

## Fast Auxiliary Space Preconditioning

1.5.8 Sep/16/2014

Generated by Doxygen 1.8.8

Tue Sep 16 2014 13:40:46



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# Chapter 1

## Introduction

Over the last few decades, researchers have expended significant effort on developing efficient iterative methods for solving discretized partial differential equations (PDEs). Though these efforts have yielded many mathematically optimal solvers such as the multigrid method, the unfortunate reality is that multigrid methods have not been much used in practical applications. This marked gap between theory and practice is mainly due to the fragility of traditional multigrid (MG) methodology and the complexity of its implementation. We aim to develop techniques and the corresponding software that will narrow this gap, specifically by developing mathematically optimal solvers that are robust and easy to use in practice.

We believe that there is no one-size-for-all solution method for discrete linear systems from different applications. And, efficient iterative solvers can be constructed by taking the properties of PDEs and discretizations into account. In this project, we plan to construct a pool of discrete problems arising from partial differential equations (PDEs) or  $P \leftrightarrow DE$  systems and efficient linear solvers for these problems. We mainly utilize the methodology of Auxiliary Space Preconditioning (ASP) to construct efficient linear solvers. Due to this reason, this software package is called Fast Auxiliary Space Preconditioning or FASP for short.

FASP contains the kernel part and several applications (ranging from fluid dynamics to reservoir simulation). The kernel part is open-source and licensed under GNU Lesser General Public License or LGPL version 3.0 or later. Some of the applications contain contributions from and owned partially by other parties.

For the moment, FASP is under alpha testing. If you wish to obtain a current version of FASP or you have any questions, feel free to contact us at [faspdev@gmail.com](mailto:faspdev@gmail.com).

This software is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU Lesser General Public License for more details.



## Chapter 2

# How to obtain FASP

For the moment, FASP is still under alpha testing. You need a password to download the package. Sorry about it!

The most updated version of FASP can be downloaded from

<http://fasp.sourceforge.net/download/faspsolver.zip>

We use HG (Mecurial) as our main version control tool. HG is easy to use and it is available at all OS platforms. For people who is interested in the developer version, you can obtain the FASP package with hg:

```
$ hg clone https://faspusers@bitbucket.org/fasp/faspsolver
```

will give you the developer version of the FASP package.





## Chapter 3

# Building and Installation

This is a simple instruction on building and testing. For more details, please refer to the README files and the short [User's Guide](#) in "faspolver/doc/".

To compile, you need a Fortran and a C compiler. First, you can type in the "faspolver/" root directory:

```
$ make config
```

which will config the environment automatically. And, then, you can need to type:

```
$ make install
```

which will make the FASP shared static library and install to PREFIX/. By default, FASP libraries and executables will be installed in the FASP home directory "faspolver/".

There is a simple GUI tool for building and installing FASP included in the package. You need Tcl/Tk support in your computer. You may call this GUI by run in the root directory:

```
$ wish fasp_install.tcl
```

If you need to see the detailed usage of "make" or need any help, please type:

```
$ make help
```

After installation, tutorial examples can be found in "tutorial/".



## Chapter 4

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## Chapter 5

# Doxygen

We use Doxygen as our automatically documentation generator which will make our future maintainance minimized. You can obtain the software (Windows, Linux and OS X) as well as its manual on the official website

<http://www.doxygen.org>

For an ordinary user, Doxygen is completely trivial to use. We only need to use some special marker in the usual comment as we put in c-files.



## Chapter 6

# Data Structure Index

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<a href="#">ddenmat</a>	Dense matrix of REAL type . . . . .	30
<a href="#">dSTRmat</a>	Structure matrix of REAL type . . . . .	31
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## Chapter 7

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## Chapter 8

# Data Structure Documentation

### 8.1 AMG\_data Struct Reference

Data for AMG solvers.

```
#include <fasp.h>
```

#### Data Fields

- [SHORT max\\_levels](#)  
*max number of levels*
- [SHORT num\\_levels](#)  
*number of levels in use  $\leq$  max\_levels*
- [dCSRmat A](#)  
*pointer to the matrix at level level\_num*
- [dCSRmat R](#)  
*restriction operator at level level\_num*
- [dCSRmat P](#)  
*prolongation operator at level level\_num*
- [dvector b](#)  
*pointer to the right-hand side at level level\_num*
- [dvector x](#)  
*pointer to the iterative solution at level level\_num*
- [ivector cfmark](#)  
*pointer to the CF marker at level level\_num*
- [INT ILU\\_levels](#)  
*number of levels use ILU smoother*
- [ILU\\_data LU](#)  
*ILU matrix for ILU smoother.*
- [INT near\\_kernel\\_dim](#)  
*dimension of the near kernel for SAMG*
- [REAL \\*\\* near\\_kernel\\_basis](#)  
*basis of near kernel space for SAMG*
- [INT schwarz\\_levels](#)

- *number of levels use schwarz smoother*
- [Schwarz\\_data schwarz](#)  
*data of Schwarz smoother*
- [dvector w](#)  
*Temporary work space.*

### 8.1.1 Detailed Description

Data for AMG solvers.

#### Note

This is needed for the AMG solver/preconditioner.

Definition at line 639 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.2 AMG\_data\_bsr Struct Reference

Data for multigrid levels. (BSR format)

```
#include <fasp_block.h>
```

### Data Fields

- [INT max\\_levels](#)  
*max number of levels*
- [INT num\\_levels](#)  
*number of levels in use <= max\_levels*
- [dBSRmat A](#)  
*pointer to the matrix at level level\_num*
- [dBSRmat R](#)  
*restriction operator at level level\_num*
- [dBSRmat P](#)  
*prolongation operator at level level\_num*
- [dvector b](#)  
*pointer to the right-hand side at level level\_num*
- [dvector x](#)  
*pointer to the iterative solution at level level\_num*
- [dvector diagin](#)  
*pointer to the diagonal inverse at level level\_num*
- [dCSRmat Ac](#)  
*pointer to the matrix at level level\_num (csr format)*
- `void *` [Numeric](#)  
*pointer to the numerical dactorization from UMFPACK*



- [dCSRmat PP](#)  
*pointer to the pressure block (only for reservoir simulation)*
- [REAL \\* pw](#)  
*pointer to the auxiliary vectors for pressure block*
- [dBSRmat SS](#)  
*pointer to the saturation block (only for reservoir simulation)*
- [REAL \\* sw](#)  
*pointer to the auxiliary vectors for saturation block*
- [dvector diaginvs\\_SS](#)  
*pointer to the diagonal inverse of the saturation block at level level\_num*
- [ILU\\_data PP\\_LU](#)  
*ILU data for pressure block.*
- [ivector cfmark](#)  
*pointer to the CF marker at level level\_num*
- [INT ILU\\_levels](#)  
*number of levels use ILU smoother*
- [ILU\\_data LU](#)  
*ILU matrix for ILU smoother.*
- [INT near\\_kernel\\_dim](#)  
*dimension of the near kernel for SAMG*
- [REAL \\*\\* near\\_kernel\\_basis](#)  
*basis of near kernel space for SAMG*
- [dCSRmat \\* A\\_nk](#)  
*Matrix data for near kernel.*
- [dCSRmat \\* P\\_nk](#)  
*Prolongation for near kernel.*
- [dCSRmat \\* R\\_nk](#)  
*Restriction for near kernel.*
- [dvector w](#)  
*temporary work space*

### 8.2.1 Detailed Description

Data for multigrid levels. (BSR format)

#### Note

This structure is needed for the AMG solver/preconditioner in BSR format

Definition at line 191 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.3 AMG\_param Struct Reference

Parameters for AMG solver.

```
#include <fasp.h>
```

## Data Fields

- [SHORT AMG\\_type](#)  
*type of AMG method*
- [SHORT print\\_level](#)  
*print level for AMG*
- [INT maxit](#)  
*max number of iterations of AMG*
- [REAL tol](#)  
*stopping tolerance for AMG solver*
- [SHORT max\\_levels](#)  
*max number of levels of AMG*
- [INT coarse\\_dof](#)  
*max coarsest level dof*
- [SHORT cycle\\_type](#)  
*type of AMG cycle*
- [SHORT smoother](#)  
*smoother type*
- [SHORT smooth\\_order](#)  
*smoother order*
- [SHORT presmooth\\_iter](#)  
*number of presmootherers*
- [SHORT postsmooth\\_iter](#)  
*number of postsmootherers*
- [REAL relaxation](#)  
*relaxation parameter for SOR smoother*
- [SHORT polynomial\\_degree](#)  
*degree of the polynomial smoother*
- [SHORT coarse\\_solver](#)  
*coarse solver type*
- [SHORT coarse\\_scaling](#)  
*switch of scaling of the coarse grid correction*
- [SHORT amli\\_degree](#)  
*degree of the polynomial used by AMLI cycle*
- [REAL \\* amli\\_coef](#)  
*coefficients of the polynomial used by AMLI cycle*
- [SHORT nl\\_amli\\_krylov\\_type](#)  
*type of krylov method used by Nonlinear AMLI cycle*
- [SHORT coarsening\\_type](#)  
*coarsening type*
- [SHORT aggregation\\_type](#)  
*aggregation type*
- [SHORT interpolation\\_type](#)  
*interpolation type*
- [REAL strong\\_threshold](#)  
*strong connection threshold for coarsening*
- [REAL max\\_row\\_sum](#)

- maximal row sum parameter*
- [REAL truncation\\_threshold](#)
  - truncation threshold*
- [INT aggressive\\_level](#)
  - number of levels use aggressive coarsening*
- [INT aggressive\\_path](#)
  - numebr of paths use to determin stongly coupled C points*
- [INT pair\\_number](#)
  - numebr of pairwise matchings*
- [REAL strong\\_coupled](#)
  - strong coupled threshold for aggregate*
- [INT max\\_aggregation](#)
  - max size of each aggregate*
- [REAL tentative\\_smooth](#)
  - relaxation parameter for smoothing the tentative prolongation*
- [SHORT smooth\\_filter](#)
  - switch for filtered matrix used for smoothing the tentative prolongation*
- [SHORT ILU\\_levels](#)
  - number of levels use ILU smoother*
- [SHORT ILU\\_type](#)
  - ILU type for smoothing.*
- [INT ILU\\_lfil](#)
  - level of fill-in for ILUs and ILUk*
- [REAL ILU\\_droptol](#)
  - drop tolerance for ILU<sub>t</sub>*
- [REAL ILU\\_relax](#)
  - relaxiation for ILUs*
- [REAL ILU\\_permtol](#)
  - permuted if  $\text{permtol} * |a(i,j)| > |a(i,i)|$*
- [INT schwarz\\_levels](#)
  - number of levels use schwarz smoother*
- [INT schwarz\\_mmsize](#)
  - maximal block size*
- [INT schwarz\\_maxlvl](#)
  - maximal levels*
- [INT schwarz\\_type](#)
  - type of schwarz method*

### 8.3.1 Detailed Description

Parameters for AMG solver.

#### Note

This is needed for the AMG solver/preconditioner.

Definition at line 506 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.4 block\_BSR Struct Reference

Block REAL matrix format for reservoir simulation.

```
#include <fasp_block.h>
```

### Data Fields

- [dBSRmat ResRes](#)  
*reservoir-reservoir block*
- [dCSRmat ResWel](#)  
*reservoir-well block*
- [dCSRmat WelRes](#)  
*well-reservoir block*
- [dCSRmat WelWel](#)  
*well-well block*

### 8.4.1 Detailed Description

Block REAL matrix format for reservoir simulation.

Definition at line 165 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.5 block\_dCSRmat Struct Reference

Block REAL CSR matrix format.

```
#include <fasp_block.h>
```

### Data Fields

- [INT brow](#)  
*row number of blocks in A, m*
- [INT bcol](#)  
*column number of blocks A, n*
- [dCSRmat \\*\\* blocks](#)  
*blocks of [dCSRmat](#), point to blocks[brow][bcol]*

### 8.5.1 Detailed Description

Block REAL CSR matrix format.

**Note**

The starting index of A is 0.

Definition at line 77 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.6 block\_dvector Struct Reference

Block REAL vector structure.

```
#include <fasp_block.h>
```

**Data Fields**

- [INT brow](#)  
*row number of blocks in A, m*
- [dvector \\*\\* blocks](#)  
*blocks of dvector, point to blocks[brow]*

### 8.6.1 Detailed Description

Block REAL vector structure.

Definition at line 113 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.7 block\_iCSRmat Struct Reference

Block INT CSR matrix format.

```
#include <fasp_block.h>
```

**Data Fields**

- [INT brow](#)  
*row number of blocks in A, m*
- [INT bcol](#)  
*column number of blocks A, n*
- [iCSRmat \\*\\* blocks](#)  
*blocks of iCSRmat, point to blocks[brow][bcol]*

### 8.7.1 Detailed Description

Block INT CSR matrix format.

#### Note

The starting index of A is 0.

Definition at line 96 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.8 block\_ivector Struct Reference

Block INT vector structure.

```
#include <fasp_block.h>
```

### Data Fields

- [INT brow](#)  
*row number of blocks in A, m*
- [ivector \\*\\* blocks](#)  
*blocks of dvector, point to blocks[brow]*

### 8.8.1 Detailed Description

Block INT vector structure.

#### Note

The starting index of A is 0.

Definition at line 129 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.9 block\_Reservoir Struct Reference

Block REAL matrix format for reservoir simulation.

```
#include <fasp_block.h>
```

## Data Fields

- [dSTRmat ResRes](#)  
*reservoir-reservoir block*
- [dCSRmat ResWel](#)  
*reservoir-well block*
- [dCSRmat WelRes](#)  
*well-reservoir block*
- [dCSRmat WelWel](#)  
*well-well block*

### 8.9.1 Detailed Description

Block REAL matrix format for reservoir simulation.

Definition at line 144 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.10 dBSRmat Struct Reference

Block sparse row storage matrix of REAL type.

```
#include <fasp_block.h>
```

## Data Fields

- [INT ROW](#)  
*number of rows of sub-blocks in matrix A, M*
- [INT COL](#)  
*number of cols of sub-blocks in matrix A, N*
- [INT NNZ](#)  
*number of nonzero sub-blocks in matrix A, NNZ*
- [INT nb](#)  
*dimension of each sub-block*
- [INT storage\\_manner](#)  
*storage manner for each sub-block*
- [REAL \\* val](#)
- [INT \\* IA](#)  
*integer array of row pointers, the size is ROW+1*
- [INT \\* JA](#)

### 8.10.1 Detailed Description

Block sparse row storage matrix of REAL type.

#### Note

This data structure is adapted from the Intel MKL library. Refer to: <http://software.intel.com/sites/products/documentation/hpc/mkl/lin/index.htm>  
Some of the following entries are capitalized to stress that they are for blocks!

Definition at line 37 of file fasp\_block.h.

### 8.10.2 Field Documentation

#### 8.10.2.1 INT\* JA

Element  $i$  of the integer array columns is the number of the column in the block matrix that contains the  $i$ -th non-zero block. The size is NNZ.

Definition at line 67 of file fasp\_block.h.

#### 8.10.2.2 REAL\* val

A real array that contains the elements of the non-zero blocks of a sparse matrix. The elements are stored block-by-block in row major order. A non-zero block is the block that contains at least one non-zero element. All elements of non-zero blocks are stored, even if some of them is equal to zero. Within each nonzero block elements are stored in row-major order and the size is  $(NNZ * nb * nb)$ .

Definition at line 60 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.11 dCOOmat Struct Reference

Sparse matrix of REAL type in COO (or IJ) format.

```
#include <fasp.h>
```

### Data Fields

- [INT row](#)  
*row number of matrix A, m*
- [INT col](#)  
*column of matrix A, n*
- [INT nnz](#)  
*number of nonzero entries*
- [INT \\* rowind](#)  
*integer array of row indices, the size is nnz*
- [INT \\* colind](#)



*integer array of column indices, the size is nnz*

- [REAL \\* val](#)

*nonzero entries of A*

### 8.11.1 Detailed Description

Sparse matrix of REAL type in COO (or IJ) format.

