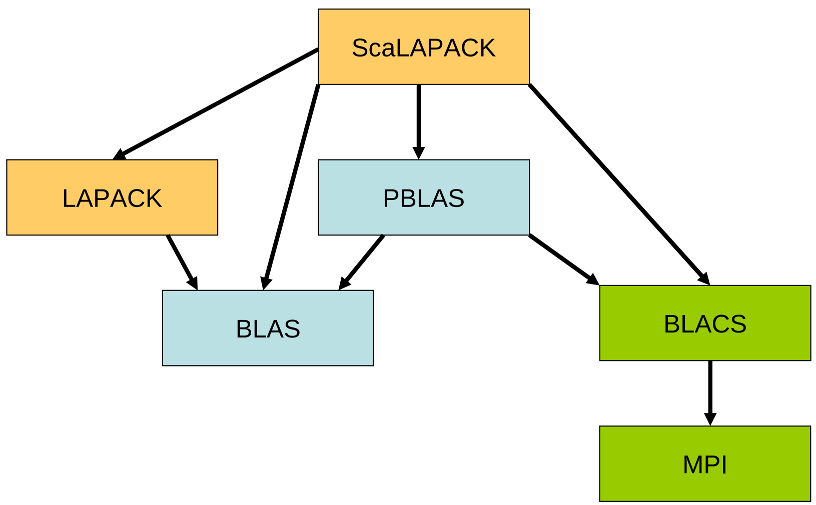
BLAS, LAPACK
BLACS, PBLAS, ScaLAPACK

High Performance Portable Libraries for
Dense Linear Algebra

Introduction

- In this lecture we will cover the following topic:
  - High performance portable dense linear algebra libraries
- The following libraries will be introduced:
  - BLAS
  - LAPACK
  - BLACS
  - PBLAS
  - ScaLAPACK
- This will also be covered:
  - FORTRAN 77+

The Overall Picture



NETLIB

- All software discussed in this lecture can be downloaded free of charge from NETLIB (repository for freely distributable numerical software)
  - http://www.netlib.org/
- Collection of all NETLIB links mentioned in the notes:
  - http://www.netlib.org/blas/
  - http://www.netlib.org/atlas/
  - http://www.netlib.org/blas/gemm_based/
  - http://www.netlib.org/lapack/
  - http://www.netlib.org/blacs/
  - http://www.netlib.org/scalapack/ (includes PBLAS)

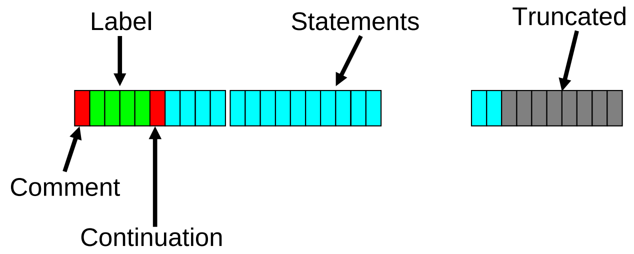
Crash Course: FORTRAN 77+

- FORTRAN 77+ is used in these notes to refer to the dialect of FORTRAN 77 used by LAPACK and ScaLAPACK developers.
  - Straight FORTRAN 77 is quite arcane and most compilers have implemented a set of extensions.
- FORTRAN has been the language of choice for scientific and engineering for a long time, partly because it:
  - Has an extensive compiler support for multi-dimensional arrays
  - Has restrictions in the language to allow aggressive compiler optimizations
  - Has language support (in FORTRAN 90 and onwards) for dynamic memory management, derived types, object orientation, operator overloading, generic interfaces, array expressions, distributed arrays (co-arrays), etc

Fixed Source Format

- FORTRAN 77+ has a strict source format known as the ”fixed source format” (removed in later standards)
- Columns are used for different things:
  - 1: Comment column
  - 2-5: Label columns
  - 6: Continuation column
  - 7-72: Statement columns
  - 73-: Truncated (silently)

