NAG Library

Tuned and Enhanced Routines in the
NAG Library for SMP & Multicore

1   Introduction

Tuned routines are user-callable routines that have been parallelized, or otherwise optimized, in the NAG Library for SMP & Multicore to give improved performance over the equivalent routines in the NAG Fortran Library or in the standard Netlib version of LAPACK. Enhanced routines are defined to be those user-callable routines which internally call one or more of the tuned routines, and hence may also exhibit improved performance and scalability. There are a total of 226 tuned routines and a total of 361 enhanced routines within the Library.

The NAG Library for SMP & Multicore is designed to be used in conjunction with the appropriate vendor library on each platform, as it relies upon the vendor library for optimized BLAS and FFT routines. The vendor libraries generally include LAPACK as well, and the vendor may also have parallelized or otherwise optimized some of these LAPACK routines. For each implementation, the performance of the LAPACK routines listed in Section 2 has been investigated, and the best combination of NAG Library for SMP & Multicore and vendor library versions is selected. Thus, in a given implementation, not all of the routines listed in Section 2 will actually be the NAG Library for SMP & Multicore version – consult the Users' Note for your implementation for further information.

2   Tuned LAPACK Routines

There are 77 tuned LAPACK routines within the Library.

Routine Name	Purpose
F07ADF	LU factorization of real m by n matrix
F07AEF	Solution of real system of linear equations, multiple right-hand sides, matrix already factorized by F07ADF (DGETRF)
F07AHF	Refined solution with error bounds of real system of linear equations, multiple right-hand sides
F07ARF	LU factorization of complex m by n matrix
F07ASF	Solution of complex system of linear equations, multiple right-hand sides, matrix already factorized by F07ARF (ZGETRF)
F07AVF	Refined solution with error bounds of complex system of linear equations, multiple right-hand sides
F07BDF	LU factorization of real m by n band matrix
F07BEF	Solution of real band system of linear equations, multiple right-hand sides, matrix already factorized by F07BDF (DGBTRF)
F07BHF	Refined solution with error bounds of real band system of linear equations, multiple right-hand sides
F07BRF	LU factorization of complex m by n band matrix
F07BSF	Solution of complex band system of linear equations, multiple right-hand sides, matrix already factorized by F07BRF (ZGBTRF)
F07BVF	Refined solution with error bounds of complex band system of linear equations, multiple right-hand sides
F07CHF	Refined solution with error bounds of real tridiagonal system of linear equations, multiple right-hand sides

F07CVF   Refined solution with error bounds of complex tridiagonal system of linear equations, multiple right-hand sides

F07FDF   Cholesky factorization of real symmetric positive definite matrix

F07FEF   Solution of real symmetric positive definite system of linear equations, multiple right-hand sides, matrix already factorized by F07FDF (DPOTRF)

F07FHF   Refined solution with error bounds of real symmetric positive definite system of linear equations, multiple right-hand sides

F07FRF   Cholesky factorization of complex Hermitian positive definite matrix

F07FSF   Solution of complex Hermitian positive definite system of linear equations, multiple right-hand sides, matrix already factorized by F07FRF (ZPOTRF)

F07FVF   Refined solution with error bounds of complex Hermitian positive definite system of linear equations, multiple right-hand sides

F07GEF   Solution of real symmetric positive definite system of linear equations, multiple right-hand sides, matrix already factorized by F07GDF (DPPTRF), packed storage

F07GHF   Refined solution with error bounds of real symmetric positive definite system of linear equations, multiple right-hand sides, packed storage

F07GSF   Solution of complex Hermitian positive definite system of linear equations, multiple right-hand sides, matrix already factorized by F07GRF (ZPPTRF), packed storage

F07GVF   Refined solution with error bounds of complex Hermitian positive definite system of linear equations, multiple right-hand sides, packed storage

F07HEF   Solution of real symmetric positive definite band system of linear equations, multiple right-hand sides, matrix already factorized by F07HDF (DPBTRF)

F07HHF   Refined solution with error bounds of real symmetric positive definite band system of linear equations, multiple right-hand sides

F07HSF   Solution of complex Hermitian positive definite band system of linear equations, multiple right-hand sides, matrix already factorized by F07HRF (ZPBTRF)

F07HVF   Refined solution with error bounds of complex Hermitian positive definite band system of linear equations, multiple right-hand sides

F07JHF   Refined solution with error bounds of real symmetric positive definite tridiagonal system of linear equations, multiple right-hand sides

F07JVF   Refined solution with error bounds of complex Hermitian positive definite tridiagonal system of linear equations, multiple right-hand sides

F07MHF   Refined solution with error bounds of real symmetric indefinite system of linear equations, multiple right-hand sides

F07MVF   Refined solution with error bounds of complex Hermitian indefinite system of linear equations, multiple right-hand sides

F07NVF   Refined solution with error bounds of complex symmetric system of linear equations, multiple right-hand sides

F07PHF   Refined solution with error bounds of real symmetric indefinite system of linear equations, multiple right-hand sides, packed storage

F07PVF   Refined solution with error bounds of complex Hermitian indefinite system of linear equations, multiple right-hand sides, packed storage

F07QVF   Refined solution with error bounds of complex symmetric system of linear equations, multiple right-hand sides, packed storage

F07THF   Error bounds for solution of real triangular system of linear equations, multiple right-hand sides

F07TVF	Error bounds for solution of complex triangular system of linear equations, multiple right-hand sides
F07UEF	Solution of real triangular system of linear equations, multiple right-hand sides, packed storage
F07UHF	Error bounds for solution of real triangular system of linear equations, multiple right-hand sides, packed storage
F07USF	Solution of complex triangular system of linear equations, multiple right-hand sides, packed storage
F07UVF	Error bounds for solution of complex triangular system of linear equations, multiple right-hand sides, packed storage
F07VEF	Solution of real band triangular system of linear equations, multiple right-hand sides
F07VHF	Error bounds for solution of real band triangular system of linear equations, multiple right-hand sides
F07VSF	Solution of complex band triangular system of linear equations, multiple right-hand sides
F07VVF	Error bounds for solution of complex band triangular system of linear equations, multiple right-hand sides
F08AEF	QR factorization of real general rectangular matrix
F08AFF	Form all or part of orthogonal Q from QR factorization determined by F08AEF (DGEQRF), F08BEF (DGEQPF) or F08BFF (DGEQP3)
F08AGF	Apply orthogonal transformation determined by F08AEF (DGEQRF), F08BEF (DGEQPF) or F08BFF (DGEQP3)
F08ASF	QR factorization of complex general rectangular matrix
F08ATF	Form all or part of unitary Q from QR factorization determined by F08ASF (ZGEQRF), F08BSF (ZGEQPF) or F08BTF (ZGEQP3)
F08AUF	Apply unitary transformation determined by F08ASF (ZGEQRF), F08BSF (ZGEQPF) or F08BTF (ZGEQP3)
F08FEF	Orthogonal reduction of real symmetric matrix to symmetric tridiagonal form
F08FFF	Generate orthogonal transformation matrix from reduction to tridiagonal form determined by F08FEF (DSYTRD)
F08FSF	Unitary reduction of complex Hermitian matrix to real symmetric tridiagonal form
F08FTF	Generate unitary transformation matrix from reduction to tridiagonal form determined by F08FSF (ZHETRD)
F08GFF	Generate orthogonal transformation matrix from reduction to tridiagonal form determined by F08GEF (DSPTRD)
F08GTF	Generate unitary transformation matrix from reduction to tridiagonal form determined by F08GSF (ZHPTRD)
F08HEF	Orthogonal reduction of real symmetric band matrix to symmetric tridiagonal form
F08HSF	Unitary reduction of complex Hermitian band matrix to real symmetric tridiagonal form
F08JEF	All eigenvalues and eigenvectors of real symmetric tridiagonal matrix, reduced from real symmetric matrix using the implicit QL or QR algorithm
F08JJF	Selected eigenvalues of real symmetric tridiagonal matrix by bisection
F08JKF	Selected eigenvectors of real symmetric tridiagonal matrix by inverse iteration, storing eigenvectors in real array
F08JSF	All eigenvalues and eigenvectors of real symmetric tridiagonal matrix, reduced from complex Hermitian matrix, using the implicit QL or QR algorithm

