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Rowdlas User's Guide

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Abstract
This report is a user's guide to ROWDLAS, a Row-oriented Distributed Linear Algebra Subroutine package. ROWDLAS can be used to develop higher level linear algebra blocks (like direct and iterative solvers) on distributed multiprocessor systems. It also provides portability across several distributed-memory multiprocessors and execution tracing for monitoring the performance and for debugging purposes.

1. Introduction. ROWDLAS is a collection of FORTRAN routines that perform basic linear algebra operations on distributed memory systems. They assume that matrices are row distributed among processors. Only information concerning the data distribution, and the interconnection topology, is required while all other architectural details are hidden from the user.

For both efficiency and portability ROWDLAS is built on top of BLAS [7], [8], [9] and PICL [4] BLAS routines are used at the processor level to perform local linear algebra operations and PICL high-level communication routines are used to accumulate global information. Build-in execution tracing for monitoring the performance is available through PICL and PARAGRAPH [5]. Some preliminary data on the performance evaluation of ROWDLAS routines, together with the detailed description of the parallel algorithms used, can be found in [1].

Some of the ROWDLAS routines assume certain distribution, mapping and storage schemes for the data they involve. This information can be found in section 2. In section 3 we give detailed descriptions of the ROWDLAS routines and their arguments.

2. Assumptions and requirements. Parallel distributed memory algorithms and routines are based on certain architectural parameters like the number of processors, the interconnection topology, the numbering of the node processors and the mapping of the data onto the architecture. In ROWDLAS we have tried to make the definition of these parameters as easy as possible. In this section we list the available choices for these parameters and describe the mechanisms to assign values to them.

Before the call of any of the ROWDLAS routines the users should:
* Call the PICL routine open0 to specify the number of processors nprocs, the host and node ids, me and host respectively and enable communication. These parameters should be stored in the common block
  
  common /open/ nprocs, me, host

* Call the PICL routine setare0 to specify the interconnection topology and the numbering of the nodes. setare0 can be called more than once in case one needs to modify the topology or the node numbering according to the needs of the ROWDLAS routines.

* Some routines require information on the distribution of the data. In this case the user should provide the array idst. idst(i), i = 1, \ldots, nprocs + 1 hold the global index of the first element of the data that belongs to processor i.
In the following table we list the possible choices for the above mentioned parameters for each ROWDLAS routine.

The user simply links the ROWDLAS and PICL libraries together with his favored uni-processor BLAS routines, like the highly optimized ones in [6].

3. Routine Descriptions. In this section we describe the Linear Algebra Subprograms currently available in ROWDLAS. We use the BLAS naming convention and the argument lists are essential the BLAS ones with the only exception of the idist array that hold the data distribution information.

The routines are arranged in alphabetical order and all of them come in single and double precision real.
dsamin/ddamin

Syntax: \( w = \text{dsamin/ddamin}(n,x,\text{idst}) \)

Purpose: Finds the smallest (in absolute value) element of the vector \( x \).

\[
w = \min_{1 \leq i \leq n} (|x_i|)
\]

On Entry

- \( n \quad \text{integer} \)
  the order of the vector \( x \).
- \( x \quad \text{Single precision real for dsamin} \)
  \( \text{Double precision real for ddamin} \)
  array of dimension \( n \)
- \( \text{idst} \quad \text{integer array of dimension nprocs} \)
  array holding the distribution information of \( x \).

On Return

- \( w \quad \text{single precision real for dsamin} \)
  \( \text{single precision real for ddamin} \)
  the absolute value of the smallest (in absolute value) element of \( x \).
dsamax/ddamax

Syntax:  \( w = \text{dsamax/ddamax}(n,x,idst) \)

Purpose:  Finds the largest (in absolute value) element of the vector \( x \).

\[
  w = \max_{1 \leq i \leq n}(|x_i|)
\]

On Entry

\( n \)  \hspace{1cm} \text{integer}

the order of the vector \( x \).

\( x \)  \hspace{1cm} \text{Single precision real for dsamax}

Double precision real for ddamax

array of dimension \( n \)

\( \text{idst} \)  \hspace{1cm} \text{integer array of dimension \( nprocs \)}

array holding the distribution information of \( x \).

On Return

\( w \)  \hspace{1cm} \text{single precision real for dsamax}

double precision real for ddamax

the absolute value of the largest (in absolute value) element of \( x \).
idsamin/iddamin

Syntax: \( iw = \text{idsamin/iddamin}(n,x,idst) \)

Purpose: Finds the smallest index \( i \) such that:
\[
|x_i| = \min_{1 \leq j \leq n} (|x_j|), j = 1, \ldots, n
\]

On Entry
\( n \) integer
the order of the vector \( x \).
\( x \) Single precision real for idsamin
Double precision real for iddamin
array of dimension \( n \)
\( idst \) integer array of dimension \( nproe \)
array holding the distribution information of \( x \).