Set your editor to expand tabs to spaces.
Use 3 as tabstop (two tabs takes you to column 7)



IF-THEN-ELSE

- IF-statement:
  - **IF(** <logical expression> **)** <statement>
- IF-construct:
  - **IF(** <logical expression> **) THEN**
    <block>
    [**ELSE IF(** <logical expression> **) THEN**
    <block>]
    [**ELSE**
    <block>]
    END IF

GO TO, CONTINUE and Labels

- Labels
  - Integers from **1** to **9999**
  - Placed in columns 2 to 5
  - Used as targets for GO TO statements and in DO loops
- GO TO-statement:
  - **GO TO <label>**
  - Transfers control to statement labeled with <label>
- CONTINUE-statement:
  - **CONTINUE**
  - A do-nothing statement often used as target statement and DO loop end statement.
-

DO

- DO-construct:
  - DO <label> <var> = <low>, <high>[, <step>]
    <block>
    <label> CONTINUE
  - Example:
    - ```
            DO 10 J = 1, M, 2
               ...
         10 CONTINUE
      ```
  - New syntax:
    - ```
      DO J = 1, M, 2
         ...
      END DO
      ```

PROGRAM

- In FORTRAN you do not have a special function called MAIN, instead you have the PROGRAM construct:
  - PROGRAM [name]
    <declarations>
    <statements>
    END [PROGRAM name]

SUBROUTINEs and FUNCTIONs

- SUBROUTINEs (think of C functions returning void)
  - CALL mysub(<arglist>)
- FUNCTIONs (think of C functions returning non-void)
  - <lval> = myfunc(<arglist>)

- Declaring a SUBROUTINE:
  - SUBROUTINE <name>(<dummy arglist>)
    <dummy argument type declarations>
    END [SUBROUTINE name]
- Declaring a FUNCTION:
  - <type> FUNCTION <name>(<dummy arglist>)
    <dummy argument type declarations>
    END [FUNCTION name]
  - Example:
    - ```
            INTEGER FUNCTION MAX(a, b)
               INTEGER a, b
               MAX = a
               IF( b .GT. a ) MAX = b
            END
      ```

Arithmetic Operators

FORTRAN	C/Java
+	+
-	-
*	*
/	/
**	N/A
N/A	+=
N/A	++
      ```

Logical Operators

FORTRAN	C/Java
`.GT.`	`>`
`.LT.`	`<`
`.LE.`	`<=`
`.GE.`	`>=`
`.EQ.` `.EQV.` (logical)	`==`
`.NE.` `.NEQV.` (logical)	`!=` (exclusive or)
`.AND.`	`&&`
`.OR.`	`||`
`.NOT.`	`!`

Data Types

- `INTEGER`
  - Signed 32-bit (usually) integer
- `LOGICAL`
  - `.TRUE.` or `.FALSE.`
- `CHARACTER(`<length>`)` or `CHARACTER` (just one character)
  - `'`string`'` or `"`string`"`
- `REAL`
  - Single precision IEEE (usually) floating point `f = 5E+0`
- `DOUBLE PRECISION`
  - Double precision IEEE (usually) floating point `d = 5D+0`
- `COMPLEX`
  - Single precision IEEE (usually) complex number `c = (r, i)`
- `COMPLEX*16`
  - Double precision IEEE (usually) complex number `c = (r, i)`

Arrays (Matrices and Vectors)

- Declaring a vector of 50 INTEGERs
  - `INTEGER vec(50)`
- Declaring a 25x47 matrix of 50 INTEGERs
  - `INTEGER mtx(25, 47)`
- Indexing starts from 1 (unless explicitly stated in the declaration)
- Indexing top left element in matrix:
  - `mtx(1, 1)`
- Indexing bottom right index in matrix:
  - `mtx(25, 47)`

Automatic Arrays

- Size of array is either known at compile time or determined by dummy arguments and the array is not a dummy argument itself.
- Storage will be allocated (think of it as being allocated on the stack) at runtime and deallocated automatically when variable falls out of scope.
  - Example:

```
      SUBROUTINE auto(N)
         INTEGER A(N)
      END
```