F08JXF   Selected eigenvectors of real symmetric tridiagonal matrix by inverse iteration, storing eigenvectors in complex array

F08KEF   Orthogonal reduction of real general rectangular matrix to bidiagonal form

F08KSF   Unitary reduction of complex general rectangular matrix to bidiagonal form

F08MEF   SVD of real bidiagonal matrix reduced from real general matrix

F08MSF   SVD of real bidiagonal matrix reduced from complex general matrix

F08PKF   Selected right and/or left eigenvectors of real upper Hessenberg matrix by inverse iteration

F08PXF   Selected right and/or left eigenvectors of complex upper Hessenberg matrix by inverse iteration

F08TAF   Computes all the eigenvalues, and optionally, the eigenvectors of a real generalized symmetric-definite eigenproblem, packed storage

F08TBF   Computes selected eigenvalues, and optionally, the eigenvectors of a real generalized symmetric-definite eigenproblem, packed storage

F08TCF   Computes all the eigenvalues, and optionally, the eigenvectors of a real generalized symmetric-definite eigenproblem, packed storage (divide-and-conquer)

F08TNF   Computes all the eigenvalues, and optionally, the eigenvectors of a complex generalized Hermitian-definite eigenproblem, packed storage

F08TPF   Computes selected eigenvalues, and optionally, the eigenvectors of a complex generalized Hermitian-definite eigenproblem, packed storage

F08TQF   Computes selected eigenvalues, and optionally, the eigenvectors of a complex generalized Hermitian-definite eigenproblem, packed storage (divide-and-conquer)

3   Routines Enhanced by Calling Tuned LAPACK Routines

These routines call one or more of the tuned LAPACK routines as part of their core operations and may thereby exhibit improved performance and scalability. There are 266 of these routines within the Library.

**Routine
Name   Purpose**

C02AKF   All zeros of real cubic equation

C02ALF   All zeros of real quartic equation

C02AMF   All zeros of complex cubic equation

C02ANF   All zeros of complex quartic equation

C05QBF   Solution of a system of nonlinear equations using function values only (easy-to-use)

C05QCF   Solution of a system of nonlinear equations using function values only (comprehensive)

C05QDF   Solution of a system of nonlinear equations using function values only (reverse communication)

C05RBF   Solution of a system of nonlinear equations using first derivatives (easy-to-use)

C05RCF   Solution of a system of nonlinear equations using first derivatives (comprehensive)

C05RDF   Solution of a system of nonlinear equations using first derivatives (reverse communication)

D02AGF   Ordinary differential equations, boundary value problem, shooting and matching technique, allowing interior matching point, general parameters to be determined

D02HAF   Ordinary differential equations, boundary value problem, shooting and matching, boundary values to be determined

D02HBF   Ordinary differential equations, boundary value problem, shooting and matching, general parameters to be determined

D02NEF	Implicit ordinary differential equations/DAEs, initial value problem, DASSL method integrator
D02SAF	Ordinary differential equations, boundary value problem, shooting and matching technique, subject to extra algebraic equations, general parameters to be determined
D02TKF	Ordinary differential equations, general nonlinear boundary value problem, collocation technique
D02UEF	Solve linear constant coefficient boundary value problem on Chebyshev grid, Integral formulation
D03NCF	Finite difference solution of the Black–Scholes equations
D05BDF	Nonlinear convolution Volterra–Abel equation, second kind, weakly singular
D05BEF	Nonlinear convolution Volterra–Abel equation, first kind, weakly singular
E02JDF	Spline approximation to a set of scattered data using a two-stage approximation method
E04FCF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using function values only (comprehensive)
E04FYF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using function values only (easy-to-use)
E04GBF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and quasi-Newton algorithm using first derivatives (comprehensive)
E04GDF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using first derivatives (comprehensive)
E04GYF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and quasi-Newton algorithm, using first derivatives (easy-to-use)
E04GZF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using first derivatives (easy-to-use)
E04HEF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm, using second derivatives (comprehensive)
E04HYF	Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm, using second derivatives (easy-to-use)
E04NCF	Convex QP problem or linearly-constrained linear least squares problem (dense)
E04UCF	Minimum, function of several variables, sequential QP method, nonlinear constraints, using function values and optionally first derivatives (comprehensive)
E04UFF	Minimum, function of several variables, sequential QP method, nonlinear constraints, using function values and optionally first derivatives (reverse communication, comprehensive)
E04USF	Minimum of a sum of squares, nonlinear constraints, sequential QP method, using function values and optionally first derivatives (comprehensive)
F01ABF	Inverse of real symmetric positive definite matrix using iterative refinement
F01ADF	Inverse of real symmetric positive definite matrix
F01ECF	Real matrix exponential
F01EDF	Real symmetric matrix exponential
F01EFF	Function of a real symmetric matrix
F01ELF	Function of a real matrix (using numerical differentiation)
F01FCF	Complex matrix exponential
F01FDF	Complex Hermitian matrix exponential
F01FFF	Function of a complex Hermitian matrix
F01FLF	Function of a complex matrix (using numerical differentiation)

F01JAF   Condition number for the exponential, logarithm, sine, cosine, sinh or cosh of a real matrix

F01JBF   Condition number for a function of a real matrix (using numerical differentiation)

F01JCF   Condition number for a function of a real matrix (using user-supplied derivatives)

F01KAF   Condition number for the exponential, logarithm, sine, cosine, sinh or cosh of a complex matrix

F01KBF   Condition number for a function of a complex matrix (using numerical differentiation)

F01KCF   Condition number for a function of a complex matrix (using user-supplied derivatives)

F02ECF   Selected eigenvalues and eigenvectors of real nonsymmetric matrix (Black Box)

F02FJF   Selected eigenvalues and eigenvectors of sparse symmetric eigenproblem (Black Box)

F02GCF   Selected eigenvalues and eigenvectors of complex nonsymmetric matrix (Black Box)

F02WDF QR factorization, possibly followed by SVD

F02WGF   Computes leading terms in the singular value decomposition of a real general matrix; also computes corresponding left and right singular vectors

F02WUF   SVD of real upper triangular matrix (Black Box)

F02XUF   SVD of complex upper triangular matrix (Black Box)

F04ABF   Solution of real symmetric positive definite simultaneous linear equations with multiple right-hand sides using iterative refinement (Black Box)

F04ASF   Solution of real symmetric positive definite simultaneous linear equations, one right-hand side using iterative refinement (Black Box)

F04BAF   Computes the solution and error-bound to a real system of linear equations

F04BBF   Computes the solution and error-bound to a real banded system of linear equations

F04BDF   Computes the solution and error-bound to a real symmetric positive definite system of linear equations

F04BEF   Computes the solution and error-bound to a real symmetric positive definite system of linear equations, packed storage

F04BFF   Computes the solution and error-bound to a real symmetric positive definite banded system of linear equations

F04CAF   Computes the solution and error-bound to a complex system of linear equations

F04CBF   Computes the solution and error-bound to a complex banded system of linear equations

F04CDF   Computes the solution and error-bound to a complex Hermitian positive definite system of linear equations

F04CEF   Computes the solution and error-bound to a complex Hermitian positive definite system of linear equations, packed storage

F04CFF   Computes the solution and error-bound to a complex Hermitian positive definite banded system of linear equations

F04JGF   Least squares (if rank $= n$) or minimal least squares (if rank $< n$) solution of m real equations in n unknowns, $m \geq n$

F07AAF   Computes the solution to a real system of linear equations

F07ABF   Uses the LU factorization to compute the solution, error-bound and condition estimate for a real system of linear equations

F07ACF   Mixed precision real system solver

F07ANF   Computes the solution to a complex system of linear equations

F07APF   Uses the *LU* factorization to compute the solution, error-bound and condition estimate for a complex system of linear equations