Coordinate Format (I,J,A)

#### Note

The starting index of A is 0.

Change I to rowind, J to colind. To avoid with complex.h confliction on I.

Definition at line 209 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.12 dCSRLmat Struct Reference

Sparse matrix of REAL type in CSRL format.

```
#include <fasp.h>
```

### Data Fields

- [INT row](#)  
*number of rows*
- [INT col](#)  
*number of cols*
- [INT nnz](#)  
*number of nonzero entries*
- [INT dif](#)  
*number of different values in i-th row, i=0:nrows-1*
- [INT \\* nz\\_diff](#)  
*nz\_diff[i]: the i-th different value in 'nzrow'*
- [INT \\* index](#)  
*row index of the matrix (length-grouped): rows with same nnz are together*
- [INT \\* start](#)  
*j in {start[i],...,start[i+1]-1} means nz\_diff[i] nnz in index[j]-row*
- [INT \\* ja](#)  
*column indices of all the nonzeros*
- [REAL \\* val](#)  
*values of all the nonzero entries*

### 8.12.1 Detailed Description

Sparse matrix of REAL type in CSRL format.

Definition at line 265 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.13 dCSRmat Struct Reference

Sparse matrix of REAL type in CSR format.

```
#include <fasp.h>
```

### Data Fields

- [INT row](#)  
*row number of matrix A, m*
- [INT col](#)  
*column of matrix A, n*
- [INT nnz](#)  
*number of nonzero entries*
- [INT \\* IA](#)  
*integer array of row pointers, the size is m+1*
- [INT \\* JA](#)  
*integer array of column indexes, the size is nnz*
- [REAL \\* val](#)  
*nonzero entries of A*

### 8.13.1 Detailed Description

Sparse matrix of REAL type in CSR format.

CSR Format (IA,JA,A) in REAL

#### Note

The starting index of A is 0.

Definition at line 148 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.14 ddenmat Struct Reference

Dense matrix of REAL type.

```
#include <fasp.h>
```

## Data Fields

- [INT row](#)  
*number of rows*
- [INT col](#)  
*number of columns*
- [REAL \\*\\* val](#)  
*actual matrix entries*

### 8.14.1 Detailed Description

Dense matrix of REAL type.

A dense REAL matrix

Definition at line 108 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.15 dSTRmat Struct Reference

Structure matrix of REAL type.

```
#include <fasp.h>
```

## Data Fields

- [INT nx](#)  
*number of grids in x direction*
- [INT ny](#)  
*number of grids in y direction*
- [INT nz](#)  
*number of grids in z direction*
- [INT nxy](#)  
*number of grids on x-y plane*
- [INT nc](#)  
*size of each block (number of components)*
- [INT ngrid](#)  
*number of grids*
- [REAL \\* diag](#)  
*diagonal entries (length is ngrid\*(nc^2))*
- [INT nband](#)  
*number of off-diag bands*
- [INT \\* offsets](#)  
*offsets of the off-diagals (length is nband)*
- [REAL \\*\\* offdiag](#)  
*off-diagonal entries (dimension is nband \* [(ngrid-offsets) \* nc^2])*

### 8.15.1 Detailed Description

Structure matrix of REAL type.

#### Note

Every  $nc^2$  entries of the array `diag` and `off-diag[i]` store one block: For 2D matrix, the recommended offsets is `[-1,1,-nx,nx]`; For 3D matrix, the recommended offsets is `[-1,1,-nx,nx,-nxy,nxy]`.

Definition at line 304 of file `fasp.h`.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.16 dvector Struct Reference

Vector with `n` entries of REAL type.

```
#include <fasp.h>
```

### Data Fields

- [INT row](#)  
*number of rows*
- [REAL \\* val](#)  
*actual vector entries*

### 8.16.1 Detailed Description

Vector with `n` entries of REAL type.

Definition at line 342 of file `fasp.h`.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.17 grid2d Struct Reference

Two dimensional grid data structure.

```
#include <fasp.h>
```

### Data Fields

- [REAL\(\\* p\)\[2\]](#)
- [INT\(\\* e\)\[2\]](#)
- [INT\(\\* t\)\[3\]](#)
- [INT\(\\* s\)\[3\]](#)

- `INT * pdir`
- `INT * edir`
- `INT * pfather`
- `INT * efather`
- `INT * tfather`
- `INT vertices`
- `INT edges`
- `INT triangles`

### 8.17.1 Detailed Description

Two dimensional grid data structure.

#### Note

The `grid2d` structure is simply a list of triangles, edges and vertices. edge  $i$  has 2 vertices  $e[i]$ , triangle  $i$  has 3 edges  $s[i]$ , 3 vertices  $t[i]$  vertex  $i$  has two coordinates  $p[i]$

Definition at line 1028 of file `asp.h`.

### 8.17.2 Field Documentation

#### 8.17.2.1 `INT(* e)[2]`

Vertices of edges

Definition at line 1031 of file `asp.h`.

#### 8.17.2.2 `INT edges`

Number of edges

Definition at line 1042 of file `asp.h`.

#### 8.17.2.3 `INT* edir`

Boundary flags (0 <=> interior edge)

Definition at line 1035 of file `asp.h`.

#### 8.17.2.4 `INT* efather`

Father edge or triangle

Definition at line 1038 of file `asp.h`.

#### 8.17.2.5 `REAL(* p)[2]`

Coordinates of vertices

Definition at line 1030 of file `asp.h`.

#### 8.17.2.6 `INT* pdiri`

Boundary flags (0 <=> interior point)

Definition at line 1034 of file fasp.h.

#### 8.17.2.7 `INT* pfather`

Father point or edge

Definition at line 1037 of file fasp.h.

#### 8.17.2.8 `INT(* s)[3]`

Edges of triangles

Definition at line 1033 of file fasp.h.

#### 8.17.2.9 `INT(* t)[3]`

Vertices of triangles

Definition at line 1032 of file fasp.h.

#### 8.17.2.10 `INT* tfather`

Father triangle

Definition at line 1039 of file fasp.h.

#### 8.17.2.11 `INT triangles`

Number of triangles

Definition at line 1043 of file fasp.h.

#### 8.17.2.12 `INT vertices`

Number of grid points

Definition at line 1041 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.18 iCOOmat Struct Reference

Sparse matrix of INT type in COO (or IJ) format.

```
#include <fasp.h>
```

## Data Fields

- [INT row](#)  
*row number of matrix A, m*
- [INT col](#)  
*column of matrix A, n*
- [INT nnz](#)  
*number of nonzero entries*
- [INT \\* I](#)  
*integer array of row indices, the size is nnz*
- [INT \\* J](#)  
*integer array of column indices, the size is nnz*
- [INT \\* val](#)  
*nonzero entries of A*

### 8.18.1 Detailed Description

Sparse matrix of INT type in COO (or IJ) format.

Coordinate Format (I,J,A)

#### Note

The starting index of A is 0.

Definition at line 239 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.19 iCSRmat Struct Reference

Sparse matrix of INT type in CSR format.

```
#include <fasp.h>
```

## Data Fields

- [INT row](#)  
*row number of matrix A, m*
- [INT col](#)  
*column of matrix A, n*
- [INT nnz](#)  
*number of nonzero entries*
- [INT \\* IA](#)  
*integer array of row pointers, the size is m+1*
- [INT \\* JA](#)  
*integer array of column indexes, the size is nnz*
- [INT \\* val](#)  
*nonzero entries of A*

### 8.19.1 Detailed Description

Sparse matrix of INT type in CSR format.

CSR Format (IA,JA,A) in integer

#### Note

The starting index of A is 0.

Definition at line 178 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.20 idenmat Struct Reference

Dense matrix of INT type.

```
#include <fasp.h>
```

### Data Fields

- [INT row](#)  
*number of rows*
- [INT col](#)  
*number of columns*
- [INT \\*\\* val](#)  
*actual matrix entries*

### 8.20.1 Detailed Description

Dense matrix of INT type.

A dense INT matrix

Definition at line 127 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.21 ILU\_data Struct Reference

Data for ILU setup.

```
#include <fasp.h>
```



### Data Fields

- [INT row](#)  
*row number of matrix LU, m*
- [INT col](#)  
*column of matrix LU, n*
- [INT nzlu](#)  
*number of nonzero entries*
- [INT \\* ijlu](#)  
*integer array of row pointers and column indexes, the size is nzlu*
- [REAL \\* luval](#)  
*nonzero entries of LU*
- [INT nb](#)  
*block size for BSR type only*
- [INT nwork](#)  
*work space size*
- [REAL \\* work](#)  
*work space*

#### 8.21.1 Detailed Description

Data for ILU setup.

Definition at line 400 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.22 ILU\_param Struct Reference

Parameters for ILU.

```
#include <fasp.h>
```

### Data Fields

- [SHORT print\\_level](#)  
*print leve*
- [SHORT ILU\\_type](#)  
*ILU type for decomposition.*
- [INT ILU\\_ifil](#)  
*level of fill-in for ILUk*
- [REAL ILU\\_droptol](#)  
*drop tolerance for ILUt*
- [REAL ILU\\_relax](#)  
*add the sum of dropped elements to diagonal element in proportion relax*
- [REAL ILU\\_permtol](#)  
*permuted if  $\text{permtol} * |a(i,j)| > |a(i,i)|$*

### 8.22.1 Detailed Description

Parameters for ILU.

Definition at line 374 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.23 input\_param Struct Reference

Input parameters.

```
#include <fasp.h>
```

### Data Fields

- [SHORT print\\_level](#)
- [SHORT output\\_type](#)
- [char inifile \[256\]](#)
- [char workdir \[256\]](#)
- [INT problem\\_num](#)
- [SHORT solver\\_type](#)
- [SHORT precondition\\_type](#)
- [SHORT stop\\_type](#)
- [REAL itsolver\\_tol](#)
- [INT itsolver\\_maxit](#)
- [INT restart](#)
- [SHORT ILU\\_type](#)
- [INT ILU\\_lfil](#)
- [REAL ILU\\_droptol](#)
- [REAL ILU\\_relax](#)
- [REAL ILU\\_permtol](#)
- [INT Schwarz\\_mmsize](#)
- [INT Schwarz\\_maxlvl](#)
- [INT Schwarz\\_type](#)
- [SHORT AMG\\_type](#)
- [SHORT AMG\\_levels](#)
- [SHORT AMG\\_cycle\\_type](#)
- [SHORT AMG\\_smoother](#)
- [SHORT AMG\\_smooth\\_order](#)
- [REAL AMG\\_relaxation](#)
- [SHORT AMG\\_polynomial\\_degree](#)
- [SHORT AMG\\_presmooth\\_iter](#)
- [SHORT AMG\\_postsmooth\\_iter](#)
- [INT AMG\\_coarse\\_dof](#)
- [REAL AMG\\_tol](#)
- [INT AMG\\_maxit](#)
- [SHORT AMG\\_ILU\\_levels](#)
- [SHORT AMG\\_coarse\\_solver](#)

- [SHORT AMG\\_coarse\\_scaling](#)
- [SHORT AMG\\_amli\\_degree](#)
- [SHORT AMG\\_nl\\_amli\\_krylov\\_type](#)
- [INT AMG\\_schwarz\\_levels](#)
- [SHORT AMG\\_coarsening\\_type](#)
- [SHORT AMG\\_aggregation\\_type](#)
- [SHORT AMG\\_interpolation\\_type](#)
- [REAL AMG\\_strong\\_threshold](#)
- [REAL AMG\\_truncation\\_threshold](#)
- [REAL AMG\\_max\\_row\\_sum](#)
- [INT AMG\\_aggressive\\_level](#)
- [INT AMG\\_aggressive\\_path](#)
- [INT AMG\\_pair\\_number](#)
- [REAL AMG\\_strong\\_coupled](#)
- [INT AMG\\_max\\_aggregation](#)
- [REAL AMG\\_tentative\\_smooth](#)
- [SHORT AMG\\_smooth\\_filter](#)

### 8.23.1 Detailed Description

Input parameters.

Input parameters, reading from disk file

Definition at line 932 of file fasp.h.

### 8.23.2 Field Documentation

#### 8.23.2.1 [SHORT AMG\\_aggregation\\_type](#)

aggregation type

Definition at line 985 of file fasp.h.

#### 8.23.2.2 [INT AMG\\_aggressive\\_level](#)

number of levels use aggressive coarsening

Definition at line 990 of file fasp.h.

#### 8.23.2.3 [INT AMG\\_aggressive\\_path](#)

number of paths used to determine strongly coupled C-set

Definition at line 991 of file fasp.h.

#### 8.23.2.4 [SHORT AMG\\_amli\\_degree](#)

degree of the polynomial used by AMLI cycle

Definition at line 979 of file fasp.h.

**8.23.2.5 INT AMG\_coarse\_dof**

minimal coarsest level dof

Definition at line 973 of file fasp.h.

**8.23.2.6 SHORT AMG\_coarse\_scaling**

switch of scaling of the coarse grid correction

Definition at line 978 of file fasp.h.

**8.23.2.7 SHORT AMG\_coarse\_solver**

coarse solver type

Definition at line 977 of file fasp.h.

**8.23.2.8 SHORT AMG\_coarsening\_type**

coarsening type

Definition at line 984 of file fasp.h.

**8.23.2.9 SHORT AMG\_cycle\_type**

type of cycle

Definition at line 966 of file fasp.h.

**8.23.2.10 SHORT AMG\_ILU\_levels**

how many levels use ILU smoother

Definition at line 976 of file fasp.h.

**8.23.2.11 SHORT AMG\_interpolation\_type**

interpolation type

Definition at line 986 of file fasp.h.

**8.23.2.12 SHORT AMG\_levels**

maximal number of levels

Definition at line 965 of file fasp.h.

**8.23.2.13 INT AMG\_max\_aggregation**

max size of each aggregate

Definition at line 996 of file fasp.h.

**8.23.2.14 REAL AMG\_max\_row\_sum**

maximal row sum

Definition at line 989 of file fasp.h.

**8.23.2.15 INT AMG\_maxit**

number of iterations for AMG used as preconditioner

Definition at line 975 of file fasp.h.

**8.23.2.16 SHORT AMG\_nl\_amli\_krylov\_type**

type of krylov method used by nonlinear AMLI cycle

Definition at line 980 of file fasp.h.

**8.23.2.17 INT AMG\_pair\_number**

number of pairs in matching algorithm

Definition at line 992 of file fasp.h.

**8.23.2.18 SHORT AMG\_polynomial\_degree**

degree of the polynomial smoother

Definition at line 970 of file fasp.h.

**8.23.2.19 SHORT AMG\_postsmooth\_iter**

number of postsmoothing

Definition at line 972 of file fasp.h.

**8.23.2.20 SHORT AMG\_presmooth\_iter**

number of presmoothing

Definition at line 971 of file fasp.h.

**8.23.2.21 REAL AMG\_relaxation**

over-relaxation parameter for SOR

Definition at line 969 of file fasp.h.

**8.23.2.22 INT AMG\_schwarz\_levels**

number of levels use schwarz smoother

Definition at line 981 of file fasp.h.

**8.23.2.23 SHORT AMG\_smooth\_filter**

use filter for smoothing the tentative prolongation or not

Definition at line 998 of file fasp.h.

**8.23.2.24 SHORT AMG\_smooth\_order**

order for smoothers

Definition at line 968 of file fasp.h.

**8.23.2.25 SHORT AMG\_smoother**

type of smoother

Definition at line 967 of file fasp.h.

**8.23.2.26 REAL AMG\_strong\_coupled**

strong coupled threshold for aggregate

Definition at line 995 of file fasp.h.

**8.23.2.27 REAL AMG\_strong\_threshold**

strong threshold for coarsening

Definition at line 987 of file fasp.h.