Assumed Shape Array

- The shape (extent of all dimensions) need not be known at compile time.
- An array where the extent of one or more dimension is determined by dummy arguments is referred to as an assumed shape array.
  - Useful for passing arrays as arguments to subroutines.
  - Example:
    - ```
            SUBROUTINE mysub(A, LDA, M, N)
               INTEGER LDA, M, N
               REAL A(LDA, N)
            END
      ```

Assumed Size Arrays

- Extent of last dimension in FORTRAN arrays need not be known at compile time (or at runtime for that matter) to generate indexing code (first dimension in the case of C).
- An array declared with unknown last dimension extent is referred to as an assumed size array.
  - `REAL A(LDA, *)`
    - Indexing code:
      `A(i, j)` → `A + (i-1) + (j-1)*LDA`

Comments

- Comment lines are created by putting (almost) any character (usually `*` or `c`) in the first column:
  - Example:
    - ```
      c     This is a comment
      *     This is also a comment
            A = 1 c This is not a comment
      ```

Continuation (long statements)

- Long statements (going beyond column 72) can be broken into several lines by placing (almost) any character (usually numbers, `$`, `&`, `+`) in the continuation column (column 6)
  - Example:
    - ```
            A(1, 2) = longvariablename +
           $   anotherlongvariable
      ```
      ```

FORTRAN 77+/C "Interoperability"

- Calling FORTRAN 77+ from C:
  - These are usual type relationships:
    - ```
      LOGICAL            (?)
      INTEGER            int
      CHARACTER          char
      REAL               float
      DOUBLE PRECISION   double
      COMPLEX            float[2]
      COMPLEX*16         double[2]
      ```
  - Everything in FORTRAN is passed by reference
    - This is usually implemented by passing a pointer.
    - ```
      INTEGER            int*
      DOUBLE PRECISION   double*
      CHARACTER          char*
      ```
  - Symbols are usually lower case with added underscore:
    - `SUBROUTINE MySUB(...)          mysub_`
  - Symbols with underscore sometimes get extra underscore:
    - `SUBROUTINE My_SUB(...)          my_sub__`

Other things to know about FORTRAN

- FORTRAN is case insensitive
- FORTRAN passes everything by reference
- FORTRAN 77 has no type checking of arguments
- FORTRAN 77 has no support for recursive subroutines or functions

Storage Formats used by the Libraries

- General matrices:
  - Column Major
- Symmetric and triangular matrices
  - Column Major Column Packed
- Band matrices
  - Diagonal Storage
- Tridiagonal matrices
  - Diagonal Storage

Full Storage Format

Matrix Indices

11	12	13	14	15	16	17	18	19
21	22	23	24	25	26	27	28	29
31	32	33	34	35	36	37	38	39
41	42	43	44	45	46	47	48	49
51	52	53	54	55	56	57	58	59
61	62	63	64	65	66	67	68	69
71	72	73	74	75	76	77	78	79
81	82	83	84	85	86	87	88	89
91	92	93	94	95	96	97	98	99

Memory Placement

0	9	18	27	36	45	54	63	72
1	10	19	28	37	46	55	64	73
2	11	20	29	38	47	56	65	74
3	12	21	30	39	48	57	66	75
4	13	22	31	40	49	58	67	76
5	14	23	32	41	50	59	68	77
6	15	24	33	42	51	60	69	78
7	16	25	34	43	52	61	70	79
8	17	26	35	44	53	62	71	80

Standard Packed Storage Format

Matrix Indices

11	*	*	*	*	*	*	*	*
21	22	*	*	*	*	*	*	*
31	32	33	*	*	*	*	*	*
41	42	43	44	*	*	*	*	*
51	52	53	54	55	*	*	*	*
61	62	63	64	65	66	*	*	*
71	72	73	74	75	76	77	*	*
81	82	83	84	85	86	87	88	*
91	92	93	94	95	96	97	98	99