F07AQF   Mixed precision complex system solver

F07BAF   Computes the solution to a real banded system of linear equations

F07BBF   Uses the *LU* factorization to compute the solution, error-bound and condition estimate for a real banded system of linear equations

F07BNF   Computes the solution to a complex banded system of linear equations

F07BPF   Uses the *LU* factorization to compute the solution, error-bound and condition estimate for a complex banded system of linear equations

F07CBF   Uses the *LU* factorization to compute the solution, error-bound and condition estimate for a real tridiagonal system of linear equations

F07CPF   Uses the *LU* factorization to compute the solution, error-bound and condition estimate for a complex tridiagonal system of linear equations

F07FAF   Computes the solution to a real symmetric positive definite system of linear equations

F07FBF   Uses the Cholesky factorization to compute the solution, error-bound and condition estimate for a real symmetric positive definite system of linear equations

F07FCF   Uses the Cholesky factorization to compute the solution for a real symmetric positive definite system of linear equations

F07FNF   Computes the solution to a complex Hermitian positive definite system of linear equations

F07FPF   Uses the Cholesky factorization to compute the solution, error-bound and condition estimate for a complex Hermitian positive definite system of linear equations

F07FQF   Uses the Cholesky factorization to compute the solution for a complex Hermitian positive definite system of linear equations

F07GAF   Computes the solution to a real symmetric positive definite system of linear equations, packed storage

F07GBF   Uses the Cholesky factorization to compute the solution, error-bound and condition estimate for a real symmetric positive definite system of linear equations, packed storage

F07GNF   Computes the solution to a complex Hermitian positive definite system of linear equations, packed storage

F07GPF   Uses the Cholesky factorization to compute the solution, error-bound and condition estimate for a complex Hermitian positive definite system of linear equations, packed storage

F07HAF   Computes the solution to a real symmetric positive definite banded system of linear equations

F07HBF   Uses the Cholesky factorization to compute the solution, error-bound and condition estimate for a real symmetric positive definite banded system of linear equations

F07HNF   Computes the solution to a complex Hermitian positive definite banded system of linear equations

F07HPF   Uses the Cholesky factorization to compute the solution, error-bound and condition estimate for a complex Hermitian positive definite banded system of linear equations

F07JBF   Uses the modified Cholesky factorization to compute the solution, error-bound and condition estimate for a real symmetric positive definite tridiagonal system of linear equations

F07JPF   Uses the modified Cholesky factorization to compute the solution, error-bound and condition estimate for a complex Hermitian positive definite tridiagonal system of linear equations

F07MBF   Uses the diagonal pivoting factorization to compute the solution to a real symmetric system of linear equations

F07MPF   Uses the diagonal pivoting factorization to compute the solution to a complex Hermitian system of linear equations

F07NPF   Uses the diagonal pivoting factorization to compute the solution to a complex symmetric system of linear equations

F07PBF   Uses the diagonal pivoting factorization to compute the solution to a real symmetric system of linear equations, packed storage

F07PPF   Uses the diagonal pivoting factorization to compute the solution to a complex Hermitian system of linear equations, packed storage

F07QPF   Uses the diagonal pivoting factorization to compute the solution to a complex symmetric system of linear equations, packed storage

F07WDF   Cholesky factorization of real symmetric positive definite matrix, Rectangular Full Packed format

F07WRF   Cholesky factorization of complex Hermitian positive definite matrix, Rectangular Full Packed format

F08AAF   Solves an overdetermined or underdetermined real linear system

F08ANF   Solves an overdetermined or underdetermined complex linear system

F08BAF   Computes the minimum-norm solution to a real linear least squares problem

F08BFF QR factorization of real general rectangular matrix with column pivoting, using BLAS-3

F08BNF   Computes the minimum-norm solution to a complex linear least squares problem

F08BTF QR factorization of complex general rectangular matrix with column pivoting, using BLAS-3

F08FAF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric matrix

F08FBF   Computes selected eigenvalues and, optionally, eigenvectors of a real symmetric matrix

F08FCF   Computes all eigenvalues and, optionally, all eigenvectors of real symmetric matrix (divide-and-conquer)

F08FDF   Computes selected eigenvalues and, optionally, eigenvectors of a real symmetric matrix (Relatively Robust Representations)

F08FGF   Apply orthogonal transformation determined by F08FEF (DSYTRD)

F08FNF   Computes all eigenvalues and, optionally, eigenvectors of a complex Hermitian matrix

F08FPF   Computes selected eigenvalues and, optionally, eigenvectors of a complex Hermitian matrix

F08FQF   Computes all eigenvalues and, optionally, all eigenvectors of complex Hermitian matrix (divide-and-conquer)

F08FRF   Computes selected eigenvalues and, optionally, eigenvectors of a complex Hermitian matrix (Relatively Robust Representations)

F08FUF   Apply unitary transformation matrix determined by F08FSF (ZHETRD)

F08GAF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric matrix, packed storage

F08GBF   Computes selected eigenvalues and, optionally, eigenvectors of a real symmetric matrix, packed storage

F08GCF   Computes all eigenvalues and, optionally, all eigenvectors of real symmetric matrix, packed storage (divide-and-conquer)

F08GNF   Computes all eigenvalues and, optionally, eigenvectors of a complex Hermitian matrix, packed storage

F08GPF   Computes selected eigenvalues and, optionally, eigenvectors of a complex Hermitian matrix, packed storage

F08GQF   Computes all eigenvalues and, optionally, all eigenvectors of complex Hermitian matrix, packed storage (divide-and-conquer)

F08HAF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric band matrix

F08HBF   Computes selected eigenvalues and, optionally, eigenvectors of a real symmetric band matrix

F08HCF   Computes all eigenvalues and, optionally, all eigenvectors of real symmetric band matrix (divide-and-conquer)

F08HNF   Computes all eigenvalues and, optionally, eigenvectors of a complex Hermitian band matrix

F08HPF   Computes selected eigenvalues and, optionally, eigenvectors of a complex Hermitian band matrix

F08HQF   Computes all eigenvalues and, optionally, all eigenvectors of complex Hermitian band matrix (divide-and-conquer)

F08JAF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric tridiagonal matrix

F08JBF   Computes selected eigenvalues and, optionally, eigenvectors of a real symmetric tridiagonal matrix

F08JCF   Computes all eigenvalues and, optionally, all eigenvectors of real symmetric tridiagonal matrix (divide-and-conquer)

F08JDF   Computes selected eigenvalues and, optionally, eigenvectors of a real symmetric tridiagonal matrix (Relatively Robust Representations)

F08JGF   Computes all eigenvalues and eigenvectors of real symmetric positive definite tridiagonal matrix, reduced from real symmetric positive definite matrix

F08JHF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric tridiagonal matrix or a matrix reduced to this form (divide-and-conquer)

F08JLF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric tridiagonal matrix or a symmetric matrix reduced to this form (Relatively Robust Representations)

F08JUF   Computes all eigenvalues and eigenvectors of real symmetric positive definite tridiagonal matrix, reduced from complex Hermitian positive definite matrix

F08JVF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric tridiagonal matrix or a complex Hermitian matrix reduced to this form (divide-and-conquer)

F08JYF   Computes all eigenvalues and, optionally, eigenvectors of a real symmetric tridiagonal matrix or a complex Hermitian matrix reduced to this form (Relatively Robust Representations)

F08KAF   Computes the minimum-norm solution to a real linear least squares problem using singular value decomposition

F08KBF   Computes the singular value decomposition of a real matrix, optionally computing the left and/or right singular vectors

F08KCF   Computes the minimum-norm solution to a real linear least squares problem using singular value decomposition (divide-and-conquer)

F08KDF   Computes the singular value decomposition of a real matrix, optionally computing the left and/or right singular vectors (divide-and-conquer)

F08KFF   Generate orthogonal transformation matrices from reduction to bidiagonal form determined by F08KEF (DGEBRD)