**8.23.2.28 REAL AMG\_tentative\_smooth**

relaxation factor for smoothing the tentative prolongation

Definition at line 997 of file fasp.h.

**8.23.2.29 REAL AMG\_tol**

tolerance for AMG if used as preconditioner

Definition at line 974 of file fasp.h.

**8.23.2.30 REAL AMG\_truncation\_threshold**

truncation factor for interpolation

Definition at line 988 of file fasp.h.

**8.23.2.31 SHORT AMG\_type**

Type of AMG

Definition at line 964 of file fasp.h.

**8.23.2.32 REAL ILU\_droptol**

drop tolerance

Definition at line 954 of file fasp.h.

**8.23.2.33 INT ILU\_ifil**

level of fill-in

Definition at line 953 of file fasp.h.

**8.23.2.34 REAL ILU\_permtol**

permutation tolerance

Definition at line 956 of file fasp.h.

**8.23.2.35 REAL ILU\_relax**

scaling factor: add the sum of dropped entries to diagonal

Definition at line 955 of file fasp.h.

**8.23.2.36 SHORT ILU\_type**

ILU type for decomposition

Definition at line 952 of file fasp.h.

**8.23.2.37 char inifile[256]**

ini file name

Definition at line 939 of file fasp.h.

**8.23.2.38 INT itsolver\_maxit**

maximal number of iterations for iterative solvers

Definition at line 948 of file fasp.h.

**8.23.2.39 REAL itsolver\_tol**

tolerance for iterative linear solver

Definition at line 947 of file fasp.h.

**8.23.2.40 SHORT output\_type**

type of output stream

Definition at line 936 of file fasp.h.

**8.23.2.41 SHORT precondition\_type**

type of preconditioner for iterative solvers

Definition at line 945 of file fasp.h.

**8.23.2.42 SHORT print\_level**

print level

Definition at line 935 of file fasp.h.

**8.23.2.43 INT problem\_num**

problem number to solve

Definition at line 941 of file fasp.h.

**8.23.2.44 INT restart**

restart number used in GMRES

Definition at line 949 of file fasp.h.

**8.23.2.45 INT Schwarz\_maxlvl**

maximal levels

Definition at line 960 of file fasp.h.

**8.23.2.46 INT Schwarz\_mmsize**

maximal block size

Definition at line 959 of file fasp.h.

**8.23.2.47 INT Schwarz\_type**

type of schwarz method

Definition at line 961 of file fasp.h.

**8.23.2.48 SHORT solver\_type**

type of iterative solvers

Definition at line 944 of file fasp.h.

**8.23.2.49 SHORT stop\_type**

type of stopping criteria for iterative solvers

Definition at line 946 of file fasp.h.



#### 8.23.2.50 char workdir[256]

working directory for data files

Definition at line 940 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.24 itsolver\_param Struct Reference

Parameters passed to iterative solvers.

```
#include <fasp.h>
```

### Data Fields

- [SHORT itsolver\\_type](#)
- [SHORT precondition\\_type](#)
- [SHORT stop\\_type](#)
- [INT maxit](#)
- [REAL tol](#)
- [INT restart](#)
- [SHORT print\\_level](#)

### 8.24.1 Detailed Description

Parameters passed to iterative solvers.

Definition at line 1006 of file fasp.h.

### 8.24.2 Field Documentation

#### 8.24.2.1 SHORT itsolver\_type

solver type: see message.h

Definition at line 1008 of file fasp.h.

#### 8.24.2.2 INT maxit

max number of iterations

Definition at line 1011 of file fasp.h.

#### 8.24.2.3 SHORT precondition\_type

preconditioner type: see message.h

Definition at line 1009 of file fasp.h.

#### 8.24.2.4 **SHORT** print\_level

print level: 0–10

Definition at line 1014 of file fasp.h.

#### 8.24.2.5 **INT** restart

number of steps for restarting: for GMRES etc

Definition at line 1013 of file fasp.h.

#### 8.24.2.6 **SHORT** stop\_type

stopping criteria type

Definition at line 1010 of file fasp.h.

#### 8.24.2.7 **REAL** tol

convergence tolerance

Definition at line 1012 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

### 8.25 **ivector** Struct Reference

Vector with n entries of INT type.

```
#include <fasp.h>
```

#### Data Fields

- [INT](#) row  
*number of rows*
- [INT](#) \* val  
*actual vector entries*

#### 8.25.1 Detailed Description

Vector with n entries of INT type.

Definition at line 356 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.26 Link Struct Reference

Struct for Links.

```
#include <fasp.h>
```

### Data Fields

- [INT prev](#)  
*previous node in the linklist*
- [INT next](#)  
*next node in the linklist*

### 8.26.1 Detailed Description

Struct for Links.

Definition at line 1055 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.27 linked\_list Struct Reference

A linked list node.

```
#include <fasp.h>
```

### Data Fields

- [INT data](#)  
*data*
- [INT head](#)  
*starting of the list*
- [INT tail](#)  
*ending of the list*
- struct [linked\\_list](#) \* [next\\_node](#)  
*next node*
- struct [linked\\_list](#) \* [prev\\_node](#)  
*previous node*

### 8.27.1 Detailed Description

A linked list node.

**Note**

This definition is adapted from hypre 2.0.

Definition at line 1072 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.28 mxv\_matfree Struct Reference

Matrix-vector multiplication, replace the actual matrix.

```
#include <fasp.h>
```

**Data Fields**

- void \* [data](#)  
*data for MxV, can be a Matrix or something else*
- void(\* [fct](#))(void \*, [REAL](#) \*, [REAL](#) \*)  
*action for MxV, void function pointer*

### 8.28.1 Detailed Description

Matrix-vector multiplication, replace the actual matrix.

Definition at line 916 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.29 precondition Struct Reference

Preconditioner data and action.

```
#include <fasp.h>
```

**Data Fields**

- void \* [data](#)  
*data for preconditioner, void pointer*
- void(\* [fct](#))([REAL](#) \*, [REAL](#) \*, void \*)  
*action for preconditioner, void function pointer*

### 8.29.1 Detailed Description

Preconditioner data and action.

#### Note

This is the preconditioner structure for preconditioned iterative methods.

Definition at line 902 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.30 precondition\_block\_data Struct Reference

Data passed to the preconditioner for block preconditioning for [block\\_dCSRmat](#) format.

```
#include <fasp_block.h>
```

### Data Fields

- [block\\_dCSRmat](#) \* [Abcsr](#)
- [dCSRmat](#) \* [A\\_diag](#)
- [dvector](#) r
- void \*\* [LU\\_diag](#)
- [AMG\\_data](#) \*\* [mgl](#)
- [AMG\\_param](#) \* [amgparam](#)

### 8.30.1 Detailed Description

Data passed to the preconditioner for block preconditioning for [block\\_dCSRmat](#) format.

Data passed to the preconditioner for block diagonal preconditioning.

This is needed for the block preconditioner.

#### Note

This is needed for the diagonal block preconditioner.

Definition at line 489 of file fasp\_block.h.

### 8.30.2 Field Documentation

#### 8.30.2.1 dCSRmat\* A\_diag

data for each diagonal block which need to solve in the block preconditioners

Definition at line 496 of file fasp\_block.h.

#### 8.30.2.2 **block\_dCSRmat\*** Abcsr

problem data, the blocks

Definition at line 494 of file fasp\_block.h.

#### 8.30.2.3 **AMG\_param\*** amgparam

parameters for AMG

Definition at line 508 of file fasp\_block.h.

#### 8.30.2.4 **void\*\*** LU\_diag

LU decomposition for the diagonal blocks – (only for UMFpack – Xiaozhe Hu)

Definition at line 504 of file fasp\_block.h.

#### 8.30.2.5 **AMG\_data\*\*** mgl

AMG data for the diagonal blocks

Definition at line 507 of file fasp\_block.h.

#### 8.30.2.6 **dvector** r

temp work space

Definition at line 498 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.31 **precond\_block\_reservoir\_data** Struct Reference

Data passed to the preconditioner for preconditioning reservoir simulation problems.

```
#include <fasp_block.h>
```

### Data Fields

- [block\\_Reservoir](#) \* A  
*problem data in [block\\_Reservoir](#) format*
- [block\\_dCSRmat](#) \* Abcsr  
*problem data in [block\\_dCSRmat](#) format*
- [dCSRmat](#) \* Acsr  
*problem data in CSR format*
- [INT](#) ILU\_ifil  
*level of fill-in for structured ILU(k)*
- [dSTRmat](#) \* LU

- *LU matrix for Reservoir-Reservoir block in STR format.*
- [ILU\\_data](#) \* [LUcsr](#)
  - *LU matrix for Reservoir-Reservoir block in CSR format.*
- [AMG\\_data](#) \* [mgl\\_data](#)
  - *AMG data for pressure-pressure block.*
- [SHORT print\\_level](#)
  - *print level in AMG preconditioner*
- [INT maxit\\_AMG](#)
  - *max number of iterations of AMG preconditioner*
- [SHORT max\\_levels](#)
  - *max number of AMG levels*
- [REAL amg\\_tol](#)
  - *tolerance for AMG preconditioner*
- [SHORT cycle\\_type](#)
  - *AMG cycle type.*
- [SHORT smoother](#)
  - *AMG smoother type.*
- [SHORT presmooth\\_iter](#)
  - *number of presmoothing*
- [SHORT postsmooth\\_iter](#)
  - *number of postsmoothing*
- [SHORT coarsening\\_type](#)
  - *coarsening type*
- [REAL relaxation](#)
  - *relaxation parameter for SOR smoother*
- [SHORT coarse\\_scaling](#)
  - *switch of scaling of coarse grid correction*
- [INT maxit](#)
  - *max number of iterations*
- [INT restart](#)
  - *number of iterations for restart*
- [REAL tol](#)
  - *tolerance for convergence*
- [REAL](#) \* [invS](#)
  - *inverse of the schur complement  $(-I - Awr*Arr^{-1}*Arw)^{-1}$ , Arr may be replaced by LU*
- [dvector](#) \* [DPSinvDSS](#)
  - *Diag(Ps) \* inv(Diag(SS))*
- [SHORT scaled](#)
- [ivector](#) \* [perf\\_idx](#)
- [dSTRmat](#) \* [RR](#)
- [dCSRmat](#) \* [WW](#)
- [dCSRmat](#) \* [PP](#)
- [dSTRmat](#) \* [SS](#)
- [precond\\_diagstr](#) \* [diag](#)
- [dvector](#) \* [diaginv](#)
- [ivector](#) \* [pivot](#)
- [dvector](#) \* [diaginvS](#)
- [ivector](#) \* [pivotS](#)
- [ivector](#) \* [order](#)
- [dvector](#) [r](#)
- [REAL](#) \* [w](#)

### 8.31.1 Detailed Description

Data passed to the preconditioner for preconditioning reservoir simulation problems.

#### Note

This is only needed for the Black Oil model with wells

Definition at line 391 of file fasp\_block.h.

### 8.31.2 Field Documentation

#### 8.31.2.1 `precond_diagstr*` `diag`

the diagonal inverse for diagonal scaling

Definition at line 471 of file fasp\_block.h.

#### 8.31.2.2 `dvector*` `diaginv`

the inverse of the diagonals for GS/block GS smoother (whole reservoir matrix)

Definition at line 472 of file fasp\_block.h.

#### 8.31.2.3 `dvector*` `diaginvS`

the inverse of the diagonals for GS/block GS smoother (saturation block)

Definition at line 474 of file fasp\_block.h.

#### 8.31.2.4 `ivector*` `order`

order for smoothing

Definition at line 476 of file fasp\_block.h.

#### 8.31.2.5 `ivector*` `perf_idx`

variable index for perf

Definition at line 464 of file fasp\_block.h.

#### 8.31.2.6 `ivector*` `pivot`

the pivot for the GS/block GS smoother (whole reservoir matrix)

Definition at line 473 of file fasp\_block.h.

#### 8.31.2.7 `ivector*` `pivotS`

the pivot for the GS/block GS smoother (saturation block)

Definition at line 475 of file fasp\_block.h.



#### 8.31.2.8 dCSRmat\* PP

pressure block after diagonal scaling

Definition at line 468 of file fasp\_block.h.

#### 8.31.2.9 dvector r

temporary dvector used to store and restore the residual

Definition at line 479 of file fasp\_block.h.

#### 8.31.2.10 dSTRmat\* RR

Diagonal scaled reservoir block

Definition at line 466 of file fasp\_block.h.

#### 8.31.2.11 SHORT scaled

whether the matrix is scaled

Definition at line 463 of file fasp\_block.h.

#### 8.31.2.12 dSTRmat\* SS

saturation block after diagonal scaling

Definition at line 469 of file fasp\_block.h.

#### 8.31.2.13 REAL\* w

temporary work space for other usage

Definition at line 480 of file fasp\_block.h.

#### 8.31.2.14 dCSRmat\* WW

Argumented well block

Definition at line 467 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.32 precondition\_data Struct Reference

Data passed to the preconditioners.

```
#include <fasp.h>
```

## Data Fields

- [SHORT AMG\\_type](#)  
*type of AMG method*
- [SHORT print\\_level](#)  
*print level in AMG preconditioner*
- [INT maxit](#)  
*max number of iterations of AMG preconditioner*
- [SHORT max\\_levels](#)  
*max number of AMG levels*
- [REAL tol](#)  
*tolerance for AMG preconditioner*
- [SHORT cycle\\_type](#)  
*AMG cycle type.*
- [SHORT smoother](#)  
*AMG smoother type.*
- [SHORT smooth\\_order](#)  
*AMG smoother ordering.*
- [SHORT presmooth\\_iter](#)  
*number of presmoothing*
- [SHORT postsmooth\\_iter](#)  
*number of postsmoothing*
- [REAL relaxation](#)  
*relaxation parameter for SOR smoother*
- [SHORT polynomial\\_degree](#)  
*degree of the polynomial smoother*
- [SHORT coarsening\\_type](#)  
*switch of scaling of the coarse grid correction*
- [SHORT coarse\\_solver](#)  
*coarse solver type for AMG*
- [SHORT coarse\\_scaling](#)  
*switch of scaling of the coarse grid correction*
- [SHORT amli\\_degree](#)  
*degree of the polynomial used by AMLI cycle*
- [SHORT nl\\_amli\\_krylov\\_type](#)  
*type of krylov method used by Nonlinear AMLI cycle*
- [REAL tentative\\_smooth](#)  
*smooth factor for smoothing the tentative prolongation*
- [REAL \\* amli\\_coef](#)  
*coefficients of the polynomial used by AMLI cycle*
- [AMG\\_data \\* mgl\\_data](#)  
*AMG preconditioner data.*
- [ILU\\_data \\* LU](#)  
*ILU preconditioner data (needed for CPR type preconditioner)*
- [dCSRmat \\* A](#)  
*Matrix data.*
- [dCSRmat \\* A\\_nk](#)

- *Matrix data for near kernal.*
- [dCSRmat \\* P\\_nk](#)
- *Prolongation for near kernal.*
- [dCSRmat \\* R\\_nk](#)
- *Resriction for near kernal.*
- [dvector r](#)
- *temporary dvector used to store and restore the residual*
- [REAL \\* w](#)
- *temporary work space for other usage*

### 8.32.1 Detailed Description

Data passed to the preconditioners.