On Return
\( iw \) integer
index of smallest (in absolute value) element of \( x \).
**idsamax/iddamax**

Syntax: \( iw = \text{idsamax/iddamax}(n,x,\text{idst}) \)

Purpose: Finds the largest index \( i \) such that:
\[
|x_i| = \max_{1 \leq j \leq n} |x_j|, \quad j = 1, \ldots, n
\]

On Entry

- \( n \) integer
  - the order of the vector \( x \).
- \( x \)
  - Single precision real for idsamax
  - Double precision real for iddamax
  - array of dimension \( n \)
- \( \text{idst} \)
  - integer array of dimension \( nproes \)
  - array holding the distribution information of \( x \).

On Return

- \( iw \) integer
  - index of largest (in absolute value) element of \( x \).
**dsasum/ddasum**

**Syntax:** \( w = \text{dsasum/ddasum}(n,x,idst) \)

**Purpose:** Computes the sum of magnitudes of the elements of the vector \( x \):

\[
w = \sum_{i=1}^{n} |x_i|
\]

**On Entry**

- \( n \) integer
  - the order of the vector \( x \).
- \( x \) Single precision real for \( \text{dsasum} \)
  - Double precision real for \( \text{ddasum} \)
  - array of dimension \( n \).
- \( idst \) integer array of dimension \( nproes \)
  - array holding the distribution information of \( x \).

**On Return**

- \( w \) single precision real for \( \text{dsasum} \)
  - double precision real for \( \text{ddasum} \)
  - sum of magnitudes of the elements of \( x \).
**dsnrm2/ddnrm2**

**Syntax:**  
\[ w = \text{dsnrm2/ddnrm2}(n,x,\text{idst}) \]

**Purpose:** Computes the *Euclidean norm* of the vector \( x \):

\[
\|x\|_2 = \left( \sum_{i=1}^{n} x_i^2 \right)^{1/2}
\]

**On Entry**
- \( n \)  
  integer
  the order of the vector \( x \).
- \( x \)  
  Single precision real for \( \text{dsnrm2} \)  
  Double precision real for \( \text{ddnrm2} \)
  array of dimension \( n \)
- \( \text{idst} \)  
  integer array of dimension \( nprocs \)
  array holding the distribution information of \( x \).

**On Return**
- \( w \)  
  single precision real for \( \text{dsnrm2} \)  
  double precision real for \( \text{ddnrm2} \)
  Euclidean norm of \( x \).
**dsdot/dddot/ddsdot**

**Syntax:** \( w = \text{dsdot/dddot/ddsdot}(n,x,y,idst) \)

**Purpose:** Computes the dot product of two vector:

\[ w = x^T y \]

dsdsdot takes single precision arguments, but performs the summation in double precision and returns a double precision result.

**On Entry**

- **n**  
  integer  
  the order of the vector \( x \).

- **x**  
  LOCAL single precision real for dsdot and ddsdot  
  LOCAL double precision real for dddot  
  array of dimension \( n \)

- **y**  
  Single precision real for dsdot and ddsdot  
  Double precision real for dddot  
  array of dimension \( n \)

- **idst**  
  integer array of dimension \( nprocs \)  
  array holding the distribution information of \( y \).

**On Return**

- **w**  
  single precision real for dsdot  
  double precision real for dddot and ddsdot  
  the dot product of \( x \) and \( y \).
dsgemv/ddgemv

Syntax: \( w = \text{dsgemv/ddgemv}(\text{trans.m.n.alph.a.lda.x.beta.y.idst}) \)

Purpose: Performs one of the matrix-vector operations

\[
y = \alpha Ax + \beta y
\]

\[
y = \alpha A^T x + \beta y
\]

where \( \alpha \) and \( \beta \) are scalars, \( x \) and \( y \) are vectors and \( A \) is an \( m \) by \( n \) matrix.

On Entry

- \textbf{trans} character"n"
  - specifies the operation to be performed as follows
    - \text{trans} = \text{'N'} or \text{'n'} \( y = \alpha Ax + \beta y \)
    - \text{trans} = \text{'T'} or \text{'t'} \( y = \alpha A^T x + \beta y \)

- \textbf{m} integer
  - the number of rows of the matrix \( a \).

- \textbf{n} integer
  - the number of columns of the matrix \( a \).

- \textbf{alpha} Single precision for dsgemv
  - Double precision for ddgemv
  - specifies the scalar \( \alpha \)

- \textbf{a} Single precision for dsgemv
  - Double precision for ddgemv
  - array of dimension \((\text{lda},n)\). Contains the matrix on its leading \( m \) by \( n \) part

- \textbf{lda} integer
  - the first dimension of \( a \) as declared in the calling (sub)program.
  - must be at least \( \max(1,m) \)

- \textbf{x} Single precision for dsgemv
  - Double precision for ddgemv
  - array of dimension \( n \) if \text{trans = 'n'} \ or \( m \) if \text{trans = 't'}.\]
beta
Single precision for ds gemv
Double precision for dd gemv

specifies the scalar $\beta$

$y$
Single precision for ds gemv
Double precision for dd gemv

array of dimension $n$ if $\text{trans} = 'n'$ or $m$ if $\text{trans} = 'T'$.