F08KGF   Apply orthogonal transformations from reduction to bidiagonal form determined by F08KEF (DGEBRD)

F08KHF   Computes the singular value decomposition of a real matrix, optionally computing the left and/or right singular vectors (preconditioned Jacobi)

F08KNF   Computes the minimum-norm solution to a complex linear least squares problem using singular value decomposition

F08KPF   Computes the singular value decomposition of a complex matrix, optionally computing the left and/or right singular vectors

F08KQF   Computes the minimum-norm solution to a complex linear least squares problem using singular value decomposition (divide-and-conquer)

F08KRF   Computes the singular value decomposition of a complex matrix, optionally computing the left and/or right singular vectors (divide-and-conquer)

F08KTF   Generate unitary transformation matrices from reduction to bidiagonal form determined by F08KSF (ZGEBRD)

F08KUF   Apply unitary transformations from reduction to bidiagonal form determined by F08KSF (ZGEBRD)

F08MDF   Computes the singular value decomposition of a real bidiagonal matrix, optionally computing the singular vectors (divide-and-conquer)

F08NAF   Computes all eigenvalues and, optionally, left and/or right eigenvectors of a real nonsymmetric matrix

F08NBF   Computes all eigenvalues and, optionally, left and/or right eigenvectors of a real nonsymmetric matrix; also, optionally, the balancing transformation, the reciprocal condition numbers for the eigenvalues and for the right eigenvectors

F08NFF   Generate orthogonal transformation matrix from reduction to Hessenberg form determined by F08NEF (DGEHRD)

F08NGF   Apply orthogonal transformation matrix from reduction to Hessenberg form determined by F08NEF (DGEHRD)

F08NNF   Computes all eigenvalues and, optionally, left and/or right eigenvectors of a complex nonsymmetric matrix

F08NPF   Computes all eigenvalues and, optionally, left and/or right eigenvectors of a complex nonsymmetric matrix; also, optionally, the balancing transformation, the reciprocal condition numbers for the eigenvalues and for the right eigenvectors

F08NTF   Generate unitary transformation matrix from reduction to Hessenberg form determined by F08NSF (ZGEHRD)

F08NUF   Apply unitary transformation matrix from reduction to Hessenberg form determined by F08NSF (ZGEHRD)

F08PAF   Computes for real square nonsymmetric matrix, the eigenvalues, the real Schur form, and, optionally, the matrix of Schur vectors

F08PBF   Computes for real square nonsymmetric matrix, the eigenvalues, the real Schur form, and, optionally, the matrix of Schur vectors; also, optionally, computes reciprocal condition numbers for selected eigenvalues

F08PEF   Computes the eigenvalues and Schur factorization of real upper Hessenberg matrix reduced from real general matrix

F08PNF   Computes for complex square nonsymmetric matrix, the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors

F08PPF   Computes for real square nonsymmetric matrix, the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors; also, optionally, computes reciprocal condition numbers for selected eigenvalues

F08PSF   Computes the eigenvalues and Schur factorization of complex upper Hessenberg matrix reduced from complex general matrix

F08SAF   Computes all the eigenvalues, and optionally, the eigenvectors of a real generalized symmetric-definite eigenproblem

F08SBF   Computes selected eigenvalues, and optionally, the eigenvectors of a real generalized symmetric-definite eigenproblem

F08SCF   Computes all the eigenvalues, and optionally, the eigenvectors of a real generalized symmetric-definite eigenproblem (divide-and-conquer)

F08SNF   Computes all the eigenvalues, and optionally, the eigenvectors of a complex generalized Hermitian-definite eigenproblem

F08SPF   Computes selected eigenvalues, and optionally, the eigenvectors of a complex generalized Hermitian-definite eigenproblem

F08SQF   Computes all the eigenvalues, and optionally, the eigenvectors of a complex generalized Hermitian-definite eigenproblem (divide-and-conquer)

F08UAF   Computes all the eigenvalues, and optionally, the eigenvectors of a real banded generalized symmetric-definite eigenproblem

F08UBF   Computes selected eigenvalues, and optionally, the eigenvectors of a real banded generalized symmetric-definite eigenproblem

F08UCF   Computes all the eigenvalues, and optionally, the eigenvectors of a real banded generalized symmetric-definite eigenproblem (divide-and-conquer)

F08UNF   Computes all the eigenvalues, and optionally, the eigenvectors of a complex banded generalized Hermitian-definite eigenproblem

F08UPF   Computes selected eigenvalues, and optionally, the eigenvectors of a complex banded generalized Hermitian-definite eigenproblem

F08UQF   Computes all the eigenvalues, and optionally, the eigenvectors of a complex banded generalized Hermitian-definite eigenproblem (divide-and-conquer)

F08WAF   Computes, for a real nonsymmetric matrix pair, the generalized eigenvalues, and optionally, the left and/or right generalized eigenvectors

F08WBF   Computes, for a real nonsymmetric matrix pair, the generalized eigenvalues, and optionally, the left and/or right generalized eigenvectors; also, optionally, the balancing transformation, the reciprocal condition numbers for the eigenvalues and for the right eigenvectors

F08WNF   Computes, for a complex nonsymmetric matrix pair, the generalized eigenvalues, and optionally, the left and/or right generalized eigenvectors

F08WPF   Computes, for a complex nonsymmetric matrix pair, the generalized eigenvalues, and optionally, the left and/or right generalized eigenvectors; also, optionally, the balancing transformation, the reciprocal condition numbers for the eigenvalues and for the right eigenvectors

F08XAF   Computes, for a real nonsymmetric matrix pair, the generalized eigenvalues, the generalized real Schur form and, optionally, the left and/or right matrices of Schur vectors

F08XBF   Computes, for a real nonsymmetric matrix pair, the generalized eigenvalues, the generalized real Schur form and, optionally, the left and/or right matrices of Schur vectors; also, optionally, computes reciprocal condition numbers for selected eigenvalues

F08XNF   Computes, for a complex nonsymmetric matrix pair, the generalized eigenvalues, the generalized complex Schur form and, optionally, the left and/or right matrices of Schur vectors

F08XPF   Computes, for a complex nonsymmetric matrix pair, the generalized eigenvalues, the generalized complex Schur form and, optionally, the left and/or right matrices of Schur vectors; also, optionally, computes reciprocal condition numbers for selected eigenvalues

F08ZAF   Solves the real linear equality-constrained least squares (LSE) problem

F08ZBF   Solves a real general Gauss–Markov linear model (GLM) problem

F08ZEF   Computes a generalized QR factorization of a real matrix pair

F08ZFF   Computes a generalized RQ factorization of a real matrix pair

F08ZNF   Solves the complex linear equality-constrained least squares (LSE) problem

