly computed by swapping the $dl$ and $du$ arrays in the code for the 1-norm.

$\text{anorm}$ must be computed either *before* calling nag_zgttrf (f07crc) or else from a *copy* of the original matrix $A$ (see Section 10).

*Constraint:* $\text{anorm} \geq 0.0$.

9: rcond – double *

*Output*

*On exit:* contains an estimate of the reciprocal condition number.

10: 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 ⟨value⟩ had an illegal value.

**NE_INT**
On entry, n = ⟨value⟩.
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 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.

**NE_REAL**
On entry, anorm = ⟨value⟩.
Constraint: anorm ≥ 0.0.

7 Accuracy
In practice the condition number estimator is very reliable, but it can underestimate the true condition number; see Section 15.3 of Higham (2002) for further details.

8 Parallelism and Performance
nag_zgtcon (f07cuc) is not threaded by NAG in any implementation.

nag_zgtcon (f07cuc) 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
The condition number estimation typically requires between four and five solves and never more than eleven solves, following the factorization. The total number of floating-point operations required to perform a solve is proportional to n.

The real analogue of this function is nag_dgtcon (f07cge).
10 Example

This example estimates the condition number in the 1-norm of the tridiagonal matrix $A$ given by

$$
A = \begin{pmatrix}
-1.3 + 1.3i & 2.0 - 1.0i & 0 & 0 & 0 \\
1.0 - 2.0i & -1.3 + 1.3i & 2.0 + 1.0i & 0 & 0 \\
0 & 1.0 + 1.0i & -1.3 + 3.3i & -1.0 + 1.0i & 0 \\
0 & 0 & 2.0 - 3.0i & -0.3 + 4.3i & 1.0 - 1.0i \\
0 & 0 & 0 & 1.0 + 1.0i & -3.3 + 1.3i
\end{pmatrix}.
$$

10.1 Program Text

/* nag_zgtcon (f07cuc) Example Program. 
* Copyright 2014 Numerical Algorithms Group. 
* Mark 23, 2011. 
*/
#include <stdio.h>
#include <math.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagf07.h>
#include <nagx02.h>

int main(void)
{
    /* Scalars */
    double anorm, rcond;
    Integer exit_status = 0, i, n;

    /* Arrays */
    Complex *d = 0, *dl = 0, *du = 0, *du2 = 0;
    Integer *ipiv = 0;

    /* Nag Types */
    NagError fail;

    #define CABS(dl) sqrt(dl.re * dl.re + dl.im * dl.im)
    INIT_FAIL(fail);

    printf("nag_zgtcon (f07cuc) Example Program Results\n\n");

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

    #ifdef _WIN32
    scanf_s("%"NAG_IFMT"%*[\n"] , &n);
    #else
    scanf("%"NAG_IFMT"%*[\n"] , &n);
    #endif

    if (n < 0)
    {
        printf("Invalid n\n");
        exit_status = -2;
        goto END;
    }

    /* Allocate memory */
    if (! (d = NAG_ALLOC(n, Complex)) ||
        ! (dl = NAG_ALLOC(n-1, Complex)) ||
        ! (du = NAG_ALLOC(n-1, Complex)) ||
        ! (du2 = NAG_ALLOC(n-2, Complex)) ||
        ! (ipiv = NAG_ALLOC(n, Integer)))
    {
        /* ... */
    }

    /* ... */

    return exit_status;
}

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printf("Allocation failure\n");
exit_status = -1;
goto END;
}

/* Read the tridiagonal matrix A from data file */
#ifdef _WIN32
for (i = 0; i < n - 1; ++i) scanf_s(" ( %lf , %lf )", &du[i].re, &du[i].im);
#else
for (i = 0; i < n - 1; ++i) scanf(" ( %lf , %lf )", &du[i].re, &du[i].im);
#endif
#ifdef _WIN32
scanf_s("%*[\n]");
#else
scanf("%*[\n]");
#endif
#ifdef _WIN32
for (i = 0; i < n; ++i) scanf_s(" ( %lf , %lf )", &d[i].re, &d[i].im);
#else
for (i = 0; i < n; ++i) scanf(" ( %lf , %lf )", &d[i].re, &d[i].im);
#endif
#ifdef _WIN32
scanf_s("%*[\n]");
#else
scanf("%*[\n]");
#endif
#ifdef _WIN32
for (i = 0; i < n - 1; ++i) scanf_s(" ( %lf , %lf )", &dl[i].re, &dl[i].im);
#else
for (i = 0; i < n - 1; ++i) scanf(" ( %lf , %lf )", &dl[i].re, &dl[i].im);
#endif
#ifdef _WIN32
scanf_s("%*[\n]");
#else
scanf("%*[\n]");
#endif

/* Compute the 1-norm of A */
if (n == 1)
{
anorm = CABS(d[0]);
}
else
{
anorm = MAX(CABS(d[0])+CABS(dl[0]), CABS(d[n-1])+CABS(du[n-2]));
for (i = 1; i < n-1; ++i)
    anorm = MAX(anorm, CABS(d[i])+CABS(dl[i])+CABS(du[i-1]));
}

/* nag_zgttrf (f07crc)
 * LU factorization of complex tridiagonal matrix A
 */
nag_zgttrf(n, dl, d, du, du2, ipiv, &fail);
if (fail.code != NE_NOERROR)
{
    printf("Error from nag_zgttrf (f07crc).\n\n\n", fail.message);
    exit_status = 1;
goto END;
}

/* Estimate the condition number of A using
 * nag_zgtcon (f07cuc).
 * Estimates the reciprocal of the condition number of a LU factorized
 * complex tridiagonal matrix.
 */
nag_zgtcon(Nag_OneNorm, n, dl, d, du, du2, ipiv, anorm, &rcond, &fail);
if (fail.code != NE_NOERROR)
{
    printf("Error from nag_zgtcon (f07cuc).\n\n\n", fail.message);
    exit_status = 2;
goto END;

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if (rcond >= nag_machine_precision)
    printf("Estimate of condition number = %11.2e\n\n", 1.0/rcond);
else
    printf("A is singular to working precision. RCOND = %11.2e\n\n", rcond);
END:
NAG_FREE(d);
NAG_FREE(dl);
NAG_FREE(du);
NAG_FREE(du2);
NAG_FREE(ipiv);
return exit_status;
}