Definition at line 700 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.33 precondition\_data\_bsr Struct Reference

Data passed to the preconditioners.

```
#include <fasp_block.h>
```

### Data Fields

- [SHORT AMG\\_type](#)
- *type of AMG method*
- [SHORT print\\_level](#)
- *print level in AMG preconditioner*
- [INT maxit](#)
- *max number of iterations of AMG preconditioner*
- [INT max\\_levels](#)
- *max number of AMG levels*
- [REAL tol](#)
- *tolerance for AMG preconditioner*
- [SHORT cycle\\_type](#)
- *AMG cycle type.*
- [SHORT smoother](#)
- *AMG smoother type.*
- [SHORT smooth\\_order](#)
- *AMG smoother ordering.*
- [SHORT presmooth\\_iter](#)
- *number of presmoothing*
- [SHORT postsmooth\\_iter](#)
- *number of postsmoothing*

- [SHORT coarsening\\_type](#)  
*coarsening type*
- [REAL relaxation](#)  
*relaxation parameter for SOR smoother*
- [SHORT coarse\\_solver](#)  
*coarse solver type for AMG*
- [SHORT coarse\\_scaling](#)  
*switch of scaling of the coarse grid correction*
- [SHORT amli\\_degree](#)  
*degree of the polynomial used by AMLI cycle*
- [REAL \\* amli\\_coef](#)  
*coefficients of the polynomial used by AMLI cycle*
- [REAL tentative\\_smooth](#)  
*smooth factor for smoothing the tentative prolongation*
- [SHORT nl\\_amli\\_krylov\\_type](#)  
*type of krylov method used by Nonlinear AMLI cycle*
- [AMG\\_data\\_bsr \\* mgl\\_data](#)  
*AMG preconditioner data.*
- [AMG\\_data \\* pres\\_mgl\\_data](#)  
*AMG preconditioner data for pressure block.*
- [ILU\\_data \\* LU](#)  
*ILU preconditioner data (needed for CPR type preconditioner)*
- [dBSRmat \\* A](#)  
*Matrix data.*
- [dCSRmat \\* A\\_nk](#)  
*Matrix data for near kernal.*
- [dCSRmat \\* P\\_nk](#)  
*Prolongation for near kernal.*
- [dCSRmat \\* R\\_nk](#)  
*Resriction for near kernal.*
- [dvector r](#)  
*temporary dvector used to store and restore the residual*
- [REAL \\* w](#)  
*temporary work space for other usage*

### 8.33.1 Detailed Description

Data passed to the preconditioners.

#### Note

This structure is needed for the AMG solver/preconditioner in BSR format

Definition at line 298 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.34 precondition\_data\_str Struct Reference

Data passed to the preconditioner for dSTRmat matrices.

```
#include <fasp.h>
```

### Data Fields

- [SHORT AMG\\_type](#)  
*type of AMG method*
- [SHORT print\\_level](#)  
*print level in AMG preconditioner*
- [INT maxit](#)  
*max number of iterations of AMG preconditioner*
- [SHORT max\\_levels](#)  
*max number of AMG levels*
- [REAL tol](#)  
*tolerance for AMG preconditioner*
- [SHORT cycle\\_type](#)  
*AMG cycle type.*
- [SHORT smoother](#)  
*AMG smoother type.*
- [SHORT presmooth\\_iter](#)  
*number of presmoothing*
- [SHORT postsmooth\\_iter](#)  
*number of postsmoothing*
- [SHORT coarsening\\_type](#)  
*coarsening type*
- [REAL relaxation](#)  
*relaxation parameter for SOR smoother*
- [SHORT coarse\\_scaling](#)  
*switch of scaling of the coarse grid correction*
- [AMG\\_data](#) \* [mgl\\_data](#)  
*AMG preconditioner data.*
- [ILU\\_data](#) \* [LU](#)  
*ILU preconditioner data (needed for CPR type preconditioner)*
- [SHORT scaled](#)  
*whether the matrix are scaled or not*
- [dCSRmat](#) \* [A](#)  
*the original CSR matrix*
- [dSTRmat](#) \* [A\\_str](#)  
*store the whole reservoir block in STR format*
- [dSTRmat](#) \* [SS\\_str](#)  
*store Saturation block in STR format*
- [dvector](#) \* [diaginv](#)  
*the inverse of the diagonals for GS/block GS smoother (whole reservoir matrix)*
- [ivector](#) \* [pivot](#)

- the pivot for the GS/block GS smoother (whole reservoir matrix)*
- [dvector](#) \* [diaginvS](#)
  - the inverse of the diagonals for GS/block GS smoother (saturation block)*
- [ivector](#) \* [pivotS](#)
  - the pivot for the GS/block GS smoother (saturation block)*
- [ivector](#) \* [order](#)
  - order for smoothing*
- [ivector](#) \* [neigh](#)
  - array to store neighbor information*
- [dvector](#) [r](#)
  - temporary dvector used to store and restore the residual*
- [REAL](#) \* [w](#)
  - temporary work space for other usage*

### 8.34.1 Detailed Description

Data passed to the preconditioner for [dSTRmat](#) matrices.

Definition at line 793 of file [fasp.h](#).

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.35 [precond\\_diagbsr](#) Struct Reference

Data passed to diagonal preconditioner for [dBSRmat](#) matrices.

`#include <fasp\_block.h>`

### Data Fields

- [INT](#) [nb](#)
  - dimension of each sub-block*
- [dvector](#) [diag](#)
  - diagonal elements*

### 8.35.1 Detailed Description

Data passed to diagonal preconditioner for [dBSRmat](#) matrices.

#### Note

This is needed for the diagonal preconditioner.

Definition at line 280 of file [fasp\\_block.h](#).

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

## 8.36 precondition\_diagstr Struct Reference

Data passed to diagonal preconditioner for [dSTRmat](#) matrices.

```
#include <fasp.h>
```

### Data Fields

- [INT](#) `nc`  
*number of components*
- [dvector](#) `diag`  
*diagonal elements*

### 8.36.1 Detailed Description

Data passed to diagonal preconditioner for [dSTRmat](#) matrices.

#### Note

This is needed for the diagonal preconditioner.

Definition at line 886 of file `fasp.h`.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.37 precondition\_FASP\_blkoi\_data Struct Reference

Data passed to the preconditioner for preconditioning reservoir simulation problems.

```
#include <fasp_block.h>
```

### Data Fields

- [block\\_BSR](#) \* `A`  
*Part 1: Basic data.*
- [SHORT](#) `scaled`  
*Part 2: Data for CPR-like preconditioner for reservoir block.*
- [dvector](#) \* `diaginv_noscale`
- [dBSRmat](#) \* `RR`
- [ivector](#) \* `neigh`
- [ivector](#) \* `order`
- [dBSRmat](#) \* `SS`
- [dvector](#) \* `diaginv_S`
- [ivector](#) \* `pivot_S`
- [dCSRmat](#) \* `PP`
- [AMG\\_data](#) \* `mgl_data`
- [SHORT](#) `print_level`

- print level in AMG preconditioner*
- **INT** `maxit_AMG`  
*max number of iterations of AMG preconditioner*
- **SHORT** `max_levels`  
*max number of AMG levels*
- **REAL** `amg_tol`  
*tolerance for AMG preconditioner*
- **SHORT** `cycle_type`  
*AMG cycle type.*
- **SHORT** `smoother`  
*AMG smoother type.*
- **SHORT** `smooth_order`  
*AMG smoothing order.*
- **SHORT** `presmooth_iter`  
*number of presmoothing*
- **SHORT** `postsmooth_iter`  
*number of postsmoothing*
- **SHORT** `coarsening_type`  
*coarsening type*
- **REAL** `relaxation`  
*relaxation parameter for SOR smoother*
- **SHORT** `coarse_scaling`  
*switch of scaling of coarse grid correction*
- **SHORT** `amli_degree`  
*degree of the polynomial used by AMLI cycle*
- **REAL** \* `amli_coef`  
*coefficients of the polynomial used by AMLI cycle*
- **REAL** `tentative_smooth`  
*relaxation parameter for smoothing the tentative prolongation*
- **dvector** \* `diaginv`
- **ivector** \* `pivot`
- **ILU\_data** \* `LU`  
*data of ILU for reservoir block*
- **ivector** \* `perf_idx`
- **ivector** \* `perf_neigh`
- **dCSRmat** \* `WW`
- **void** \* `Numeric`  
*data for direct solver for argumented well block*
- **REAL** \* `invS`  
*inverse of the schur complement  $(-I - Awr*Arr^{-1}*Arw)^{-1}$ , Arr may be replaced by LU*
- **INT** `maxit`
- **INT** `restart`
- **REAL** `tol`
- **dvector** `r`
- **REAL** \* `w`



### 8.37.1 Detailed Description

Data passed to the preconditioner for preconditioning reservoir simulation problems.

#### Note

This is only needed for the Black Oil model with wells

Definition at line 542 of file fasp\_block.h.

### 8.37.2 Field Documentation

#### 8.37.2.1 block\_BSR\* A

Part 1: Basic data.

whole jacobian system in block\_BSRmat

Definition at line 547 of file fasp\_block.h.

#### 8.37.2.2 dvector\* diaginv

inverse of the diagonal blocks of reservoir block

Definition at line 616 of file fasp\_block.h.

#### 8.37.2.3 dvector\* diaginv\_noscale

inverse of diagonal blocks for diagonal scaling

Definition at line 554 of file fasp\_block.h.

#### 8.37.2.4 dvector\* diaginv\_S

inverse of the diagonal blocks of saturation block

Definition at line 563 of file fasp\_block.h.

#### 8.37.2.5 INT maxit

max number of iterations

Definition at line 634 of file fasp\_block.h.

#### 8.37.2.6 AMG\_data\* mgl\_data

AMG data for presure-presure block

Definition at line 568 of file fasp\_block.h.

**8.37.2.7 ivector\* neigh**

neighbor information of the reservoir block

Definition at line 558 of file fasp\_block.h.

**8.37.2.8 ivector\* order**

ordering of the reservoir block

Definition at line 559 of file fasp\_block.h.

**8.37.2.9 ivector\* perf\_idx**

index of blocks which have perforation

Definition at line 623 of file fasp\_block.h.

**8.37.2.10 ivector\* perf\_neigh**

index of blocks which are neighbors of perforations (include perforations)

Definition at line 624 of file fasp\_block.h.

**8.37.2.11 ivector\* pivot**

pivot for the GS smoothers for the reservoir matrix

Definition at line 617 of file fasp\_block.h.

**8.37.2.12 ivector\* pivot\_S**

pivoting for the GS smoothers for saturation block

Definition at line 564 of file fasp\_block.h.

**8.37.2.13 dCSRmat\* PP**

pressure block

Definition at line 567 of file fasp\_block.h.

**8.37.2.14 dvector r**

temporary dvector used to store and restore the residual

Definition at line 639 of file fasp\_block.h.

**8.37.2.15 INT restart**

number of iterations for restart

Definition at line 635 of file fasp\_block.h.

**8.37.2.16 dBSRmat\* RR**

reservoir block

Definition at line 555 of file fasp\_block.h.

**8.37.2.17 SHORT scaled**

Part 2: Data for CPR-like preconditioner for reservoir block.

scaled = 1 means the the following RR block is diagonal scaled

Definition at line 553 of file fasp\_block.h.

**8.37.2.18 dBSRmat\* SS**

saturation block

Definition at line 562 of file fasp\_block.h.

**8.37.2.19 REAL tol**

tolerance

Definition at line 636 of file fasp\_block.h.

**8.37.2.20 REAL\* w**

temporary work space for other usage

Definition at line 640 of file fasp\_block.h.

**8.37.2.21 dCSRmat\* WW**

Argumented well block

Definition at line 625 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

**8.38 precondition\_sweeping\_data Struct Reference**

Data passed to the preconditioner for sweeping preconditioning.

```
#include <fasp_block.h>
```

**Data Fields**

- [INT NumLayers](#)
- [block\\_dCSRmat \\* A](#)

- `block_dCSRmat * Ai`
- `dCSRmat * local_A`
- `void ** local_LU`
- `ivector * local_index`
- `dvector r`
- `REAL * w`

### 8.38.1 Detailed Description

Data passed to the preconditioner for sweeping preconditioning.

#### Author

Xiaozhe Hu

#### Date

05/01/2014

#### Note

This is needed for the sweeping preconditioner.

Definition at line 653 of file `fasp_block.h`.

### 8.38.2 Field Documentation

#### 8.38.2.1 `block_dCSRmat* A`

problem data, the sparse matrix

Definition at line 657 of file `fasp_block.h`.

#### 8.38.2.2 `block_dCSRmat* Ai`

preconditioner data, the sparse matrix

Definition at line 658 of file `fasp_block.h`.

#### 8.38.2.3 `dCSRmat* local_A`

local stiffness matrix for each layer

Definition at line 660 of file `fasp_block.h`.

#### 8.38.2.4 `ivector* local_index`

local index for each layer

Definition at line 663 of file `fasp_block.h`.

**8.38.2.5 void\*\* local\_LU**

lcoal LU decomposition – (only for UMFpack – Xiaozhe Hu)

Definition at line 661 of file fasp\_block.h.

**8.38.2.6 INT NumLayers**

number of layers

Definition at line 655 of file fasp\_block.h.

**8.38.2.7 dvector r**

temporary dvector used to store and restore the residual

Definition at line 666 of file fasp\_block.h.

**8.38.2.8 REAL\* w**

temporary work space for other usage

Definition at line 667 of file fasp\_block.h.

The documentation for this struct was generated from the following file:

- [fasp\\_block.h](#)

**8.39 Schwarz\_data Struct Reference**

Data for Schwarz methods.

```
#include <fasp.h>
```

**Data Fields**

- [dCSRmat A](#)  
*pointer to the matrix*
- [INT nblk](#)  
*number of blocks*
- [INT \\* iblock](#)  
*row index of blocks*
- [INT \\* jblock](#)  
*column index of blocks*
- [REAL \\* rhsloc](#)  
*local right hand side*
- [REAL \\* au](#)  
*LU decomposition: the U block.*
- [REAL \\* al](#)  
*LU decomposition: the L block.*

- [INT schwarz\\_type](#)  
*Schwarz method type.*
- [INT memt](#)  
*working space size*
- [INT \\* mask](#)  
*mask*
- [INT \\* maxa](#)  
*maxa*

### 8.39.1 Detailed Description

Data for Schwarz methods.

This is needed for the schwarz solver, preconditioner/smoothen.

Definition at line 459 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## 8.40 Schwarz\_param Struct Reference

Parameters for Schwarz method.

```
#include <fasp.h>
```

### Data Fields

- [SHORT print\\_level](#)  
*print leve*
- [SHORT schwarz\\_type](#)  
*type for Schwarz method*
- [INT schwarz\\_maxlvl](#)  
*maximal level for constructing the blocks*
- [INT schwarz\\_mmsize](#)  
*maxiaml size of blocks*

### 8.40.1 Detailed Description

Parameters for Schwarz method.

Added on 05/14/2012

Definition at line 435 of file fasp.h.

The documentation for this struct was generated from the following file:

- [fasp.h](#)

## Chapter 9

# File Documentation

### 9.1 aggregation\_bsr.inl File Reference

Utilities for multigrid cycles in BSR format.

#### 9.1.1 Detailed Description

Utilities for multigrid cycles in BSR format.

Definition in file [aggregation\\_bsr.inl](#).

### 9.2 aggregation\_csr.inl File Reference

Utilities for multigrid cycles for CSR matrices.

#### 9.2.1 Detailed Description

Utilities for multigrid cycles for CSR matrices.

Definition in file [aggregation\\_csr.inl](#).

### 9.3 amg.c File Reference

AMG method as an iterative solver (main file)

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

#### Functions

- void [fasp\\_solver\\_amg](#) (dCSRmat \*A, dvector \*b, dvector \*x, AMG\_param \*param)  
*Solve  $Ax = b$  by algebraic multigrid methods.*

### 9.3.1 Detailed Description

AMG method as an iterative solver (main file)

Definition in file [amg.c](#).

### 9.3.2 Function Documentation

9.3.2.1 `void fasp_solver_amg ( dCSRmat * A, dvector * b, dvector * x, AMG_param * param )`

Solve  $Ax = b$  by algebraic multigrid methods.

Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>param</i>	Pointer to <a href="#">AMG_param</a> : AMG parameters

Author

Chensong Zhang

Date

04/06/2010

Note

Refer to "Multigrid" by U. Trottenberg, C. W. Oosterlee and A. Schuller Appendix A.7 (by A. Brandt, P. Oswald and K. Stuben) Academic Press Inc., San Diego, CA, 2001.