F08ZPF   Solves a complex general Gauss–Markov linear model (GLM) problem

F08ZSF   Computes a generalized QR factorization of a complex matrix pair

F08ZTF	Computes a generalized RQ factorization of a complex matrix pair
F12AUF	Selected eigenvalues and, optionally, eigenvectors of complex non-Hermitian banded eigenproblem, driver
F12FCF	Selected eigenvalues and, optionally, eigenvectors of a real symmetric sparse eigenproblem, postprocessing for F12FBF
F12FGF	Selected eigenvalues and, optionally, eigenvectors of a real symmetric banded eigenproblem, driver
G01HBF	Computes probabilities for the multivariate Normal distribution
G01LBF	Computes a vector of values for the probability density function of the multivariate Normal distribution
G02ABF	Computes the nearest correlation matrix to a real square matrix, augmented G02AAF to incorporate weights and bounds
G02AEF	Computes the nearest correlation matrix with k-factor structure to a real square matrix
G02AJF	Computes the nearest correlation matrix to a real square matrix, using element-wise weighting
G02BYF	Computes partial correlation/variance-covariance matrix from correlation/variance-covariance matrix computed by G02BXF
G02CGF	Multiple linear regression, from correlation coefficients, with constant term
G02CHF	Multiple linear regression, from correlation-like coefficients, without constant term
G02DAF	Fits a general (multiple) linear regression model
G02DDF	Estimates of linear parameters and general linear regression model from updated model
G02EAF	Computes residual sums of squares for all possible linear regressions for a set of independent variables
G02EEF	Fits a linear regression model by forward selection
G02GAF	Fits a generalized linear model with Normal errors
G02GBF	Fits a generalized linear model with binomial errors
G02GCF	Fits a generalized linear model with Poisson errors
G02GDF	Fits a generalized linear model with gamma errors
G02HAF	Robust regression, standard M-estimates
G02HDF	Robust regression, compute regression with user-supplied functions and weights
G02HFF	Robust regression, variance-covariance matrix following G02HDF
G02JAF	Linear mixed effects regression using Restricted Maximum Likelihood (REML)
G02JBF	Linear mixed effects regression using Maximum Likelihood (ML)
G02KAF	Ridge regression, optimizing a ridge regression parameter
G02KBF	Ridge regression using a number of supplied ridge regression parameters
G02LAF	Partial least squares (PLS) regression using singular value decomposition
G02LCF	PLS parameter estimates following partial least squares regression by G02LAF or G02LBF
G02QFF	Linear quantile regression, simple interface, independent, identically distributed (IID) errors
G02QGF	Linear quantile regression, comprehensive interface
G03AAF	Performs principal component analysis
G03ACF	Performs canonical variate analysis
G03ADF	Performs canonical correlation analysis

G03BAF   Computes orthogonal rotations for loading matrix, generalized orthomax criterion

G03BCF   Computes Procrustes rotations

G03BDF   ProMax rotations

G03DAF   Computes test statistic for equality of within-group covariance matrices and matrices for discriminant analysis

G03FAF   Performs principal coordinate analysis, classical metric scaling

G04BBF   Analysis of variance, randomized block or completely randomized design, treatment means and standard errors

G04BCF   Analysis of variance, general row and column design, treatment means and standard errors

G05PJF   Generates a realisation of a multivariate time series from a VARMA model

G08RAF   Regression using ranks, uncensored data

G08RBF   Regression using ranks, right-censored data

G11CAF   Returns parameter estimates for the conditional analysis of stratified data

G11SAF   Contingency table, latent variable model for binary data

G12ABF   Computes rank statistics for comparing survival curves

G12BAF   Fits Cox's proportional hazard model

G13AEF   Univariate time series, estimation, seasonal ARIMA model (comprehensive)

G13AFF   Univariate time series, estimation, seasonal ARIMA model (easy-to-use)

G13AJF   Univariate time series, state set and forecasts, from fully specified seasonal ARIMA model

G13ASF   Univariate time series, diagnostic checking of residuals, following G13AEF or G13AFF

G13BAF   Multivariate time series, filtering (pre-whitening) by an ARIMA model

G13BBF   Multivariate time series, filtering by a transfer function model

G13BDF   Multivariate time series, preliminary estimation of transfer function model

G13BEF   Multivariate time series, estimation of multi-input model

G13BJF   Multivariate time series, state set and forecasts from fully specified multi-input model

G13DBF   Multivariate time series, multiple squared partial autocorrelations

G13DDF   Multivariate time series, estimation of VARMA model

G13DJF   Multivariate time series, forecasts and their standard errors

G13DNF   Multivariate time series, sample partial lag correlation matrices, χ^2 statistics and significance levels

G13DPF   Multivariate time series, partial autoregression matrices

G13DSF   Multivariate time series, diagnostic checking of residuals, following G13DDF

G13DXF   Calculates the zeros of a vector autoregressive (or moving average) operator

G13FAF   Univariate time series, parameter estimation for either a symmetric GARCH process or a GARCH process with asymmetry of the form $(\epsilon_{t-1} + \gamma)^2$

G13FCF   Univariate time series, parameter estimation for a GARCH process with asymmetry of the form $(|\epsilon_{t-1}| + \gamma\epsilon_{t-1})^2$

G13FEF   Univariate time series, parameter estimation for an asymmetric Glosten, Jagannathan and Runkle (GJR) GARCH process

G13FGF   Univariate time series, parameter estimation for an exponential GARCH (EGARCH) process

4 Tuned NAG-specific Routines

These NAG-specific routines have been parallelized, or otherwise optimized, in the NAG Library for SMP & Multicore compared to the equivalent routine in the NAG Fortran Library. There are 149 of these routines within the Library.

Routine Name	Purpose
C06FKF	Circular convolution or correlation of two real vectors, extra workspace for greater speed
C06FPF	Multiple one-dimensional real discrete Fourier transforms
C06FQF	Multiple one-dimensional Hermitian discrete Fourier transforms
C06FXF	Three-dimensional complex discrete Fourier transform
C06PAF	Single one-dimensional real and Hermitian complex discrete Fourier transform, using complex storage format for Hermitian sequences
C06PFF	One-dimensional complex discrete Fourier transform of multidimensional data (using complex data type)
C06PJF	Multidimensional complex discrete Fourier transform of multidimensional data (using complex data type)
C06PKF	Circular convolution or correlation of two complex vectors
C06PPF	Multiple one-dimensional real and Hermitian complex discrete Fourier transforms, using row ordered complex storage format for Hermitian sequences
C06PQF	Multiple one-dimensional real and Hermitian complex discrete Fourier transforms, using column ordered complex storage format for Hermitian sequences
C06PRF	Multiple one-dimensional complex discrete Fourier transforms using complex data type
C06PSF	Multiple one-dimensional complex discrete Fourier transforms using complex data type and sequences stored as columns
C06PUF	Two-dimensional complex discrete Fourier transform, complex data type
C06PVF	Two-dimensional real-to-complex discrete Fourier transform
C06PWF	Two-dimensional complex-to-real discrete Fourier transform
C06PXF	Three-dimensional complex discrete Fourier transform, complex data type
C06PYF	Three-dimensional real-to-complex discrete Fourier transform
C06PZF	Three-dimensional complex-to-real discrete Fourier transform
C06RAF	Discrete sine transform (easy-to-use)
C06RBF	Discrete cosine transform (easy-to-use)
C06RCF	Discrete quarter-wave sine transform (easy-to-use)
C06RDF	Discrete quarter-wave cosine transform (easy-to-use)
C09EAF	Two-dimensional discrete wavelet transform
C09EBF	Two-dimensional inverse discrete wavelet transform
C09ECF	Two-dimensional multi-level discrete wavelet transform
C09EDF	Two-dimensional inverse multi-level discrete wavelet transform
C09FAF	Three-dimensional discrete wavelet transform
C09FBF	Three-dimensional inverse discrete wavelet transform
C09FCF	Three-dimensional multi-level discrete wavelet transform
C09FDF	Three-dimensional inverse multi-level discrete wavelet transform

D01DAF   Two-dimensional quadrature, finite region

D01FCF   Multidimensional adaptive quadrature over hyper-rectangle

D01GAF   One-dimensional quadrature, integration of function defined by data values, Gill–Miller method

D03FAF   Elliptic PDE, Helmholtz equation, three-dimensional Cartesian coordinates

D03RAF   General system of second-order PDEs, method of lines, finite differences, remeshing, two space variables, rectangular region

D03RBF   General system of second-order PDEs, method of lines, finite differences, remeshing, two space variables, rectilinear region

E01SGF   Interpolating functions, modified Shepard's method, two variables

E01SHF   Interpolated values, evaluate interpolant computed by E01SGF, function and first derivatives, two variables

E01TGF   Interpolating functions, modified Shepard's method, three variables

E01THF   Interpolated values, evaluate interpolant computed by E01TGF, function and first derivatives, three variables

E01TKF   Interpolating functions, modified Shepard's method, four variables

E01TLF   Interpolated values, evaluate interpolant computed by E01TKF, function and first derivatives, four variables

E01TMF   Interpolating functions, modified Shepard's method, five variables

E01TNF   Interpolated values, evaluate interpolant computed by E01TMF, function and first derivatives, five variables

