NAG Fortran Library Routine Document

F08AUF (CUNMQR/ZUNMQR)

Note: before using this routine, please read the Users' Note for your implementation to check the interpretation of ***bold italicised*** terms and other implementation-dependent details.

1 Purpose

F08AUF (CUNMQR/ZUNMQR) multiplies an arbitrary complex matrix C by the complex unitary matrix Q from a QR factorization computed by F08ASF (CGEQRF/ZGEQRF) or F08BSF (CGEQPF/ZGEQPF).

2 Specification

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 SUBROUTINE F08AUF(SIDE, TRANS, M, N, K, A, LDA, TAU, C, LDC, WORK,
1                  LWORK, INFO)
 ENTRY      cunmqr(SIDE, TRANS, M, N, K, A, LDA, TAU, C, LDC, WORK,
1                  LWORK, INFO)
 INTEGER           M, N, K, LDA, LDC, LWORK, INFO
 complex           A(LDA,*), TAU(*), C(LDC,*), WORK(*)
 CHARACTER*1       SIDE, TRANS
```

The ENTRY statement enables the routine to be called by its LAPACK name.

3 Description

This routine is intended to be used after a call to F08ASF (CGEQRF/ZGEQRF) or F08BSF (CGEQPF/ZGEQPF), which perform a QR factorization of a complex matrix A. The unitary matrix Q is represented as a product of elementary reflectors.

This routine may be used to form one of the matrix products

$$QC,\ Q^HC,\ CQ \text{ or } CQ^H,$$

overwriting the result on C (which may be any complex rectangular matrix).

A common application of this routine is in solving linear least-squares problems, as described in the F08 Chapter Introduction, and illustrated in Section 9 of the document for F08ASF (CGEQRF/ZGEQRF).

4 References

Golub G H and van Loan C F (1996) *Matrix Computations* (3rd Edition) Johns Hopkins University Press, Baltimore

5 Parameters

1: SIDE – CHARACTER*1 *Input*

On entry: indicates how Q or Q^H is to be applied to C as follows:

if SIDE = 'L', Q or Q^H is applied to C from the left;

if SIDE = 'R', Q or Q^H is applied to C from the right.

Constraint: SIDE = 'L' or 'R'.

2: TRANS – CHARACTER*1 *Input*

On entry: indicates whether Q or Q^H is to be applied to C as follows:

if TRANS = 'N', Q is applied to C;

if TRANS = 'C', Q^H is applied to C.

Constraint: TRANS = 'N' or 'C'.

3: M – INTEGER *Input*

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

Constraint: $\mathrm{M} \geq 0$.

4: N – INTEGER *Input*

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

Constraint: $\mathrm{N} \geq 0$.

5: K – INTEGER *Input*

On entry: k, the number of elementary reflectors whose product defines the matrix Q.

Constraints:

$\mathrm{M} \geq \mathrm{K} \geq 0$ if SIDE = 'L',
$\mathrm{N} \geq \mathrm{K} \geq 0$ if SIDE = 'R'.

6: A(LDA,*) – ***complex*** array *Input/Output*

Note: the second dimension of the array A must be at least $\max(1, \mathrm{K})$.

On entry: details of the vectors which define the elementary reflectors, as returned by F08ASF (CGEQRF/ZGEQRF) or F08BSF (CGEQPF/ZGEQPF).

On exit: used as internal workspace prior to being restored and hence is unchanged.

7: LDA – INTEGER *Input*

On entry: the first dimension of the array A as declared in the (sub)program from which F08AUF (CUNMQR/ZUNMQR) is called.

Constraints:

$\mathrm{LDA} \geq \max(1, \mathrm{M})$ if SIDE = 'L',
$\mathrm{LDA} \geq \max(1, \mathrm{N})$ if SIDE = 'R'.

8: TAU($*$) – ***complex*** array *Input*

Note: the dimension of the array TAU must be at least $\max(1, \mathrm{K})$.

On entry: further details of the elementary reflectors, as returned by F08ASF (CGEQRF/ZGEQRF) or F08BSF (CGEQPF/ZGEQPF).

9: C(LDC,*) – ***complex*** array *Input/Output*

Note: the second dimension of the array C must be at least $\max(1, \mathrm{N})$.

On entry: the m by n matrix C.

On exit: C is overwritten by QC or Q^HC or CQ or CQ^H as specified by SIDE and TRANS.

10: LDC – INTEGER *Input*

On entry: the first dimension of the array C as declared in the (sub)program from which F08AUF (CUNMQR/ZUNMQR) is called.

Constraint: LDC $\geq$ max$(1, \mathrm{M})$.

11: WORK(*) – ***complex*** array *Workspace*

Note: the dimension of the array WORK must be at least max$(1, \mathrm{LWORK})$.

On exit: if INFO $= 0$, the real part of WORK(1) contains the minimum value of LWORK required for optimum performance.

12: LWORK – INTEGER *Input*

On entry: the dimension of the array WORK as declared in the (sub)program from which F08AUF (CUNMQR/ZUNMQR) is called, unless LWORK $= -1$, in which case a workspace query is assumed and the routine only calculates the optimal dimension of WORK (using the formula given below).

Suggested value: for optimum performance LWORK should be at least N $\times$ nb if SIDE = 'L' and at least M $\times$ nb if SIDE = 'R', where nb is the ***blocksize***.

Constraints:

LWORK $\geq$ max$(1, \mathrm{N})$ or LWORK $= -1$ if SIDE = 'L',
LWORK $\geq$ max$(1, \mathrm{M})$ or LWORK $= -1$ if SIDE = 'R'.

13: INFO – INTEGER *Output*

On exit: INFO $= 0$ unless the routine detects an error (see Section 6).

6 Error Indicators and Warnings

Errors or warnings detected by the routine:

INFO < 0

If INFO $= -i$, the ith parameter had an illegal value. An explanatory message is output, and execution of the program is terminated.

7 Accuracy

The computed result differs from the exact result by a matrix E such that

$$\|E\|_2 = O(\epsilon)\|C\|_2,$$

where ϵ is the ***machine precision***.

8 Further Comments

The total number of real floating-point operations is approximately $8nk(2m-k)$ if SIDE = 'L' and $8mk(2n-k)$ if SIDE = 'R'.

The real analogue of this routine is F08AGF (SORMQR/DORMQR).

9 Example

See Section 9 of the document for F08ASF (CGEQRF/ZGEQRF).