Memory Placement

0	*	*	*	*	*	*	*	*
1	9	*	*	*	*	*	*	*
2	10	17	*	*	*	*	*	*
3	11	18	24	*	*	*	*	*
4	12	19	25	30	*	*	*	*
5	13	20	26	31	35	*	*	*
6	14	21	27	32	36	39	*	*
7	15	22	28	33	37	40	42	*
8	16	23	29	34	38	41	43	44

Rectangular Full Packed Storage Format

Matrix Indices

11	66	76	86	96
21	22	77	87	97
31	32	33	88	98
41	42	43	44	99
51	52	53	54	55
61	62	63	64	65
71	72	73	74	75
81	82	83	84	85
91	92	93	94	95

Memory Placement

0	9	18	27	36
1	10	19	28	37
2	11	20	29	38
3	12	21	30	39
4	13	22	31	40
5	14	23	32	41
6	15	24	33	42
7	16	25	34	43
8	17	26	35	44

Banded Storage Format

Full Matrix Indices

11	12	*	*	*	*	*	*	*
21	22	23	*	*	*	*	*	*
31	32	33	34	*	*	*	*	*
*	42	43	44	45	*	*	*	*
*	*	53	54	55	56	*	*	*
*	*	*	64	65	66	67	*	*
*	*	*	*	75	76	77	78	*
*	*	*	*	*	86	87	88	89
*	*	*	*	*	*	97	98	99

Matrix Indices

*	12	23	34	45	56	67	78	89
11	22	33	44	55	66	77	88	99
21	32	43	54	65	76	87	98	*
31	42	53	64	75	86	97	*	*

Memory Placement

0	9	18	27	36	45	54	63	72
1	10	19	28	37	46	55	64	73
2	11	20	29	38	47	56	65	74
3	12	21	30	39	48	57	66	75

BLAS

- Basic Linear Algebra Subroutines (BLAS)
  - http://www.netlib.org/blas/ Reference implementation
  - http://www.netlib.org/atlas/ Auto-tuning HPC impl.
  - http://www.netlib.org/blas/gemm_based/ GEMM-based BLAS by Kågström et. al.
  - http://www.tacc.utexas.edu/resources/software/ GotoBLAS
- Interfaces:
  - FORTRAN (official)
  - C, C++, Java, ... (unofficial)
- Language:
  - C, assembler, FORTRAN, ... (depends on vendor)

BLAS - Content

- BLAS contains subroutines and functions for a number of basic linear algebra operations.
  - Dot product
  - Givens rotation generation and application
  - Vector updates
  - Matrix-vector product update
  - Triangular system solve (with single or multiple right hand sides)
  - Matrix-matrix product update
  - ...
- The routines operate on various storage formats and on four data types (single, double, complex, double complex).

Coding Conventions

- _XXYY
  - _: Data type
    - **S**, **D**, **C**, or **Z**
  - XX: Type of matrix
    - **GE**, **GB**: GEneral, General Banded
    - **HE**, **HB**, **HP**: HErmitian, Hermitian Banded, Hermitian Packed
    - **SY**, **SB**, **SP**: SYmmetric, Symmetric Banded, Symmetric Packed
    - **TR**, **TB**, **TP**: TRiangular, Triangular Banded, Triangular Packed
  - YY: Operation
    - **S**: "Solve"
    - **M**: "Matrix"
    - **V**: "Vector"
    - **R**: Rank-1
    - **R2**: Rank-2
    - **RK**: Rank-k
    - **R2K**: Rank-2k
- Example:
  - **DTRSM**:
    - Double precision
    - TRiangular
    - Solve
    - Multiple right hand sides

Memory Traffic - Limitations

- Memory bandwidth and latency can not match the high performance of floating point computations on the chip.
- Solution:
  - Exploit caches by data locality in space and time
- Solution requires:
  - An operation that has much inherent locality
- Metric for estimating inherent locality in linear algebra:
  - Number of floating point operations