E01ZMF   Interpolating function, modified Shepard's method, d dimensions

E01ZNF   Interpolated values, evaluate interpolant computed by E01ZMF, function and first derivatives, d dimensions

E02BFF   Evaluation of fitted cubic spline, function and optionally derivatives at a vector of points

E02CAF   Least squares surface fit by polynomials, data on lines parallel to one independent coordinate axis

E02CBF   Evaluation of fitted polynomial in two variables

E02DFF   Evaluation of fitted bicubic spline at a mesh of points

E05SAF   Global optimization using particle swarm algorithm (PSO), bound constraints only

E05SBF   Global optimization using particle swarm algorithm (PSO), comprehensive

E05UCF   Global optimization using multi-start, nonlinear constraints

E05USF   Global optimization of a sum of squares problem using multi-start, nonlinear constraints

F01CTF   Sum or difference of two real matrices, optional scaling and transposition

F01CWF   Sum or difference of two complex matrices, optional scaling and transposition

F01EJF   Real matrix logarithm

F01EKF   Exponential, sine, cosine, sinh or cosh of a real matrix (Schur–Parlett algorithm)

F01EMF   Function of a real matrix (using user-supplied derivatives)

F01FJF   Complex matrix logarithm

F01FKF   Exponential, sine, cosine, sinh or cosh of a complex matrix (Schur–Parlett algorithm)

F01FMF   Function of a complex matrix (using user-supplied derivatives)

F05AAF   Gram–Schmidt orthogonalization of n vectors of order m

F11BEF	Real sparse nonsymmetric linear systems, preconditioned RGMRES, CGS, Bi-CGSTAB or TFQMR method
F11BSF	Complex sparse non-Hermitian linear systems, preconditioned RGMRES, CGS, Bi-CGSTAB or TFQMR method
F11GEF	Real sparse symmetric linear systems, preconditioned conjugate gradient or Lanczos method or the MINRES algorithm
F11GSF	Complex sparse Hermitian linear systems, preconditioned conjugate gradient or Lanczos
F11MEF	*LU* factorization of real sparse matrix
F11MFF	Solution of real sparse simultaneous linear equations (coefficient matrix already factorized)
F11MHF	Refined solution with error bounds of real system of linear equations, multiple right-hand sides
F11MKF	Real sparse nonsymmetric matrix-matrix multiply, compressed column storage
F11XAF	Real sparse nonsymmetric matrix vector multiply
F11XEF	Real sparse symmetric matrix vector multiply
F11XNF	Complex sparse non-Hermitian matrix vector multiply
F11XSF	Complex sparse Hermitian matrix vector multiply
F12ABF	Selected eigenvalues and, optionally, eigenvectors of a real nonsymmetric sparse eigenproblem, reverse communication
F12AGF	Selected eigenvalues and, optionally, eigenvectors of a real nonsymmetric banded eigenproblem, driver
F12APF	Selected eigenvalues and, optionally, eigenvectors of a complex sparse eigenproblem, reverse communication
F12FBF	Selected eigenvalues and, optionally, eigenvectors of a real symmetric sparse eigenproblem, reverse communication
G01ATF	Computes univariate summary information: mean, variance, skewness, kurtosis
G01WAF	Computes the mean and standard deviation using a rolling window
G02AAF	Computes the nearest correlation matrix to a real square matrix, using the method of Qi and Sun
G02BAF	Pearson product-moment correlation coefficients, all variables, no missing values
G02BDF	Correlation-like coefficients (about zero), all variables, no missing values
G02BNF	Kendall/Spearman non-parametric rank correlation coefficients, no missing values, overwriting input data
G02BPF	Kendall/Spearman non-parametric rank correlation coefficients, casewise treatment of missing values, overwriting input data
G02BQF	Kendall/Spearman non-parametric rank correlation coefficients, no missing values, preserving input data
G02BRF	Kendall/Spearman non-parametric rank correlation coefficients, casewise treatment of missing values, preserving input data
G02JDF	Hierarchical mixed effects regression using Restricted Maximum Likelihood (REML)
G02JEF	Hierarchical mixed effects regression using Maximum Likelihood (ML)
G03CAF	Computes maximum likelihood estimates of the parameters of a factor analysis model, factor loadings, communalities and residual correlations
G03EAF	Computes distance matrix
G03ECF	Hierarchical cluster analysis

G03GAF   Fits a Gaussian mixture model

G05RCF   Generates a matrix of pseudorandom numbers from a Student's t-copula

G05RDF   Generates a matrix of pseudorandom numbers from a Gaussian copula

G05REF   Generates a matrix of pseudorandom numbers from a bivariate Clayton/Cook–Johnson copula

G05RFF   Generates a matrix of pseudorandom numbers from a bivariate Frank copula

G05RGF   Generates a matrix of pseudorandom numbers from a bivariate Plackett copula

G05RHF   Generates a matrix of pseudorandom numbers from a multivariate Clayton/Cook–Johnson copula

G05RJF   Generates a matrix of pseudorandom numbers from a multivariate Frank copula

G05RKF   Generates a matrix of pseudorandom numbers from a Gumbel–Hougaard copula

G05RYF   Generates a matrix of pseudorandom numbers from a multivariate Student's t-distribution

G05SAF   Generates a vector of pseudorandom numbers from a uniform distribution over $(0, 1]$

G05SBF   Generates a vector of pseudorandom numbers from a beta distribution

G05SCF   Generates a vector of pseudorandom numbers from a Cauchy distribution

G05SDF   Generates a vector of pseudorandom numbers from a χ^2 distribution

G05SEF   Generates a vector of pseudorandom numbers from a Dirichlet distribution

G05SFF   Generates a vector of pseudorandom numbers from an exponential distribution

G05SGF   Generates a vector of pseudorandom numbers from an exponential mix distribution

G05SHF   Generates a vector of pseudorandom numbers from an F-distribution

G05SJF   Generates a vector of pseudorandom numbers from a gamma distribution

G05SKF   Generates a vector of pseudorandom numbers from a Normal distribution

G05SLF   Generates a vector of pseudorandom numbers from a logistic distribution

G05SMF   Generates a vector of pseudorandom numbers from a log-normal distribution

G05SNF   Generates a vector of pseudorandom numbers from a Student's t-distribution

G05SPF   Generates a vector of pseudorandom numbers from a triangular distribution

G05SQF   Generates a vector of pseudorandom numbers from a uniform distribution over $[a, b]$

G05SRF   Generates a vector of pseudorandom numbers from a von Mises distribution

G05SSF   Generates a vector of pseudorandom numbers from a Weibull distribution

G05XBF   Generate paths for a free or non-free Wiener process using the Brownian bridge algorithm

G05XDF   Backs out the increments from sample paths generated by a Brownian bridge algorithm

G05YJF   Generates a Normal quasi-random number sequence

G05YKF   Generates a log-normal quasi-random number sequence

G05YMF   Generates a uniform quasi-random number sequence

G13EAF   Combined measurement and time update, one iteration of Kalman filter, time-varying, square root covariance filter

G13EBF   Combined measurement and time update, one iteration of Kalman filter, time-invariant, square root covariance filter

G13MEF   Computes the iterated exponential moving average for a univariate inhomogeneous time series

G13MFF   Computes the iterated exponential moving average for a univariate inhomogeneous time series, intermediate results are also returned

G13MGF	Computes the exponential moving average for a univariate inhomogeneous time series
M01CAF	Sort a vector, real numbers
M01CBF	Sort a vector, integer numbers
M01CCF	Sort a vector, character data
S30AAF	Black–Scholes–Merton option pricing formula
S30ABF	Black–Scholes–Merton option pricing formula with Greeks
S30BAF	Floating-strike lookback option pricing formula
S30BBF	Floating-strike lookback option pricing formula with Greeks
S30CAF	Binary option, cash-or-nothing pricing formula
S30CBF	Binary option, cash-or-nothing pricing formula with Greeks
S30CCF	Binary option, asset-or-nothing pricing formula
S30CDF	Binary option, asset-or-nothing pricing formula with Greeks
S30FAF	Standard barrier option pricing formula
S30JAF	Jump-diffusion, Merton's model, option pricing formula
S30JBF	Jump-diffusion, Merton's model, option pricing formula with Greeks
S30NAF	Heston's model option pricing formula
S30NBF	Heston's model option pricing formula with Greeks
S30QCF	American option, Bjerksund and Stensland pricing formula
S30SAF	Asian option, geometric continuous average rate pricing formula
S30SBF	Asian option, geometric continuous average rate pricing formula with Greeks

5   Routines Enhanced by Calling Tuned NAG-specific Routines

These routines call one or more of the tuned NAG-specific routines as part of their core operations and may thereby exhibit improved performance and scalability. There are 165 of these routines within the Library.