Modified by Chensong Zhang on 01/10/2012 Modified by Chensong Zhang on 07/26/2014: Add error handling for AMG setup

Definition at line 37 of file amg.c.

## 9.4 amg\_setup\_cr.c File Reference

Brannick-Falgout compatible relaxation based AMG: SETUP phase.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- [SHORT fasp\\_amg\\_setup\\_cr](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Set up phase of Brannick Falgout CR coarsening for classic AMG.*



### 9.4.1 Detailed Description

Brannick-Falgout compatible relaxation based AMG: SETUP phase.

#### Note

Setup A, P, R and levels using the Compatible Relaxation coarsening for classic AMG interpolation Refer to J. Brannick and R. Falgout "Compatible relaxation and coarsening in AMG"

TODO: Not working. Yet need to be fixed. –Chensong

Definition in file [amg\\_setup\\_cr.c](#).

### 9.4.2 Function Documentation

#### 9.4.2.1 `SHORT fasp_amg_setup_cr ( AMG_data * mgl, AMG_param * param )`

Set up phase of Brannick Falgout CR coarsening for classic AMG.

#### Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

#### Returns

FASP\_SUCCESS if succeeded, otherwise, error information.

#### Author

James Brannick

#### Date

04/21/2010

Modified by Chensong Zhang on 05/10/2013: adjust the structure.

Definition at line 38 of file [amg\\_setup\\_cr.c](#).

## 9.5 amg\_setup\_rs.c File Reference

Ruge-Stuben AMG: SETUP phase.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- `SHORT fasp_amg_setup_rs (AMG_data *mgl, AMG_param *param)`  
*Setup phase of Ruge and Stuben's classic AMG.*

### 9.5.1 Detailed Description

Ruge-Stuben AMG: SETUP phase.

#### Note

Setup A, P, R, levels using classic AMG! Reffer to "Multigrid" by Stuben in U. Trottenberg, C. W. Oosterlee and A. Schuller. Appendix A.7 (by A. Brandt, P. Oswald and K. Stuben). Academic Press Inc., San Diego, CA, 2001.

Definition in file [amg\\_setup\\_rs.c](#).

### 9.5.2 Function Documentation

#### 9.5.2.1 SHORT fasp\_amg\_setup\_rs ( AMG\_data \* mgl, AMG\_param \* param )

Setup phase of Ruge and Stuben's classic AMG.

#### Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

#### Returns

FASP\_SUCCESS if succeeded, otherwise, error information.

#### Author

Chensong Zhang

#### Date

05/09/2010

Modified by Chensong Zhang on 04/04/2009. Modified by Chensong Zhang on 05/09/2010. Modified by Zhiyang Zhou on 11/17/2010. Modified by Xiaozhe Hu on 01/23/2011: add AMLI cycle. Modified by Chensong zhang on 09/09/2011↵: add min dof. Modified by Xiaozhe Hu on 04/24/2013: aggressive coarsening. Modified by Chensong Zhang on 05/03/2013: add error handling in setup. Modified by Chensong Zhang on 05/10/2013: adjust the structure. Modified by Chensong Zhang on 07/26/2014: handle coarsening errors.

Definition at line 48 of file [amg\\_setup\\_rs.c](#).

## 9.6 amg\_setup\_sa.c File Reference

Smoothed aggregation AMG: SETUP phase.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "aggregation_csr.inl"
#include "aggregation_bsr.inl"
```

## Functions

- [SHORT fasp\\_amg\\_setup\\_sa](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Set up phase of smoothed aggregation AMG.*
- [SHORT fasp\\_amg\\_setup\\_sa\\_bsr](#) ([AMG\\_data\\_bsr](#) \*mgl, [AMG\\_param](#) \*param)  
*Set up phase of smoothed aggregation AMG (BSR format)*

### 9.6.1 Detailed Description

Smoothed aggregation AMG: SETUP phase.

Definition in file [amg\\_setup\\_sa.c](#).

### 9.6.2 Function Documentation

#### 9.6.2.1 [SHORT fasp\\_amg\\_setup\\_sa](#) ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Set up phase of smoothed aggregation AMG.

##### Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

##### Returns

FASP\_SUCCESS if succeed, error otherwise

##### Author

Xiaozhe Hu

##### Date

09/29/2009

Modified by Chensong Zhang on 04/06/2010. Modified by Chensong Zhang on 05/09/2010. Modified by Xiaozhe Hu on 01/23/2011: add AMLI cycle. Modified by Chensong Zhang on 05/10/2013: adjust the structure.

Definition at line 46 of file [amg\\_setup\\_sa.c](#).

#### 9.6.2.2 [INT fasp\\_amg\\_setup\\_sa\\_bsr](#) ( [AMG\\_data\\_bsr](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Set up phase of smoothed aggregation AMG (BSR format)

##### Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data_bsr</a>
------------	---

<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>
--------------	--

**Returns**

FASP\_SUCCESS if succeed, error otherwise

**Author**

Xiaozhe Hu

**Date**

05/26/2014

Definition at line 83 of file amg\_setup\_sa.c.

## 9.7 amg\_setup\_ua.c File Reference

Unsmoothed aggregation AMG: SETUP phase.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "aggregation_csr.inl"
#include "aggregation_bsr.inl"
```

**Functions**

- [SHORT fasp\\_amg\\_setup\\_ua](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Set up phase of unsmoothed aggregation AMG.*
- [SHORT fasp\\_amg\\_setup\\_ua\\_bsr](#) ([AMG\\_data\\_bsr](#) \*mgl, [AMG\\_param](#) \*param)  
*Set up phase of unsmoothed aggregation AMG (BSR format)*

### 9.7.1 Detailed Description

Unsmoothed aggregation AMG: SETUP phase.

**Note**

Setup A, P, PT and levels using the unsmoothed aggregation algorithm; Refer to P. Vanek, J. Madel and M. Brezina "Algebraic Multigrid on Unstructured Meshes", 1994

Definition in file [amg\\_setup\\_ua.c](#).

### 9.7.2 Function Documentation

#### 9.7.2.1 SHORT fasp\_amg\_setup\_ua ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Set up phase of unsmoothed aggregation AMG.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

## Returns

FASP\_SUCCESS if succeed, error otherwise

## Author

Xiaozhe Hu

## Date

12/28/2011

Definition at line 38 of file amg\_setup\_ua.c.

9.7.2.2 INT fasp\_amg\_setup\_ua\_bsr ( [AMG\\_data\\_bsr](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Set up phase of unsmoothed aggregation AMG (BSR format)

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data_bsr</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

## Returns

FASP\_SUCCESS if succeed, error otherwise

## Author

Xiaozhe Hu

## Date

03/16/2012

Definition at line 69 of file amg\_setup\_ua.c.

## 9.8 amg\_solve.c File Reference

Algebraic multigrid iterations: SOLVE phase.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- [INT fasp\\_amg\\_solve](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*AMG – SOLVE phase.*
- [INT fasp\\_amg\\_solve\\_amli](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*AMLI – SOLVE phase.*
- [INT fasp\\_amg\\_solve\\_nl\\_amli](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Nonlinear AMLI – SOLVE phase.*
- void [fasp\\_famg\\_solve](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*FMG – SOLVE phase.*

### 9.8.1 Detailed Description

Algebraic multigrid iterations: SOLVE phase.

#### Note

Solve  $Ax=b$  using multigrid method. This is SOLVE phase only and is independent of SETUP method used! Should be called after multigrid hierarchy has been generated!

Definition in file [amg\\_solve.c](#).

### 9.8.2 Function Documentation

#### 9.8.2.1 [INT fasp\\_amg\\_solve](#) ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

AMG – SOLVE phase.

#### Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

#### Returns

Iteration number if succeed, ERROR otherwise

#### Author

Xuehai Huang, Chensong Zhang

#### Date

04/02/2010

Modified by Chensong 04/21/2013: Fix an output typo

Definition at line 36 of file [amg\\_solve.c](#).

#### 9.8.2.2 [INT fasp\\_amg\\_solve\\_amli](#) ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

AMLI – SOLVE phase.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

## Returns

Iteration number if succeed, ERROR otherwise

## Author

Xiaozhe Hu

## Date

01/23/2011

Modified by Chensong 04/21/2013: Fix an output typo

Definition at line 119 of file amg\_solve.c.

### 9.8.2.3 INT fasp\_amg\_solve\_nl\_amli ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Nonlinear AMLI – SOLVE phase.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

## Returns

Iteration number if succeed, ERROR otherwise

## Author

Xiaozhe Hu

## Date

04/30/2011

Modified by Chensong 04/21/2013: Fix an output typo

Definition at line 198 of file amg\_solve.c.

### 9.8.2.4 void fasp\_famg\_solve ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

FMG – SOLVE phase.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

## Author

Chensong Zhang

## Date

01/10/2012

Definition at line 270 of file amg\_solve.c.

## 9.9 amlirecur.c File Reference

Abstract AMLI multilevel iteration – recursive version.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "forts_ns.h"
#include "mg_util.inl"
```

### Functions

- void [fasp\\_solver\\_amli](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param, [INT](#) level)  
*Solve  $Ax=b$  with recursive AMLI-cycle.*
- void [fasp\\_solver\\_nl\\_amli](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param, [INT](#) level, [INT](#) num\_levels)  
*Solve  $Ax=b$  with recursive nonlinear AMLI-cycle.*
- void [fasp\\_solver\\_nl\\_amli\\_bsr](#) ([AMG\\_data\\_bsr](#) \*mgl, [AMG\\_param](#) \*param, [INT](#) level, [INT](#) num\_levels)  
*Solve  $Ax=b$  with recursive nonlinear AMLI-cycle.*
- void [fasp\\_amg\\_amli\\_coef](#) (const [REAL](#) lambda\_max, const [REAL](#) lambda\_min, const [INT](#) degree, [REAL](#) \*coef)  
*Compute the coefficients of the polynomial used by AMLI-cycle.*

### 9.9.1 Detailed Description

Abstract AMLI multilevel iteration – recursive version.

#### Note

Contains AMLI and nonlinear AMLI cycles

TODO: Need to add a non-recursive version! –Chensong

Definition in file [amlirecur.c](#).



## 9.9.2 Function Documentation

9.9.2.1 void fasp\_amg\_amli\_coef ( const REAL *lambda\_max*, const REAL *lambda\_min*, const INT *degree*, REAL \* *coef* )

Compute the coefficients of the polynomial used by AMLI-cycle.

## Parameters

<i>lambda_max</i>	Maximal lambda
<i>lambda_min</i>	Minimal lambda
<i>degree</i>	Degree of polynomial approximation
<i>coef</i>	Coefficient of AMLI (output)

## Author

Xiaozhe Hu

## Date

01/23/2011

Definition at line 789 of file amlirecur.c.

9.9.2.2 void fasp\_solver\_amli ( AMG\_data \* mgl, AMG\_param \* param, INT level )

Solve  $Ax=b$  with recursive AMLI-cycle.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>
<i>level</i>	Current level

## Author

Xiaozhe Hu

## Date

01/23/2011

Modified by Chensong Zhang on 02/27/2013: update direct solvers.

Definition at line 37 of file amlirecur.c.

9.9.2.3 void fasp\_solver\_nl\_amli ( AMG\_data \* mgl, AMG\_param \* param, INT level, INT num\_levels )

Solve  $Ax=b$  with recursive nonlinear AMLI-cycle.

## Parameters

<i>mgl</i>	Pointer to <a href="#">AMG_data</a> data
<i>param</i>	Pointer to AMG parameters
<i>level</i>	Current level
<i>num_levels</i>	Total numebr of levels

## Author

Xiaozhe Hu

## Date

04/06/2010

Modified by Chensong Zhang on 02/27/2013: update direct solvers.

Definition at line 307 of file amlirecur.c.

9.9.2.4 void fasp\_solver\_nl\_amli\_bsr ( AMG\_data\_bsr \* mgl, AMG\_param \* param, INT level, INT num\_levels )

Solve  $Ax=b$  with recursive nonlinear AMLI-cycle.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>
<i>level</i>	Current level
<i>num_levels</i>	Total numebr of levels

## Author

Xiaozhe Hu

## Date

04/06/2010

Modified by Chensong Zhang on 02/27/2013: update direct solvers.

Definition at line 596 of file amlirecur.c.

## 9.10 array.c File Reference

Array operations.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_array\\_null](#) (REAL \*x)  
*Initialize an array.*
- void [fasp\\_array\\_set](#) (const INT n, REAL \*x, const REAL val)  
*Set initial value for an array to be x=val.*
- void [fasp\\_iarray\\_set](#) (const INT n, INT \*x, const INT val)  
*Set initial value for an array to be x=val.*
- void [fasp\\_array\\_cp](#) (const INT n, REAL \*x, REAL \*y)  
*Copy an array to the other y=x.*
- void [fasp\\_iarray\\_cp](#) (const INT n, INT \*x, INT \*y)  
*Copy an array to the other y=x.*

- void `fasp_array_cp_nc3` (`REAL *x`, `REAL *y`)  
Copy an array to the other  $y=x$ , the length is 3.
- void `fasp_array_cp_nc5` (`REAL *x`, `REAL *y`)  
Copy an array to the other  $y=x$ , the length is 5.
- void `fasp_array_cp_nc7` (`REAL *x`, `REAL *y`)  
Copy an array to the other  $y=x$ , the length is 7.

### 9.10.1 Detailed Description

Array operations.

Simple array operations – init, set, copy, etc

Definition in file [array.c](#).

### 9.10.2 Function Documentation

#### 9.10.2.1 void `fasp_array_cp` ( `const INT n`, `REAL * x`, `REAL * y` )

Copy an array to the other  $y=x$ .

Parameters

<code>n</code>	Number of variables
<code>x</code>	Pointer to the original vector
<code>y</code>	Pointer to the destination vector

Author

Chensong Zhang

Date

2010/04/03

Definition at line 172 of file `array.c`.

#### 9.10.2.2 void `fasp_array_cp_nc3` ( `REAL * x`, `REAL * y` )

Copy an array to the other  $y=x$ , the length is 3.

Parameters

<code>x</code>	Pointer to the original vector
<code>y</code>	Pointer to the destination vector

Author

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

**Note**

Special unrolled routine designed for a specific application

Definition at line 212 of file array.c.

**9.10.2.3 void fasp\_array\_cp\_nc5 ( REAL \* x, REAL \* y )**

Copy an array to the other y=x, the length is 5.

**Parameters**

<i>x</i>	Pointer to the original vector
<i>y</i>	Pointer to the destination vector

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

**Note**

Special unrolled routine designed for a specific application

Definition at line 233 of file array.c.

**9.10.2.4 void fasp\_array\_cp\_nc7 ( REAL \* x, REAL \* y )**

Copy an array to the other y=x, the length is 7.

**Parameters**

<i>x</i>	Pointer to the original vector
<i>y</i>	Pointer to the destination vector

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

**Note**

Special unrolled routine designed for a specific application

Definition at line 256 of file array.c.

9.10.2.5 void fasp\_array\_null ( REAL \* x )

Initialize an array.

## Parameters

$x$	Pointer to the vector
-----	-----------------------

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 32 of file array.c.

**9.10.2.6 void fasp\_array\_set ( const INT  $n$ , REAL \*  $x$ , const REAL  $val$  )**

Set initial value for an array to be  $x=val$ .

## Parameters

$n$	Number of variables
$x$	Pointer to the vector
$val$	Initial value for the REAL array

## Author

Chensong Zhang

## Date

04/03/2010

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 52 of file array.c.

**9.10.2.7 void fasp\_iarray\_cp ( const INT  $n$ , INT \*  $x$ , INT \*  $y$  )**

Copy an array to the other  $y=x$ .

## Parameters

$n$	Number of variables
$x$	Pointer to the original vector
$y$	Pointer to the destination vector

## Author

Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 192 of file array.c.

9.10.2.8 void fasp\_iarray\_set ( const INT *n*, INT \* *x*, const INT *val* )Set initial value for an array to be  $x=val$ .

## Parameters

<i>n</i>	Number of variables
<i>x</i>	Pointer to the vector
<i>val</i>	Initial value for the REAL array

## Author

Chensong Zhang

## Date

04/03/2010

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/25/2012

Definition at line 114 of file array.c.

## 9.11 blas\_array.c File Reference

BLAS operations for arrays.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void `fasp_blas_array_ax` (const INT *n*, const REAL *a*, REAL \**x*)  

$$x = a * x$$
- void `fasp_blas_array_axpy` (const INT *n*, const REAL *a*, REAL \**x*, REAL \**y*)  

$$y = a * x + y$$
- void `fasp_blas_array_axpyz` (const INT *n*, const REAL *a*, REAL \**x*, REAL \**y*, REAL \**z*)  

$$z = a * x + y$$
- void `fasp_blas_array_axpby` (const INT *n*, const REAL *a*, REAL \**x*, const REAL *b*, REAL \**y*)  

$$y = a * x + b * y$$



- [REAL fasp\\_blas\\_array\\_dotprod](#) (const [INT](#) *n*, const [REAL](#) \**x*, const [REAL](#) \**y*)  
*Inner product of two arrays (x,y)*
- [REAL fasp\\_blas\\_array\\_norm1](#) (const [INT](#) *n*, const [REAL](#) \**x*)  
*L1 norm of array x.*
- [REAL fasp\\_blas\\_array\\_norm2](#) (const [INT](#) *n*, const [REAL](#) \**x*)  
*L2 norm of array x.*
- [REAL fasp\\_blas\\_array\\_norminf](#) (const [INT](#) *n*, const [REAL](#) \**x*)  
*Linf norm of array x.*

### 9.11.1 Detailed Description

BLAS operations for arrays.

Definition in file [blas\\_array.c](#).

### 9.11.2 Function Documentation

9.11.2.1 void fasp\_blas\_array\_ax ( const [INT](#) *n*, const [REAL](#) *a*, [REAL](#) \* *x* )

$x = a * x$

Parameters

<i>n</i>	Number of variables
<i>a</i>	Factor a
<i>x</i>	Pointer to x

Author

Chensong Zhang

Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Note

*x* is reused to store the resulting array.

Definition at line 35 of file blas\_array.c.

9.11.2.2 void fasp\_blas\_array\_axpy ( const [INT](#) *n*, const [REAL](#) *a*, [REAL](#) \* *x*, const [REAL](#) *b*, [REAL](#) \* *y* )

$y = a * x + b * y$

**Parameters**

$n$	Number of variables
$a$	Factor a
$x$	Pointer to x
$b$	Factor b
$y$	Pointer to y

**Author**

Chensong Zhang

**Date**

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

**Note**

y is reused to store the resulting array.

Definition at line 218 of file blas\_array.c.

9.11.2.3 void fasp\_blas\_array\_axpy ( const INT  $n$ , const REAL  $a$ , REAL \*  $x$ , REAL \*  $y$  )

$$y = a * x + y$$
**Parameters**

$n$	Number of variables
$a$	Factor a
$x$	Pointer to x
$y$	Pointer to y

**Author**

Chensong Zhang

**Date**

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

**Note**

y is reused to store the resulting array.

Definition at line 87 of file blas\_array.c.

9.11.2.4 void fasp\_blas\_array\_axpyz ( const INT  $n$ , const REAL  $a$ , REAL \*  $x$ , REAL \*  $y$ , REAL \*  $z$  )

$$z = a * x + y$$

## Parameters

$n$	Number of variables
$a$	Factor a
$x$	Pointer to x
$y$	Pointer to y
$z$	Pointer to z

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 167 of file blas\_array.c.

**9.11.2.5 REAL fasp\_blas\_array\_dotprod ( const INT  $n$ , const REAL \*  $x$ , const REAL \*  $y$  )**

Inner product of two arrays (x,y)

## Parameters

$n$	Number of variables
$x$	Pointer to x
$y$	Pointer to y

## Returns

Inner product (x,y)

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 267 of file blas\_array.c.

**9.11.2.6 REAL fasp\_blas\_array\_norm1 ( const INT  $n$ , const REAL \*  $x$  )**

L1 norm of array x.

**Parameters**

$n$	Number of variables
$x$	Pointer to $x$

**Returns**

L1 norm of  $x$

**Author**

Chensong Zhang

**Date**

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 307 of file blas\_array.c.

**9.11.2.7 REAL fasp\_blas\_array\_norm2 ( const INT  $n$ , const REAL \*  $x$  )**

L2 norm of array  $x$ .

**Parameters**

$n$	Number of variables
$x$	Pointer to $x$

**Returns**

L2 norm of  $x$

**Author**

Chensong Zhang

**Date**

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 347 of file blas\_array.c.

**9.11.2.8 REAL fasp\_blas\_array\_norminf ( const INT  $n$ , const REAL \*  $x$  )**

Linf norm of array  $x$ .

## Parameters

$n$	Number of variables
$x$	Pointer to $x$

## Returns

$L_{\infty}$  norm of  $x$

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Zheng Li on 06/28/2012

Definition at line 388 of file blas\_array.c.

## 9.12 blas\_bcsr.c File Reference

BLAS operations for [block\\_dCSRmat](#) matrices.