    Number of memory locations referenced
  - i.e., flop/memref

Locality - Examples

- Example of poor inherent locality: `AXPY (a*x + y)`
  - 2 vector loads (x, y)
  - 1 vector store (y)
  - 2 vector operations (*, +)
  - flop/memref = 2/3
- Example of good inherent locality: `GEMM (a*A*B + b*C)`
  - ~2*N^3 flops
  - ~3*N^2 loads
  - ~1*N^2 stores
  - flop/memref ~ N/2

Level 1, 2, 3

- Level-1 BLAS: Vector operations (~1 flop/memref)
  - **_dot**
    _axpy
    _swap
    _copy
    _scal
    ...
- Level-2 BLAS: Matrix-Vector operations (~1 flop/memref)
  - **_gemv**
    _symv
    _trsv
    ...
- Level-3 BLAS: Matrix-Matrix operations (~N flop/memref)
  - **_gemm**
    _syrk
    _trsm
    ...

LAPACK

- Linear Algebra PACKage (LAPACK)
  - http://www.netlib.org/lapack/ Official LAPACK releases
  - http://www.netlib.org/lapack/lanws/
    Publications related to LAPACK and DLA
- Some vendors provide their own optimized LAPACK routines as well as BLAS routines:
  - IBM: ESSL (Proprietary)
  - AMD: ACML (Free?)
  - Intel: MKL (Proprietary?)
  - Cray: libsci (Proprietary?)
- Interfaces:
  - FORTRAN (official)
  - C, C++, Java, ... (unofficial)
- Language:
  - FORTRAN 77+

LAPACK - Content

- Compared with BLAS, the high level algorithms and tricky numerical algorithms go into LAPACK.
  - Factorizing matrices
    - LU, Cholesky, QR, QL, RQ, LQ, ...
  - Applying factored-form orthogonal matrices
  - Solving linear equations
  - Solving linear least squares problems
  - Decomposing matrices
    - SVD, Schur, ...
  - Computing eigenvalues and eigenvectors
    - Symmetric, non-symmetric, ...
  - Error bounds, condition estimation

Workspace Management

- Many routines in LAPACK require auxilliary workspace to function and/or run faster.
- Users must provide this storage.
- Routines take workspace via their arguments, typically:
  - **WORK**: Workspace
  - **LWORK**: Length of workspace
- Routines requiring workspace allow workspace queries.
  - Workspace query:
    LWORK = -1
    WORK(1) contains required workspace
    Cast to **INTEGER**: **INT(WORK(1))**
  - If you do a workspace query the routine will not modify any of its arguments.

Error Reporting

- LAPACK routines have an extra **INTEGER** argument at the end of their argument lists: **INFO**
  - The value of **INFO** tells what went wrong (if anything):
    - **0**: Success
    - **< 0**: Argument number **-INFO** contained an illegal value (fatal, programming error)
    - **> 0**: Something went wrong during computation (exact interpretation is routine specific)
      - Example: **DGETRF** (LU factorization)
        INFO > 0: **U(INFO, INFO)** is exactly zero

LAPACK - Examples

- Solving a linear system after LU factorization
  - **DGETRS(TRANS, N, NRHS, A, LDA, IPIV, B, LDB, INFO)**
- Computing QR factorization
  - **DGEQRF(M, N, A, LDA, TAU, WORK, LWORK, INFO)**

BLACS

- Basic Linear Algebra Communication Subroutines
  - http://www.netlib.org/blacs/ Official BLACS releases
- Purpose:
  - Communication of submatrices appropriate for dense linear algebra algorithms (e.g., ScaLAPACK)
- Objection:
  - *"I know MPI inside out, why should I learn BLACS?"*
- Answer:
  - It will hopefully be apparent at the end of this segment.
- Interfaces:
  - FORTRAN, C (official)
- Language:
  - C

2D-Grid, Scope, Context

- Processes are arranged in a logical 2D-grid.
- Each process is a member of three scopes:
  - **'All':** All processes in the grid
  - **'Row':** All processes on the same row of the grid
  - **'Column':** All processes on the same column of the grid
- BLACS communication is tied to a context (think of MPI communicators) which is an integer.