Routine Name	**Purpose**
C05QSF	Solution of a sparse system of nonlinear equations using function values only (easy-to-use)
D01GBF	Multidimensional quadrature over hyper-rectangle, Monte–Carlo method
D01GCF	Multidimensional quadrature, general product region, number-theoretic method
D01GDF	Multidimensional quadrature, general product region, number-theoretic method, variant of D01GCF efficient on vector machines
D01PAF	Multidimensional quadrature over an n-simplex
D02EJF	Ordinary differential equations, stiff initial value problem, backward differentiation formulae method, until function of solution is zero, intermediate output (simple driver)
D02NBF	Explicit ordinary differential equations, stiff initial value problem, full Jacobian (comprehensive)
D02NCF	Explicit ordinary differential equations, stiff initial value problem, banded Jacobian (comprehensive)
D02NDF	Explicit ordinary differential equations, stiff initial value problem, sparse Jacobian (comprehensive)

D02NGF Implicit/algebraic ordinary differential equations, stiff initial value problem, full Jacobian (comprehensive)

D02NHF Implicit/algebraic ordinary differential equations, stiff initial value problem, banded Jacobian (comprehensive)

D02NJF Implicit/algebraic ordinary differential equations, stiff initial value problem, sparse Jacobian (comprehensive)

D02NMF Explicit ordinary differential equations, stiff initial value problem (reverse communication, comprehensive)

D02NNF Implicit/algebraic ordinary differential equations, stiff initial value problem (reverse communication, comprehensive)

D02UAF Coefficients of Chebyshev interpolating polynomial from function values on Chebyshev grid

D02UBF Function or low-order-derivative values on Chebyshev grid from coefficients of Chebyshev interpolating polynomial

D03PCF General system of parabolic PDEs, method of lines, finite differences, one space variable

D03PDF General system of parabolic PDEs, method of lines, Chebyshev C^0 collocation, one space variable

D03PEF General system of first-order PDEs, method of lines, Keller box discretization, one space variable

D03PFF General system of convection-diffusion PDEs with source terms in conservative form, method of lines, upwind scheme using numerical flux function based on Riemann solver, one space variable

D03PHF General system of parabolic PDEs, coupled DAEs, method of lines, finite differences, one space variable

D03PJF General system of parabolic PDEs, coupled DAEs, method of lines, Chebyshev C^0 collocation, one space variable

D03PKF General system of first-order PDEs, coupled DAEs, method of lines, Keller box discretization, one space variable

D03PLF General system of convection-diffusion PDEs with source terms in conservative form, coupled DAEs, method of lines, upwind scheme using numerical flux function based on Riemann solver, one space variable

D03PPF General system of parabolic PDEs, coupled DAEs, method of lines, finite differences, remeshing, one space variable

D03PRF General system of first-order PDEs, coupled DAEs, method of lines, Keller box discretization, remeshing, one space variable

D03PSF General system of convection-diffusion PDEs, coupled DAEs, method of lines, upwind scheme, remeshing, one space variable

D05AAF Linear nonsingular Fredholm integral equation, second kind, split kernel

D05ABF Linear nonsingular Fredholm integral equation, second kind, smooth kernel

D06CBF Generates a sparsity pattern of a Finite Element matrix associated with a given mesh

D06CCF Renumbers a given mesh using Gibbs method

E02RAF Padé approximants

E04FCF Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using function values only (comprehensive)

E04FYF Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using function values only (easy-to-use)

E04GBF   Unconstrained minimum of a sum of squares, combined Gauss–Newton and quasi-Newton algorithm using first derivatives (comprehensive)

E04GDF   Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using first derivatives (comprehensive)

E04GYF   Unconstrained minimum of a sum of squares, combined Gauss–Newton and quasi-Newton algorithm, using first derivatives (easy-to-use)

E04GZF   Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm using first derivatives (easy-to-use)

E04HEF   Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm, using second derivatives (comprehensive)

E04HYF   Unconstrained minimum of a sum of squares, combined Gauss–Newton and modified Newton algorithm, using second derivatives (easy-to-use)

E04NCF   Convex QP problem or linearly-constrained linear least squares problem (dense)

E04UCF   Minimum, function of several variables, sequential QP method, nonlinear constraints, using function values and optionally first derivatives (comprehensive)

E04UFF   Minimum, function of several variables, sequential QP method, nonlinear constraints, using function values and optionally first derivatives (reverse communication, comprehensive)

E04UGF   NLP problem (sparse)

E04USF   Minimum of a sum of squares, nonlinear constraints, sequential QP method, using function values and optionally first derivatives (comprehensive)

E04YCF   Covariance matrix for nonlinear least squares problem (unconstrained)

F01ABF   Inverse of real symmetric positive definite matrix using iterative refinement

F01ELF   Function of a real matrix (using numerical differentiation)

F01FLF   Function of a complex matrix (using numerical differentiation)

F01GAF   Action of a real matrix exponential on a real matrix

F01GBF   Action of a real matrix exponential on a real matrix (reverse communication)

F01HAF   Action of a complex matrix exponential on a complex matrix

F01HBF   Action of a complex matrix exponential on a complex matrix (reverse communication)

F01JAF   Condition number for the exponential, logarithm, sine, cosine, sinh or cosh of a real matrix

F01JBF   Condition number for a function of a real matrix (using numerical differentiation)

F01JCF   Condition number for a function of a real matrix (using user-supplied derivatives)

F01KAF   Condition number for the exponential, logarithm, sine, cosine, sinh or cosh of a complex matrix

F01KBF   Condition number for a function of a complex matrix (using numerical differentiation)

F01KCF   Condition number for a function of a complex matrix (using user-supplied derivatives)

F02EKF   Selected eigenvalues and eigenvectors of a real sparse general matrix

F02FJF   Selected eigenvalues and eigenvectors of sparse symmetric eigenproblem (Black Box)

F02WDF QR factorization, possibly followed by SVD

F02WGF   Computes leading terms in the singular value decomposition of a real general matrix; also computes corresponding left and right singular vectors

F02WUF   SVD of real upper triangular matrix (Black Box)

F02XUF   SVD of complex upper triangular matrix (Black Box)

F04ABF   Solution of real symmetric positive definite simultaneous linear equations with multiple right-hand sides using iterative refinement (Black Box)

F04AEF   Solution of real simultaneous linear equations with multiple right-hand sides using iterative refinement (Black Box)

F04ASF   Solution of real symmetric positive definite simultaneous linear equations, one right-hand side using iterative refinement (Black Box)

F04ATF   Solution of real simultaneous linear equations, one right-hand side using iterative refinement (Black Box)

F04JGF   Least squares (if rank $= n$) or minimal least squares (if rank $< n$) solution of m real equations in n unknowns, $m \geq n$

F11DCF   Solution of real sparse nonsymmetric linear system, RGMRES, CGS, Bi-CGSTAB or TFQMR method, preconditioner computed by F11DAF

F11DEF   Solution of real sparse nonsymmetric linear system, RGMRES, CGS, Bi-CGSTAB, or TFQMR method, Jacobi or SSOR preconditioner (Black Box)