```
#include <time.h>
#include "fasp.h"
#include "fasp_block.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_blas\\_bdcsr\\_aAxy](#) (const [REAL](#) alpha, [block\\_dCSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = \alpha * A * x + y$ .*
- void [fasp\\_blas\\_bdcsr\\_mxv](#) ([block\\_dCSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = A * x$ .*
- void [fasp\\_blasbdbsr\\_aAxy](#) (const [REAL](#) alpha, [block\\_BSR](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = \alpha * A * x + y$ .*
- void [fasp\\_blasbdbsr\\_mxv](#) ([block\\_BSR](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = A * x$ .*

### 9.12.1 Detailed Description

BLAS operations for [block\\_dCSRmat](#) matrices.

Definition in file [blas\\_bcsr.c](#).

## 9.12.2 Function Documentation

9.12.2.1 void fasp\_blas\_bdbsr\_aAxy ( const REAL *alpha*, block\_BSR \* *A*, REAL \* *x*, REAL \* *y* )

Matrix-vector multiplication  $y = \alpha A x + y$ .

## Parameters

<i>alpha</i>	REAL factor a
<i>A</i>	Pointer to <a href="#">block_BSR</a> matrix A
<i>x</i>	Pointer to array x
<i>y</i>	Pointer to array y

## Author

Xiaozhe Hu

## Date

11/11/2010

Definition at line 288 of file blas\_bcsr.c.

9.12.2.2 void fasp\_blas\_bdbsr\_m xv ( [block\\_BSR](#) \* *A*, REAL \* *x*, REAL \* *y* )Matrix-vector multiplication  $y = A*x$ .

## Parameters

<i>A</i>	Pointer to <a href="#">block_BSR</a> matrix A
<i>x</i>	Pointer to array x
<i>y</i>	Pointer to array y

## Author

Xiaozhe Hu

## Date

11/11/2010

Definition at line 326 of file blas\_bcsr.c.

9.12.2.3 void fasp\_blas\_bdcsr\_aAxy ( const REAL *alpha*, [block\\_dCSRmat](#) \* *A*, REAL \* *x*, REAL \* *y* )Matrix-vector multiplication  $y = \alpha * A * x + y$ .

## Parameters

<i>alpha</i>	REAL factor a
<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> matrix A
<i>x</i>	Pointer to array x
<i>y</i>	Pointer to array y

## Author

Xiaozhe Hu

## Date

06/04/2010

Definition at line 30 of file blas\_bcsr.c.

#### 9.12.2.4 void fasp\_blas\_bdcsv ( block\_dCSRmat \* A, REAL \* x, REAL \* y )

Matrix-vector multiplication  $y = A*x$ .

Parameters

A	Pointer to <a href="#">block_dCSRmat</a> matrix A
x	Pointer to array x
y	Pointer to array y

Author

Chensong Zhang

Date

04/27/2013

Definition at line 155 of file blas\_bcsr.c.