$idst$
integer array of dimension $nprocs$

array holding the distribution information of $A, x$ and $y$.

**On Return**

$y$
overwritten by the updated vector $y$. 

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dsbemv/ddbemv

Syntax: \( w = \text{dsbemv/ddbemv}(\text{trans}, m, n, \text{kl}, \text{ku}, \alpha, a, \text{lda}, x, \beta, y, \text{dest}) \)

Purpose: Performs one of the matrix-vector operations

\[
y = \alpha Ax + \beta y
\]

\[
y = \alpha A^T x + \beta y
\]

where \( \alpha \) and \( \beta \) are scalars, \( x \) and \( y \) are vectors and \( A \) is an \( m \) by \( n \) banded matrix with lower bandwidth \( \text{kl} \) and upper bandwidth \( \text{ku} \).

On Entry

- \text{trans} \quad \text{character} 't'
  
  specifies the operation to be performed as follows
  
  \( \text{trans} = 'N' \) or 'n' \( y = \alpha Ax + \beta y \)
  
  \( \text{trans} = 'T' \) or 't' \( y = \alpha A^T x + \beta y \)

- \( m \) \quad \text{integer}
  
  the number of rows of the matrix \( a \).

- \( n \) \quad \text{integer}
  
  the number of columns of the matrix \( a \).

- \( \text{kl} \) \quad \text{integer}
  
  the number of sub-diagonals of the matrix \( a \).

- \( \text{ku} \) \quad \text{integer}
  
  the number of super-diagonals of the matrix \( a \).

- \alpha \quad \text{Single precision for dsbemv}
  \text{Double precision for ddbemv}
  
  specifies the scalar \( \alpha \)

- \( a \) \quad \text{Single precision for dsbemv}
  \text{Double precision for ddbemv}
  
  array of dimension (\text{lda},n). Contains the matrix on its leading \( m \) by \( n \) part.
  
  The matrix is locally stored in standard (not banded) form
lda integer

the first dimension of a as declared in the calling (sub)program. 
must be at least max(1,m)

x Single precision for dsbenv
Double precision for ddbenv

array of dimension n if trans = 'n' or m if trans = 't'.

beta Single precision for dsbenv
Double precision for ddbenv

specifies the scalar b

y Single precision for dsbenv
Double precision for ddbenv

array of dimension n if trans = 'n' or m if trans = 't'.

idst integer array of dimension nprocs

array holding the distribution information of A, x and y.

On Return

y overwritten by the updated vector y.

NOTES

• On each processor, only the non-zero BLOCKS of the matrix A are stored.
• The distributed data should be mapped assuming ring or full connectivity and the setarcs should be called accordingly.
dssemv/ddsemv

Syntax: \( w = \text{dssemv/ddsemv}(\text{trans}, m, n, \alpha, \text{coef}, \text{idcoef}, \text{lda}, x, \beta, y, \text{idst}) \)

Purpose: Performs one of the matrix-vector operations

\[
    y = \alpha A x + \beta y
\]

\[
    y = \alpha A^T x + \beta y
\]

where \( \alpha \) and \( \beta \) are scalars, \( x \) and \( y \) are vectors and \( A \) is an \( m \times n \) sparse matrix stored in a compressed form using the arrays \( \text{coef} \) and \( \text{idcoef} \).

On Entry

\( \text{trans} \) character*1

specifies the operation to be performed as follows

\( \text{trans} = 'N' \) or \( 'n' \) \( y = \alpha A x + \beta y \)

\( \text{trans} = 'T' \) or \( 't' \) \( y = \alpha A^T x + \beta y \)

\( m \) integer

the number of rows of the matrix \( A \).

\( n \) integer

the number of columns of the matrix \( A \).

\( \alpha \) Single precision for \( \text{dssemv} \)

Double precision for \( \text{ddsemv} \)

specifies the scalar \( \alpha \)

\( \text{coef} \) Single precision for \( \text{dssemv} \)

Double precision for \( \text{ddsemv} \)

array of dimension \((\text{lda}, n)\).

Contains the coefficients of the matrix \( A \) on its leading \( m \times n \) part

\( \text{idcoef} \) Single precision for \( \text{dssemv} \)

Double precision for \( \text{ddsemv} \)

array of dimension \((\text{lda}, n)\).

Contains the indices of the coefficients of the matrix \( A \) on its leading \( m \times n \) part
lda     integer
the first dimension of coef and ideof as declared in the calling (sub)program.
must be at least max(1, n)

x     Single precision for dssemv
      Double precision for ddsemv
array of dimension n if trans = 'n' or m if trans = 't'.

beta     Single precision for dssemv
          Double precision for ddsemv
specifies the scalar β

y     Single precision for dssemv
      Double precision for ddsemv
array of dimension n if trans = 'n' or m if trans = 't'.

idst     integer array of dimension nprocs
array holding the distribution information of A, x and y.

On Return
y     overwritten by the updated vector y.

NOTES
• The distributed data should be mapped assuming ring or full connectivity
  and the setarco should be called accordingly.
REFERENCES