F11DGF   Solution of real sparse nonsymmetric linear system, RGMRES, CGS, Bi-CGSTAB or TFQMR method, incomplete LU block diagonal preconditioner computed by F11DFF

F11DKF   Real sparse nonsymmetric linear systems, line Jacobi preconditioner

F11DQF   Solution of complex sparse non-Hermitian linear system, RGMRES, CGS, Bi-CGSTAB or TFQMR method, preconditioner computed by F11DNF (Black Box)

F11DSF   Solution of complex sparse non-Hermitian linear system, RGMRES, CGS, Bi-CGSTAB or TFQMR method, Jacobi or SSOR preconditioner Black Box

F11DUF   Solution of complex sparse nonsymmetric linear system, RGMRES, CGS, Bi-CGSTAB or TFQMR method, incomplete LU block diagonal preconditioner computed by F11DTF

F11DXF   Complex sparse nonsymmetric linear systems, line Jacobi preconditioner

F11JCF   Solution of real sparse symmetric linear system, conjugate gradient/Lanczos method, preconditioner computed by F11JAF (Black Box)

F11JEF   Solution of real sparse symmetric linear system, conjugate gradient/Lanczos method, Jacobi or SSOR preconditioner (Black Box)

F11JQF   Solution of complex sparse Hermitian linear system, conjugate gradient/Lanczos method, preconditioner computed by F11JNF (Black Box)

F11JSF   Solution of complex sparse Hermitian linear system, conjugate gradient/Lanczos method, Jacobi or SSOR preconditioner (Black Box)

F11MDF   Real sparse nonsymmetric linear systems, setup for F11MEF

F12AUF   Selected eigenvalues and, optionally, eigenvectors of complex non-Hermitian banded eigenproblem, driver

F12FGF   Selected eigenvalues and, optionally, eigenvectors of a real symmetric banded eigenproblem, driver

G01AGF   Lineprinter scatterplot of two variables

G01AHF   Lineprinter scatterplot of one variable against Normal scores

G01ANF   Calculates approximate quantiles from a data stream of known size

G01APF   Calculates approximate quantiles from a data stream of unknown size

G01ARF   Constructs a stem and leaf plot

G01EMF   Computes probability for the Studentized range statistic

G01HBF   Computes probabilities for the multivariate Normal distribution

G01JDF   Computes lower tail probability for a linear combination of (central) χ^2 variables

G02ABF   Computes the nearest correlation matrix to a real square matrix, augmented G02AAF to incorporate weights and bounds

G02AEF   Computes the nearest correlation matrix with k-factor structure to a real square matrix

G02AJF   Computes the nearest correlation matrix to a real square matrix, using element-wise weighting

G02CGF   Multiple linear regression, from correlation coefficients, with constant term

G02CHF   Multiple linear regression, from correlation-like coefficients, without constant term

G02DAF   Fits a general (multiple) linear regression model

G02DDF   Estimates of linear parameters and general linear regression model from updated model

G02DEF   Add a new independent variable to a general linear regression model

G02DGF   Fits a general linear regression model to new dependent variable

G02DKF   Estimates and standard errors of parameters of a general linear regression model for given constraints

G02EEF   Fits a linear regression model by forward selection

G02GAF   Fits a generalized linear model with Normal errors

G02GBF   Fits a generalized linear model with binomial errors

G02GCF   Fits a generalized linear model with Poisson errors

G02GDF   Fits a generalized linear model with gamma errors

G02GKF   Estimates and standard errors of parameters of a general linear model for given constraints

G02HAF   Robust regression, standard M-estimates

G02HDF   Robust regression, compute regression with user-supplied functions and weights

G02HFF   Robust regression, variance-covariance matrix following G02HDF

G02HKF   Calculates a robust estimation of a correlation matrix, Huber's weight function

G02JAF   Linear mixed effects regression using Restricted Maximum Likelihood (REML)

G02JBF   Linear mixed effects regression using Maximum Likelihood (ML)

G02KAF   Ridge regression, optimizing a ridge regression parameter

G02KBF   Ridge regression using a number of supplied ridge regression parameters

G03ACF   Performs canonical variate analysis

G03ADF   Performs canonical correlation analysis

G04EAF   Computes orthogonal polynomials or dummy variables for factor/classification variable

G05PDF   Generates a realisation of a time series from a GARCH process with asymmetry of the form $(\epsilon_{t-1} + \gamma)^2$

G05PEF   Generates a realisation of a time series from a GARCH process with asymmetry of the form $(|\epsilon_{t-1}| + \gamma\epsilon_{t-1})^2$

G05PFF   Generates a realisation of a time series from an asymmetric Glosten, Jagannathan and Runkle (GJR) GARCH process

G05PGF   Generates a realisation of a time series from an exponential GARCH (EGARCH) process

G05PJF   Generates a realisation of a multivariate time series from a VARMA model

G05PYF   Generates a random correlation matrix

G05RZF   Generates a matrix of pseudorandom numbers from a multivariate Normal distribution

G05ZPF	Generates realisations of a one-dimensional random field
G05ZQF	Setup for simulating two-dimensional random fields, user-defined variogram
G05ZRF	Setup for simulating two-dimensional random fields, preset variogram
G05ZSF	Generates realisations of a two-dimensional random field
G05ZTF	Generates realisations of fractional Brownian motion
G07BEF	Computes maximum likelihood estimates for parameters of the Weibull distribution
G07BFF	Estimates parameter values of the generalized Pareto distribution
G07DAF	Robust estimation, median, median absolute deviation, robust standard deviation
G07DBF	Robust estimation, M-estimates for location and scale parameters, standard weight functions
G07DCF	Robust estimation, M-estimates for location and scale parameters, user-defined weight functions
G07DDF	Computes a trimmed and winsorized mean of a single sample with estimates of their variance
G07EAF	Robust confidence intervals, one-sample
G07EBF	Robust confidence intervals, two-sample
G08AGF	Performs the Wilcoxon one-sample (matched pairs) signed rank test
G08AKF	Computes the exact probabilities for the Mann–Whitney U statistic, ties in pooled sample
G08CBF	Performs the one-sample Kolmogorov–Smirnov test for standard distributions
G08CCF	Performs the one-sample Kolmogorov–Smirnov test for a user-supplied distribution
G08CDF	Performs the two-sample Kolmogorov–Smirnov test
G08RAF	Regression using ranks, uncensored data
G08RBF	Regression using ranks, right-censored data
G11BBF	Computes multiway table from set of classification factors using given percentile/quantile
G11BCF	Computes marginal tables for multiway table computed by G11BAF or G11BBF
G11SAF	Contingency table, latent variable model for binary data
G12ABF	Computes rank statistics for comparing survival curves
G13ADF	Univariate time series, preliminary estimation, seasonal ARIMA model
G13AEF	Univariate time series, estimation, seasonal ARIMA model (comprehensive)
G13AFF	Univariate time series, estimation, seasonal ARIMA model (easy-to-use)
G13AJF	Univariate time series, state set and forecasts, from fully specified seasonal ARIMA model
G13BCF	Multivariate time series, cross-correlations
G13BEF	Multivariate time series, estimation of multi-input model
G13BJF	Multivariate time series, state set and forecasts from fully specified multi-input model
G13DBF	Multivariate time series, multiple squared partial autocorrelations
G13DDF	Multivariate time series, estimation of VARMA model
G13DNF	Multivariate time series, sample partial lag correlation matrices, χ^2 statistics and significance levels
G13FAF	Univariate time series, parameter estimation for either a symmetric GARCH process or a GARCH process with asymmetry of the form $(\epsilon_{t-1} + \gamma)^2$
G13FCF	Univariate time series, parameter estimation for a GARCH process with asymmetry of the form $(\lvert \epsilon_{t-1} \rvert + \gamma \epsilon_{t-1})^2$

G13FEF   Univariate time series, parameter estimation for an asymmetric Glosten, Jagannathan and
          Runkle (GJR) GARCH process

G13FGF   Univariate time series, parameter estimation for an exponential GARCH (EGARCH) process

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