Submatrix Communication

- The BLACS unit of communication is a submatrix of some specified size and shape.
- Two types of submatrices:
  - General submatrices:
    - Parameters: **`M, N, A, LDA`**
  - Trapezoidal submatrices (generalization of triangular):
    - Parameters: **`M, N, A, LDA, UPLO, DIAG`**
- Packing of matrices hidden from user
- Types supported:
  - **`I`**: Integer
  - **`S`**: Single precision
  - **`D`**: Double precision
  - **`C`**: Complex single precision
  - **`Z`**: Complex double precision

Point-to-Point

- Send:
  - **`xGESD2D(CTXT, M, N, A, LDA, RDST, CDST)`**
  - **`xTRSD2D(CTXT, UPLO, DIAG, M, N, A, LDA, RDST, CDST)`**
- Receive:
  - **`xGERV2D(CTXT, M, N, A, LDA, RSRC, CSRC)`**
  - **`xTRRV2D(CTXT, UPLO, DIAG, M, N, A, LDA, RSRC, CSRC)`**

Collectives

- Broadcast (send):
  - **`xGEBS2D(CTXT, SCOPE, TOP, M, N, A, LDA)`**
  - **`xTRBS2D(CTXT, SCOPE, TOP, UPLO, DIAG, M, N, A, LDA)`**
- Broadcast (receive):
  - **`xGEBR2D(CTXT, SCOPE, TOP, M, N, A, LDA, RSRC, CSRC)`**
  - **`xTRBR2D(CTXT, SCOPE, TOP, UPLO, DIAG, M, N, A, LDA, RSRC, CSRC)`**
- Combine operations (SUM, MAX, MIN):
  - **`xGSUM2D(CTXT, SCOPE, TOP, M, N, A, LDA, RDST, CDST)`**
  - **`xGAMX2D(CTXT, SCOPE, TOP, M, N, A, LDA, RA, CA, RCFLAG, RDST, CDST)`**
  - **`xGAMN2D(CTXT, SCOPE, TOP, M, N, A, LDA, RA, CA, RCFLAG, RDST, CDST)`**

Collectives: Topology

- Topologies (TOP) specify the communication pattern.
  - **`'I'`**: Increasing ring
  - **`'D'`**: Decreasing ring
  - **`'S'`**: Split ring
  - **`'M'`**: Multi-ring
  - **`'1'`**: 1-tree
  - **`'B'`**: Bidirectional exchange
  - **`' '`**: Default (may use MPI_Bcast)

BLACS – Setup (FORTRAN)