## 9.13 blas\_bsr.c File Reference

BLAS operations for [dBSRmat](#) matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_funcs.h"
```

### Functions

- void [fasp\\_blas\\_dbsr\\_axm](#) ([dBSRmat](#) \*A, const [REAL](#) alpha)  
*Multiply a sparse matrix A in BSR format by a scalar alpha.*
- void [fasp\\_blas\\_dbsr\\_aAxpby](#) (const [REAL](#) alpha, [dBSRmat](#) \*A, [REAL](#) \*x, const [REAL](#) beta, [REAL](#) \*y)  
*Compute  $y := \alpha * A * x + \beta * y$ .*
- void [fasp\\_blas\\_dbsr\\_aAxy](#) (const [REAL](#) alpha, [dBSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Compute  $y := \alpha * A * x + y$ .*
- void [fasp\\_blas\\_dbsr\\_aAxy\\_agg](#) (const [REAL](#) alpha, [dBSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Compute  $y := \alpha * A * x + y$  where each small block matrix is an identity matrix.*
- void [fasp\\_blas\\_dbsr\\_mxv](#) ([dBSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Compute  $y := A * x$ .*
- void [fasp\\_blas\\_dbsr\\_mxv\\_agg](#) ([dBSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Compute  $y := A * x$ , where each small block matrices of A is an identity matrix.*
- void [fasp\\_blas\\_dbsr\\_mxm](#) ([dBSRmat](#) \*A, [dBSRmat](#) \*B, [dBSRmat](#) \*C)  
*Sparse matrix multiplication  $C = A * B$ .*
- void [fasp\\_blas\\_dbsr\\_rap1](#) ([dBSRmat](#) \*R, [dBSRmat](#) \*A, [dBSRmat](#) \*P, [dBSRmat](#) \*B)  
*[dBSRmat](#) sparse matrix multiplication  $B = R * A * P$*
- void [fasp\\_blas\\_dbsr\\_rap](#) ([dBSRmat](#) \*R, [dBSRmat](#) \*A, [dBSRmat](#) \*P, [dBSRmat](#) \*B)  
*[dBSRmat](#) sparse matrix multiplication  $B = R * A * P$*
- void [fasp\\_blas\\_dbsr\\_rap\\_agg](#) ([dBSRmat](#) \*R, [dBSRmat](#) \*A, [dBSRmat](#) \*P, [dBSRmat](#) \*B)  
*[dBSRmat](#) sparse matrix multiplication  $B = R * A * P$ , where small block matrices in P and R are identity matrices!!*



### 9.13.1 Detailed Description

BLAS operations for [dBSRmat](#) matrices.

Definition in file [blas\\_bsr.c](#).

### 9.13.2 Function Documentation

9.13.2.1 `void fasp_blas_dbsr_aAxpby ( const REAL alpha, dBSRmat * A, REAL * x, const REAL beta, REAL * y )`

Compute  $y := \alpha * A * x + \beta * y$ .

Parameters

<i>alpha</i>	REAL factor alpha
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>x</i>	Pointer to the array x
<i>beta</i>	REAL factor beta
<i>y</i>	Pointer to the array y

Author

Zhiyang Zhou

Date

10/25/2010

Modified by Chunsheng Feng, Zheng Li

Date

06/29/2012

Note

Works for general nb (Xiaozhe)

Definition at line 61 of file blas\_bsr.c.

9.13.2.2 `void fasp_blas_dbsr_aAxy ( const REAL alpha, dBSRmat * A, REAL * x, REAL * y )`

Compute  $y := \alpha * A * x + y$ .

Parameters

<i>alpha</i>	REAL factor alpha
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>x</i>	Pointer to the array x

<i>y</i>	Pointer to the array y
----------	------------------------

**Author**

Zhiyang Zhou

**Date**

10/25/2010

Modified by Chunsheng Feng, Xiaoqiang Yue

**Date**

05/23/2012

**Note**

Works for general nb (Xiaozhe)

Definition at line 342 of file blas\_bsr.c.

9.13.2.3 void fasp\_blas\_dbsr\_aApy\_agg ( const REAL *alpha*, dBSRmat \* *A*, REAL \* *x*, REAL \* *y* )

Compute  $y := \alpha * A * x + y$  where each small block matrix is an identity matrix.

**Parameters**

<i>alpha</i>	REAL factor alpha
<i>A</i>	Pointer to the dBSRmat matrix
<i>x</i>	Pointer to the array x
<i>y</i>	Pointer to the array y

**Author**

Xiaozhe Hu

**Date**

01/02/2014

**Note**

Works for general nb (Xiaozhe)

Definition at line 616 of file blas\_bsr.c.

9.13.2.4 void fasp\_blas\_dbsr\_axm ( dBSRmat \* *A*, const REAL *alpha* )

Multiply a sparse matrix A in BSR format by a scalar alpha.

## Parameters

<i>A</i>	Pointer to <a href="#">dBSRmat</a> matrix A
<i>alpha</i>	REAL factor alpha

## Author

Xiaozhe Hu

## Date

05/26/2014

Definition at line 31 of file blas\_bsr.c.

9.13.2.5 void fasp\_blas\_dbsr\_mxm ( [dBSRmat](#) \* *A*, [dBSRmat](#) \* *B*, [dBSRmat](#) \* *C* )

Sparse matrix multiplication  $C=A*B$ .

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix A
<i>B</i>	Pointer to the <a href="#">dBSRmat</a> matrix B
<i>C</i>	Pointer to <a href="#">dBSRmat</a> matrix equal to $A*B$

## Author

Xiaozhe Hu

## Date

05/26/2014

## Note

This fct will be replaced! – Xiaozhe

Definition at line 4863 of file blas\_bsr.c.

9.13.2.6 void fasp\_blas\_dbsr\_mxv ( [dBSRmat](#) \* *A*, REAL \* *x*, REAL \* *y* )

Compute  $y := A*x$ .

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>x</i>	Pointer to the array x
<i>y</i>	Pointer to the array y

## Author

Zhiyang Zhou

## Date

10/25/2010

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

## Note

Works for general nb (Xiaozhe)

Definition at line 927 of file blas\_bsr.c.

9.13.2.7 void fasp\_blas\_dbsr\_mxv\_agg ( dBSRmat \* *A*, REAL \* *x*, REAL \* *y* )

Compute  $y := A*x$ , where each small block matrices of *A* is an identity matrix.

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>x</i>	Pointer to the array <i>x</i>
<i>y</i>	Pointer to the array <i>y</i>

## Author

Xiaozhe Hu

## Date

01/02/2014

## Note

Works for general nb (Xiaozhe)

Definition at line 2674 of file blas\_bsr.c.

9.13.2.8 void fasp\_blas\_dbsr\_rap ( dBSRmat \* *R*, dBSRmat \* *A*, dBSRmat \* *P*, dBSRmat \* *B* )

[dBSRmat](#) sparse matrix multiplication  $B=R*A*P$

## Parameters

<i>R</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>P</i>	Pointer to the <a href="#">dBSRmat</a> matrix

<i>B</i>	Pointer to <a href="#">dBSRmat</a> matrix equal to $R*A*P$ (output)
----------	---

**Author**

Xiaozhe Hu, Chunsheng Feng, Zheng Li

**Date**

10/24/2012

**Note**

Ref. R.E. Bank and C.C. Douglas. SMMP: Sparse Matrix Multiplication Package. Advances in Computational Mathematics, 1 (1993), pp. 127-137.

Definition at line 5168 of file blas\_bsr.c.

9.13.2.9 void fasp\_blas\_dbsr\_rap1 ( [dBSRmat](#) \* *R*, [dBSRmat](#) \* *A*, [dBSRmat](#) \* *P*, [dBSRmat](#) \* *B* )

[dBSRmat](#) sparse matrix multiplication  $B=R*A*P$

**Parameters**

<i>R</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>P</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>B</i>	Pointer to <a href="#">dBSRmat</a> matrix equal to $R*A*P$ (output)

**Author**

Chunsheng Feng, Xiaoqiang Yue and Xiaozhe Hu

**Date**

08/08/2011

**Note**

Ref. R.E. Bank and C.C. Douglas. SMMP: Sparse Matrix Multiplication Package. Advances in Computational Mathematics, 1 (1993), pp. 127-137.

Definition at line 4984 of file blas\_bsr.c.

9.13.2.10 void fasp\_blas\_dbsr\_rap\_agg ( [dBSRmat](#) \* *R*, [dBSRmat](#) \* *A*, [dBSRmat](#) \* *P*, [dBSRmat](#) \* *B* )

[dBSRmat](#) sparse matrix multiplication  $B=R*A*P$ , where small block matrices in *P* and *R* are identity matrices!!

## Parameters

$R$	Pointer to the <a href="#">dBSRmat</a> matrix
$A$	Pointer to the <a href="#">dBSRmat</a> matrix
$P$	Pointer to the <a href="#">dBSRmat</a> matrix
$B$	Pointer to <a href="#">dBSRmat</a> matrix equal to $R*A*P$ (output)

## Author

Xiaozhe Hu

## Date

10/24/2012

## Note

Ref. R.E. Bank and C.C. Douglas. SMMP: Sparse Matrix Multiplication Package. Advances in Computational Mathematics, 1 (1993), pp. 127-137.

Definition at line 5426 of file blas\_bsr.c.

## 9.14 blas\_csr.c File Reference

BLAS operations for [dCSRmat](#) matrices.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- [INT fasp\\_blas\\_dcsr\\_add](#) ([dCSRmat](#) \*A, const [REAL](#) alpha, [dCSRmat](#) \*B, const [REAL](#) beta, [dCSRmat](#) \*C)  
*compute  $C = \alpha*A + \beta*B$  in CSR format*
- void [fasp\\_blas\\_dcsr\\_axm](#) ([dCSRmat](#) \*A, const [REAL](#) alpha)  
*Multiply a sparse matrix A in CSR format by a scalar alpha.*
- void [fasp\\_blas\\_dcsr\\_mxv](#) ([dCSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = A*x$ .*
- void [fasp\\_blas\\_dcsr\\_mxv\\_agg](#) ([dCSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = A*x$ , where the entries of A are all ones.*
- void [fasp\\_blas\\_dcsr\\_aAxy](#) (const [REAL](#) alpha, [dCSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = \alpha*A*x + y$ .*
- void [fasp\\_blas\\_dcsr\\_aAxy\\_agg](#) (const [REAL](#) alpha, [dCSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*Matrix-vector multiplication  $y = \alpha*A*x + y$ , where the entries of A are all ones.*
- [REAL fasp\\_blas\\_dcsr\\_vmv](#) ([dCSRmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
*vector-Matrix-vector multiplication  $\alpha = y'*A*x$*
- void [fasp\\_blas\\_dcsr\\_mxm](#) ([dCSRmat](#) \*A, [dCSRmat](#) \*B, [dCSRmat](#) \*C)  
*Sparse matrix multiplication  $C=A*B$ .*

- void [fasp\\_blas\\_dcsr\\_rap](#) ([dCSRmat](#) \*R, [dCSRmat](#) \*A, [dCSRmat](#) \*P, [dCSRmat](#) \*RAP)  
*Triple sparse matrix multiplication  $B=R*A*P$ .*
- void [fasp\\_blas\\_dcsr\\_rap\\_agg](#) ([dCSRmat](#) \*R, [dCSRmat](#) \*A, [dCSRmat](#) \*P, [dCSRmat](#) \*RAP)  
*Triple sparse matrix multiplication  $B=R*A*P$ .*
- void [fasp\\_blas\\_dcsr\\_rap\\_agg1](#) ([dCSRmat](#) \*R, [dCSRmat](#) \*A, [dCSRmat](#) \*P, [dCSRmat](#) \*B)  
*Triple sparse matrix multiplication  $B=R*A*P$ , where the entries of R and P are all ones.*
- void [fasp\\_blas\\_dcsr\\_ptap](#) ([dCSRmat](#) \*Pt, [dCSRmat](#) \*A, [dCSRmat](#) \*P, [dCSRmat](#) \*Ac)  
*Triple sparse matrix multiplication  $B=P*A*P$ .*
- void [fasp\\_blas\\_dcsr\\_rap4](#) ([dCSRmat](#) \*R, [dCSRmat](#) \*A, [dCSRmat](#) \*P, [dCSRmat](#) \*B, [INT](#) \*icor\_ysk)  
*Triple sparse matrix multiplication  $B=R*A*P$ .*

### 9.14.1 Detailed Description

BLAS operations for [dCSRmat](#) matrices.

#### Note

Sparse functions usually contain three runs. The three runs are all the same but they serve different purpose.

Example: If you do  $c=a+b$ :

- first do a dry run to find the number of non-zeroes in the result and form ic;
- allocate space (memory) for jc and form this one;
- if you only care about a "boolean" result of the addition, you stop here;
- you call another routine, which uses ic and jc to perform the addition.

Definition in file [blas\\_csr.c](#).

### 9.14.2 Function Documentation

#### 9.14.2.1 void fasp\_blas\_dcsr\_aApy ( const [REAL](#) *alpha*, [dCSRmat](#) \* A, [REAL](#) \* x, [REAL](#) \* y )

Matrix-vector multiplication  $y = \text{alpha} * A * x + y$ .

#### Parameters

<i>alpha</i>	REAL factor alpha
A	Pointer to <a href="#">dCSRmat</a> matrix A
x	Pointer to array x
y	Pointer to array y

#### Author

Chensong Zhang

#### Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/26/2012

Definition at line 481 of file blas\_csr.c.

9.14.2.2 void fasp\_blas\_dcsr\_aApy\_agg ( const REAL *alpha*, dCSRmat \* *A*, REAL \* *x*, REAL \* *y* )

Matrix-vector multiplication  $y = \alpha * A * x + y$ , where the entries of  $A$  are all ones.



## Parameters

<i>alpha</i>	REAL factor alpha
<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix A
<i>x</i>	Pointer to array x
<i>y</i>	Pointer to array y

## Author

Xiaozhe Hu

## Date

02/22/2011

Modified by Chunsheng Feng, Zheng Li on 08/29/2012

Definition at line 595 of file blas\_csr.c.

9.14.2.3 void fasp\_blas\_dcsr\_add ( [dCSRmat](#) \* *A*, const REAL *alpha*, [dCSRmat](#) \* *B*, const REAL *beta*, [dCSRmat](#) \* *C* )

compute  $C = \alpha A + \beta B$  in CSR format

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix
<i>alpha</i>	REAL factor alpha
<i>B</i>	Pointer to <a href="#">dCSRmat</a> matrix
<i>beta</i>	REAL factor beta
<i>C</i>	Pointer to <a href="#">dCSRmat</a> matrix

## Returns

FASP\_SUCCESS if succeeds, ERROR\_UNKNOWN if not

## Author

Xiaozhe Hu

## Date

11/07/2009

Modified by Chunsheng Feng, Zheng Li on 06/29/2012

Definition at line 48 of file blas\_csr.c.

9.14.2.4 void fasp\_blas\_dcsr\_axm ( [dCSRmat](#) \* *A*, const REAL *alpha* )

Multiply a sparse matrix A in CSR format by a scalar alpha.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix A
<i>alpha</i>	REAL factor alpha

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Zheng Li on 06/29/2012

Definition at line 202 of file blas\_csr.c.

9.14.2.5 void fasp\_blas\_dcsr\_mxm ( [dCSRmat](#) \* *A*, [dCSRmat](#) \* *B*, [dCSRmat](#) \* *C* )

Sparse matrix multiplication  $C=A*B$ .

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix A
<i>B</i>	Pointer to the <a href="#">dCSRmat</a> matrix B
<i>C</i>	Pointer to <a href="#">dCSRmat</a> matrix equal to $A*B$

## Author

Xiaoze Hu

## Date

11/07/2009

## Note

This fct will be replaced! –Chensong

Definition at line 761 of file blas\_csr.c.

9.14.2.6 void fasp\_blas\_dcsr\_m xv ( [dCSRmat](#) \* *A*, REAL \* *x*, REAL \* *y* )

Matrix-vector multiplication  $y = A*x$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix A
<i>x</i>	Pointer to array x

<i>y</i>	Pointer to array <i>y</i>
----------	---------------------------

**Author**

Chensong Zhang

**Date**

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/26/2012

Definition at line 226 of file blas\_csr.c.

9.14.2.7 void fasp\_blas\_dcsr\_mxv\_agg ( dCSRmat \* *A*, REAL \* *x*, REAL \* *y* )

Matrix-vector multiplication  $y = A*x$ , where the entries of *A* are all ones.

**Parameters**

<i>A</i>	Pointer to dCSRmat matrix <i>A</i>
<i>x</i>	Pointer to array <i>x</i>
<i>y</i>	Pointer to array <i>y</i>

**Author**

Xiaozhe Hu

**Date**

02/22/2011

Modified by Chunsheng Feng, Zheng Li on 08/29/2012

Definition at line 424 of file blas\_csr.c.

9.14.2.8 void fasp\_blas\_dcsr\_ptap ( dCSRmat \* *Pt*, dCSRmat \* *A*, dCSRmat \* *P*, dCSRmat \* *Ac* )

Triple sparse matrix multiplication  $B=P'*A*P$ .

**Parameters**

<i>Pt</i>	Pointer to the restriction matrix
<i>A</i>	Pointer to the fine coefficient matrix
<i>P</i>	Pointer to the prolongation matrix
<i>Ac</i>	Pointer to the coarse coefficient matrix (output)

**Author**

Ludmil Zikatanov, Chensong Zhang

## Date

05/10/2010

Modified by Chunsheng Feng, Zheng Li on 10/19/2012

## Note

Driver to compute triple matrix product  $P^*A^*P$  using Itz CSR format. In Itz format:  $ia[0]=1$ ,  $ja[0]$  and  $a[0]$  are used as usual. When called from Fortran,  $ia[0]$ ,  $ja[0]$  and  $a[0]$  will be just  $ia(1), ja(1), a(1)$ . For the indices,  $ia\_itz[k] = ia\_usual[k]+1$ ,  $ja\_itz[k] = ja\_usual[k]+1$ ,  $a\_itz[k] = a\_usual[k]$ .

Definition at line 1610 of file blas\_csr.c.

9.14.2.9 void fasp\_blas\_dcsr\_rap ( dCSRmat \* *R*, dCSRmat \* *A*, dCSRmat \* *P*, dCSRmat \* *RAP* )

Triple sparse matrix multiplication  $B=R^*A^*P$ .

## Parameters

<i>R</i>	Pointer to the <a href="#">dCSRmat</a> matrix R
<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix A
<i>P</i>	Pointer to the <a href="#">dCSRmat</a> matrix P
<i>RAP</i>	Pointer to <a href="#">dCSRmat</a> matrix equal to $R^*A^*P$

## Author

Xuehai Huang, Chensong Zhang

## Date

05/10/2010

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/26/2012

## Note

Ref. R.E. Bank and C.C. Douglas. SMMP: Sparse Matrix Multiplication Package. Advances in Computational Mathematics, 1 (1993), pp. 127-137.

Definition at line 879 of file blas\_csr.c.

9.14.2.10 void fasp\_blas\_dcsr\_rap4 ( dCSRmat \* *R*, dCSRmat \* *A*, dCSRmat \* *P*, dCSRmat \* *B*, INT \* *icor\_ysk* )

Triple sparse matrix multiplication  $B=R^*A^*P$ .

## Parameters

<i>R</i>	pointer to the <a href="#">dCSRmat</a> matrix
<i>A</i>	pointer to the <a href="#">dCSRmat</a> matrix

<i>P</i>	pointer to the <a href="#">dCSRmat</a> matrix
<i>B</i>	pointer to <a href="#">dCSRmat</a> matrix equal to $R*A*P$
<i>icor_ysk</i>	pointer to the array

**Author**

Feng Chunsheng, Yue Xiaoqiang

**Date**

08/02/2011

**Note**

Ref. R.E. Bank and C.C. Douglas. SMMP: Sparse Matrix Multiplication Package. Advances in Computational Mathematics, 1 (1993), pp. 127-137.

Definition at line 1709 of file blas\_csr.c.

9.14.2.11 `void fasp_blas_dcsr_rap_agg ( dCSRmat * R, dCSRmat * A, dCSRmat * P, dCSRmat * RAP )`

Triple sparse matrix multiplication  $B=R*A*P$ .

**Parameters**

<i>R</i>	Pointer to the <a href="#">dCSRmat</a> matrix R
<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix A
<i>P</i>	Pointer to the <a href="#">dCSRmat</a> matrix P
<i>RAP</i>	Pointer to <a href="#">dCSRmat</a> matrix equal to $R*A*P$

**Author**

Xiaozhe Hu

**Date**

05/10/2010

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/26/2012

**Note**

Ref. R.E. Bank and C.C. Douglas. SMMP: Sparse Matrix Multiplication Package. Advances in Computational Mathematics, 1 (1993), pp. 127-137.

Definition at line 1160 of file blas\_csr.c.

9.14.2.12 `void fasp_blas_dcsr_rap_agg1 ( dCSRmat * R, dCSRmat * A, dCSRmat * P, dCSRmat * B )`

Triple sparse matrix multiplication  $B=R*A*P$ , where the entries of R and P are all ones.

## Parameters

$R$	Pointer to the <a href="#">dCSRmat</a> matrix $R$
$A$	Pointer to the <a href="#">dCSRmat</a> matrix $A$
$P$	Pointer to the <a href="#">dCSRmat</a> matrix $P$
$B$	Pointer to <a href="#">dCSRmat</a> matrix equal to $R*A*P$

## Author

Xiaozhe Hu

## Date

02/21/2011

## Note

Ref. R.E. Bank and C.C. Douglas. SMMP: Sparse Matrix Multiplication Package. Advances in Computational Mathematics, 1 (1993), pp. 127-137.

Definition at line 1427 of file blas\_csr.c.

#### 9.14.2.13 `REAL fasp_blas_dcsr_vmv ( dCSRmat * A, REAL * x, REAL * y )`

vector-Matrix-vector multiplication  $\alpha = y'*A*x$

## Parameters

$A$	Pointer to <a href="#">dCSRmat</a> matrix $A$
$x$	Pointer to array $x$
$y$	Pointer to array $y$

## Author

Chensong Zhang

## Date

07/01/2009

Definition at line 706 of file blas\_csr.c.

## 9.15 blas\_csrl.c File Reference

BLAS operations for [dCSRLmat](#) matrices.

```
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_blas\\_dcsrl\\_mxv](#) ([dCSRLmat](#) \*A, [REAL](#) \*x, [REAL](#) \*y)  
Compute  $y = A*x$  for a sparse matrix in CSRL format.

### 9.15.1 Detailed Description

BLAS operations for [dCSRmat](#) matrices.

#### Note

For details of CSR format, refer to "Optimizing sparse matrix vector product computations using unroll and jam" by John Mellor-Crummey and John Garvin, Tech Report Rice Univ, Aug 2002.

Definition in file [blas\\_csrl.c](#).

### 9.15.2 Function Documentation

9.15.2.1 void fasp\_blas\_dcsl\_mxv ( dCSRmat \* A, REAL \* x, REAL \* y )

Compute  $y = A \cdot x$  for a sparse matrix in CSR format.

#### Parameters

A	Pointer to <a href="#">dCSRmat</a> matrix A
x	Pointer to REAL array of vector x
y	Pointer to REAL array of vector y

#### Date

2011/01/07

Definition at line 28 of file blas\_csrl.c.