- Initializing BLACS:
  - `CALL BLACS_PINFO(ME, NP)`
- Initializing context:
  - ```
    CALL BLACS_GET(0, 0, CTXT)
    CALL BLACS_GRIDINIT(CTXT, 'Row', P, Q)
    CALL BLACS_GRIDINFO(CTXT, P, Q, MYROW, MYCOL)
    ```
- Getting someones rank from coordinates
  - `RANK = BLACS_PNUM(CTXT, ROW, COL)`
- Getting someones coordinates from rank
  - `CALL BLACS_PCOORD(CTXT, RANK, ROW, COL)`
- Exiting BLACS
  - `CALL BLACS_EXIT(0)`

PBLAS

- Parallel BLAS
  - http://www.netlib.org/scalapack/ PBLAS reference impl. is part of ScaLAPACK
- Interfaces:
  - FORTRAN
  - C?
- Language:
  - C

2D Block Cyclic Distribution

- PBLAS operates on data distributed using the 2D block cyclic distribution.
- Recall:

11	12	13	14	15
21	22	23	24	25
31	32	33	34	35
41	42	43	44	45
51	52	53	54	55

5 x 5 matrix, 2 x 2 blocks

	0			1	
0	11	12	15	13	14
	21	22	25	23	24
	51	52	55	53	54
1	31	32	35	33	34
	41	42	45	43	44

2 x 2 process grid point of view

Matrix Descriptors

- Descriptors are used in PBLAS and ScaLAPACK to encapsulate information on a distributed matrix.
- A descriptor is a 9-item integer vector:
  - `INTEGER DESCA(9)`
  - `DESCA(1): (DTYPE)` 1
    `DESCA(2): (CTXT)` BLACS context
    `DESCA(3): (M)` Number of rows in global matrix
    `DESCA(4): (N)` Number of columns in global matrix
    `DESCA(5): (MB)` Row blocking factor
    `DESCA(6): (NB)` Column blocking factor
    `DESCA(7): (RSRC)` Row index of owner of A(1, 1)
    `DESCA(8): (CSRC)` Column index of owner of A(1, 1)
    `DESCA(9): (LLD)` Leading dimension of the local matrix
    ```

PBLAS - Example

- Parallel version of **`DGEMM`**
  - **`CALL PDGEMM( TRANSA, TRANSB,`**
```
CALL PDGEMM( TRANSA, TRANSB,
             M, N, K,
             ALPHA, A, IA, JA, DESC_A,
                    B, IB, JB, DESC_B,
             BETA,  C, IC, JC, DESC_C )
```
- Notice:
  - PBLAS has interfaces that take descriptions of submatrices
  - BLAS, on the other hand, takes submatrices implicitly

ScaLAPACK

- SCAlable LAPACK (distributed memory)
  - http://www.netlib.org/scalapack/ Official ScaLAPACK releases

ScaLAPACK - Content

- Most of LAPACK
- No support for band and packed matrices
- Missing some more advanced algorithms
  - SVD and QR w/ pivoting least squares
  - Generalized least squares
  - Non-symmetric eigenvalue problems
  - D&C SVD
  - ...

ScaLAPACK – Coding Conventions

- Symbols are similar to LAPACK (just add **`P`**)
- Submatrices are referenced explicitly in interface:
  - **`A(I, J), LDA`** LAPACK submatrix reference
  - **`A, I, J, DESCA`** ScaLAPACK submatrix reference

Utilities: DESCINIT

- **SUBROUTINE DESCINIT(DESC, M, N, MB, NB, RSRC, CSRC, CTXT, LLD, INFO)**
- Initializes all elements of a descriptor.
- Arguments:
  - **DESC** Descriptor to initialize (output)
  - **M, N** Size of global matrix
  - **MB, NB** Blocking factors
  - **RSRC, CSRC** Coordinates of owner of (1, 1) matrix element
  - **CTXT** BLACS context
  - **LLD** Leading dimension of local matrix (use **NUMROC** to find)
  - **INFO** Error reporting, 0: success (output)

Utilities: NUMROC

- **INTEGER FUNCTION NUMROC(N, NB, ME, SRC, NP)**
- Finds the number of rows (or columns) mapped to a specific grid row (or column).
- Arguments:
  - **N** Extent of matrix dimension
  - **NB** Blocking factor in matrix dimension
  - **ME** Row (or column) index of processor of interest
  - **SRC** Row (or column) index of source
  - **NP** Number of processes in grid dimension

Utilities: INFOG2L

- **SUBROUTINE INFOG2L(GRINDX, GCINDX, DESC, NPROW, NPCOL, MYROW, MYCOL, LRINDX, LCINDX, RSRC, CSRC)**
- Given a global matrix element **(GRINDX, GCINDX)**, returns the corresponding local matrix element **(LRINDX, LCINDX)** and coordinates of processor that owns that element **(RSRC, CSRC)**.
- Arguments:
  - **GRINDX, GCINDX** Global matrix element
  - **DESC** Descriptor of matrix
  - **NPROW, NPCOL** Grid size
  - **MYROW, MYCOL** My coordinates
  - **LRINDX, LCINDX** Local matrix element (output)
  - **RSRC, CSRC** Owner of element (output)