## 9.16 blas\_smat.c File Reference

BLAS operations for small full matrix.

```
#include "fasp.h"
#include "fasp_funcs.h"
```

### Functions

- void [fasp\\_blas\\_smat\\_axm](#) (REAL \*a, const INT n, const REAL alpha)  
*Compute  $\alpha \cdot a$ , store in a.*
- void [fasp\\_blas\\_smat\\_add](#) (REAL \*a, REAL \*b, const INT n, const REAL alpha, const REAL beta, REAL \*c)  
*Compute  $c = \alpha \cdot a + \beta \cdot b$ .*
- void [fasp\\_blas\\_smat\\_mxv\\_nc2](#) (REAL \*a, REAL \*b, REAL \*c)  
*Compute the product of a 2\*2 matrix a and a array b, stored in c.*
- void [fasp\\_blas\\_smat\\_mxv\\_nc3](#) (REAL \*a, REAL \*b, REAL \*c)  
*Compute the product of a 3\*3 matrix a and a array b, stored in c.*
- void [fasp\\_blas\\_smat\\_mxv\\_nc5](#) (REAL \*a, REAL \*b, REAL \*c)  
*Compute the product of a 5\*5 matrix a and a array b, stored in c.*
- void [fasp\\_blas\\_smat\\_mxv\\_nc7](#) (REAL \*a, REAL \*b, REAL \*c)

- Compute the product of a 7\*7 matrix a and a array b, stored in c.*

  - void `fasp_blas_smat_mxxv` (`REAL *a`, `REAL *b`, `REAL *c`, `const INT n`)
- Compute the product of a small full matrix a and a array b, stored in c.*

  - void `fasp_blas_smat_mul_nc2` (`REAL *a`, `REAL *b`, `REAL *c`)
- Compute the matrix product of two 2\* matrices a and b, stored in c.*

  - void `fasp_blas_smat_mul_nc3` (`REAL *a`, `REAL *b`, `REAL *c`)
- Compute the matrix product of two 3\*3 matrices a and b, stored in c.*

  - void `fasp_blas_smat_mul_nc5` (`REAL *a`, `REAL *b`, `REAL *c`)
- Compute the matrix product of two 5\*5 matrices a and b, stored in c.*

  - void `fasp_blas_smat_mul_nc7` (`REAL *a`, `REAL *b`, `REAL *c`)
- Compute the matrix product of two 7\*7 matrices a and b, stored in c.*

  - void `fasp_blas_smat_mul` (`REAL *a`, `REAL *b`, `REAL *c`, `const INT n`)
- Compute the matrix product of two small full matrices a and b, stored in c.*

  - void `fasp_blas_array_axpyz_nc2` (`REAL a`, `REAL *x`, `REAL *y`, `REAL *z`)

$z = a*x + y$

  - void `fasp_blas_array_axpyz_nc3` (`const REAL a`, `REAL *x`, `REAL *y`, `REAL *z`)

$z = a*x + y$

  - void `fasp_blas_array_axpyz_nc5` (`const REAL a`, `REAL *x`, `REAL *y`, `REAL *z`)

$z = a*x + y$

  - void `fasp_blas_array_axpyz_nc7` (`const REAL a`, `REAL *x`, `REAL *y`, `REAL *z`)

$z = a*x + y$

  - void `fasp_blas_array_axpy_nc2` (`const REAL a`, `REAL *x`, `REAL *y`)

$y = a*x + y$ , the length of x and y is 2

  - void `fasp_blas_array_axpy_nc3` (`const REAL a`, `REAL *x`, `REAL *y`)

$y = a*x + y$ , the length of x and y is 3

  - void `fasp_blas_array_axpy_nc5` (`const REAL a`, `REAL *x`, `REAL *y`)

$y = a*x + y$ , the length of x and y is 5

  - void `fasp_blas_array_axpy_nc7` (`const REAL a`, `REAL *x`, `REAL *y`)

$y = a*x + y$ , the length of x and y is 7

  - void `fasp_blas_smat_ypAx_nc2` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y + Ax$ , where 'A' is a 2\*2 dense matrix.*

  - void `fasp_blas_smat_ypAx_nc3` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y + Ax$ , where 'A' is a 3\*3 dense matrix.*

  - void `fasp_blas_smat_ypAx_nc5` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y + Ax$ , where 'A' is a 5\*5 dense matrix.*

  - void `fasp_blas_smat_ypAx_nc7` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y + Ax$ , where 'A' is a 7\*7 dense matrix.*

  - void `fasp_blas_smat_ypAx` (`REAL *A`, `REAL *x`, `REAL *y`, `const INT n`)

*Compute  $y := y + Ax$ , where 'A' is a n\*n dense matrix.*

  - void `fasp_blas_smat_ymAx_nc2` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y - Ax$ , where 'A' is a n\*n dense matrix.*

  - void `fasp_blas_smat_ymAx_nc3` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y - Ax$ , where 'A' is a n\*n dense matrix.*

  - void `fasp_blas_smat_ymAx_nc5` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y - Ax$ , where 'A' is a n\*n dense matrix.*

  - void `fasp_blas_smat_ymAx_nc7` (`REAL *A`, `REAL *x`, `REAL *y`)

*Compute  $y := y - Ax$ , where 'A' is a 7\*7 dense matrix.*



- void `fasp_blas_smat_ymAx` (`REAL *A`, `REAL *x`, `REAL *y`, `INT n`)  
Compute  $y := y - Ax$ , where 'A' is a  $n \times n$  dense matrix.
- void `fasp_blas_smat_aAxpby` (`const REAL alpha`, `REAL *A`, `REAL *x`, `const REAL beta`, `REAL *y`, `const INT n`)  
Compute  $y := \alpha A * x + \beta y$ .
- void `fasp_blas_smat_ymAx_ns2` (`REAL *A`, `REAL *x`, `REAL *y`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a  $2 \times 2$  dense matrix, Ass is its saturaton part  $1 \times 1$ .
- void `fasp_blas_smat_ymAx_ns3` (`REAL *A`, `REAL *x`, `REAL *y`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a  $3 \times 3$  dense matrix, Ass is its saturaton part  $2 \times 2$ .
- void `fasp_blas_smat_ymAx_ns5` (`REAL *A`, `REAL *x`, `REAL *y`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a  $5 \times 5$  dense matrix, Ass is its saturaton part  $4 \times 4$ .
- void `fasp_blas_smat_ymAx_ns7` (`REAL *A`, `REAL *x`, `REAL *y`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a  $7 \times 7$  dense matrix, Ass is its saturaton part  $6 \times 6$ .
- void `fasp_blas_smat_ymAx_ns` (`REAL *A`, `REAL *x`, `REAL *y`, `const INT n`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a  $n \times n$  dense matrix, Ass is its saturaton part  $(n-1) \times (n-1)$ .

### 9.16.1 Detailed Description

BLAS operations for small full matrix.

Definition in file [blas\\_smat.c](#).

### 9.16.2 Function Documentation

#### 9.16.2.1 void fasp\_blas\_array\_axpy\_nc2 ( const REAL a, REAL \* x, REAL \* y )

$y = a * x + y$ , the length of x and y is 2

Parameters

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array
<i>y</i>	Pointer to the destination array

Author

Xiaozhe Hu

Date

18/11/2011

Definition at line 683 of file blas\_smat.c.

#### 9.16.2.2 void fasp\_blas\_array\_axpy\_nc3 ( const REAL a, REAL \* x, REAL \* y )

$y = a * x + y$ , the length of x and y is 3

**Parameters**

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array
<i>y</i>	Pointer to the destination array

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 706 of file blas\_smat.c.

**9.16.2.3** void fasp\_blas\_array\_axpy\_nc5 ( const REAL a, REAL \* x, REAL \* y )

$y = a * x + y$ , the length of x and y is 5

**Parameters**

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array
<i>y</i>	Pointer to the destination array

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 735 of file blas\_smat.c.

**9.16.2.4** void fasp\_blas\_array\_axpy\_nc7 ( const REAL a, REAL \* x, REAL \* y )

$y = a * x + y$ , the length of x and y is 7

**Parameters**

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array
<i>y</i>	Pointer to the destination array

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 782 of file blas\_smat.c.

9.16.2.5 void fasp\_blas\_array\_axpyz\_nc2 ( REAL a, REAL \* x, REAL \* y, REAL \* z )

$z = a * x + y$

**Parameters**

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array 1
<i>y</i>	Pointer to the original array 2
<i>z</i>	Pointer to the destination array

**Author**

Xiaozhe Hu

**Date**

18/11/2011

**Note**

*z* is the third array and the length of *x*, *y* and *z* is 2

Definition at line 498 of file blas\_smat.c.

9.16.2.6 void fasp\_blas\_array\_axpyz\_nc3 ( const REAL *a*, REAL \* *x*, REAL \* *y*, REAL \* *z* )

$z = a * x + y$

**Parameters**

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array 1
<i>y</i>	Pointer to the original array 2
<i>z</i>	Pointer to the destination array

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

**Note**

*z* is the third array and the length of *x*, *y* and *z* is 3

Definition at line 525 of file blas\_smat.c.

9.16.2.7 void fasp\_blas\_array\_axpyz\_nc5 ( const REAL *a*, REAL \* *x*, REAL \* *y*, REAL \* *z* )

$z = a * x + y$

## Parameters

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array 1
<i>y</i>	Pointer to the original array 2
<i>z</i>	Pointer to the destination array

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

## Note

*z* is the third array and the length of *x*, *y* and *z* is 5

Definition at line 558 of file blas\_smat.c.

**9.16.2.8** void fasp\_blas\_array\_axpyz\_nc7 ( const REAL *a*, REAL \* *x*, REAL \* *y*, REAL \* *z* )

$z = a * x + y$

## Parameters

<i>a</i>	REAL factor a
<i>x</i>	Pointer to the original array 1
<i>y</i>	Pointer to the original array 2
<i>z</i>	Pointer to the destination array

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

## Note

*z* is the third array and the length of *x*, *y* and *z* is 7

Definition at line 609 of file blas\_smat.c.

**9.16.2.9** void fasp\_blas\_smat\_aAxpby ( const REAL *alpha*, REAL \* *A*, REAL \* *x*, const REAL *beta*, REAL \* *y*, const INT *n* )

Compute  $y := \alpha * A * x + \beta * y$ .

## Parameters

<i>alpha</i>	REAL factor alpha
<i>A</i>	Pointer to the REAL array which stands for a n*n full matrix
<i>x</i>	Pointer to the REAL array with length n
<i>beta</i>	REAL factor beta
<i>y</i>	Pointer to the REAL array with length n
<i>n</i>	Length of array x and y

## Author

Zhiyang Zhou

## Date

2010/10/25

Definition at line 1306 of file blas\_smat.c.

9.16.2.10 void fasp\_blas\_smat\_add ( REAL \* *a*, REAL \* *b*, const INT *n*, const REAL *alpha*, const REAL *beta*, REAL \* *c* )

Compute  $c = \alpha * a + \beta * b$ .

## Parameters

<i>a</i>	Pointer to the REAL array which stands a n*n matrix
<i>b</i>	Pointer to the REAL array which stands a n*n matrix
<i>n</i>	Dimension of the matrix
<i>alpha</i>	Scalar
<i>beta</i>	Scalar
<i>c</i>	Pointer to the REAL array which stands a n*n matrix

## Author

Xiaozhe Hu

## Date

05/26/2014

Definition at line 52 of file blas\_smat.c.

9.16.2.11 void fasp\_blas\_smat\_axm ( REAL \* *a*, const INT *n*, const REAL *alpha* )

Compute  $\alpha * a$ , store in *a*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a n*n matrix
----------	---

<i>n</i>	Dimension of the matrix
<i>alpha</i>	Scalar

**Author**

Xiaozhe Hu

**Date**

05/26/2014

Definition at line 24 of file blas\_smat.c.

**9.16.2.12** void fasp\_blas\_smat\_mul ( REAL \* *a*, REAL \* *b*, REAL \* *c*, const INT *n* )

Compute the matrix product of two small full matrices *a* and *b*, stored in *c*.

**Parameters**

<i>a</i>	Pointer to the REAL array which stands a <i>n</i> * <i>n</i> matrix
<i>b</i>	Pointer to the REAL array which stands a <i>n</i> * <i>n</i> matrix
<i>c</i>	Pointer to the REAL array which stands a <i>n</i> * <i>n</i> matrix
<i>n</i>	Dimension of the matrix

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

04/21/2010

Definition at line 446 of file blas\_smat.c.

**9.16.2.13** void fasp\_blas\_smat\_mul\_nc2 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the matrix product of two 2\* matrices *a* and *b*, stored in *c*.

**Parameters**

<i>a</i>	Pointer to the REAL array which stands a <i>n</i> * <i>n</i> matrix
<i>b</i>	Pointer to the REAL array which stands a <i>n</i> * <i>n</i> matrix
<i>c</i>	Pointer to the REAL array which stands a <i>n</i> * <i>n</i> matrix

**Author**

Xiaozhe Hu

**Date**

18/11/2011

Definition at line 231 of file blas\_smat.c.

9.16.2.14 void fasp\_blas\_smat\_mul\_nc3 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the matrix product of two 3\*3 matrices *a* and *b*, stored in *c*.



## Parameters

<i>a</i>	Pointer to the REAL array which stands a $n \times n$ matrix
<i>b</i>	Pointer to the REAL array which stands a $n \times n$ matrix
<i>c</i>	Pointer to the REAL array which stands a $n \times n$ matrix

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 260 of file blas\_smat.c.

9.16.2.15 void fasp\_blas\_smat\_mul\_nc5 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the matrix product of two  $5 \times 5$  matrices *a* and *b*, stored in *c*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a $5 \times 5$ matrix
<i>b</i>	Pointer to the REAL array which stands a $5 \times 5$ matrix
<i>c</i>	Pointer to the REAL array which stands a $5 \times 5$ matrix

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 297 of file blas\_smat.c.

9.16.2.16 void fasp\_blas\_smat\_mul\_nc7 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the matrix product of two  $7 \times 7$  matrices *a* and *b*, stored in *c*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a $7 \times 7$ matrix
<i>b</i>	Pointer to the REAL array which stands a $7 \times 7$ matrix
<i>c</i>	Pointer to the REAL array which stands a $7 \times 7$ matrix

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 356 of file blas\_smat.c.

9.16.2.17 void fasp\_blas\_smat\_mnv ( REAL \* *a*, REAL \* *b*, REAL \* *c*, const INT *n* )

Compute the product of a small full matrix *a* and a array *b*, stored in *c*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a $n \times n$ matrix
<i>b</i>	Pointer to the REAL array with length $n$
<i>c</i>	Pointer to the REAL array with length $n$
<i>n</i>	Dimension of the matrix

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

04/21/2010

Definition at line 181 of file blas\_smat.c.

**9.16.2.18** void fasp\_blas\_smat\_mnv\_nc2 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the product of a  $2 \times 2$  matrix *a* and a array *b*, stored in *c*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a $2 \times 2$ matrix
<i>b</i>	Pointer to the REAL array with length 2
<i>c</i>	Pointer to the REAL array with length 2

## Author

Xiaozhe Hu

## Date

18/11/2010

Definition at line 81 of file blas\_smat.c.

**9.16.2.19** void fasp\_blas\_smat\_mnv\_nc3 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the product of a  $3 \times 3$  matrix *a* and a array *b*, stored in *c*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a $3 \times 3$ matrix
<i>b</i>	Pointer to the REAL array with length 3
<i>c</i>	Pointer to the REAL array with length 3

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 103 of file blas\_smat.c.

9.16.2.20 void fasp\_blas\_smat\_mnv\_nc5 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the product of a 5\*5 matrix *a* and a array *b*, stored in *c*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a 5*5 matrix
<i>b</i>	Pointer to the REAL array with length 5
<i>c</i>	Pointer to the REAL array with length 5

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 126 of file blas\_smat.c.

**9.16.2.21** void fasp\_blas\_smat\_mnv\_nc7 ( REAL \* *a*, REAL \* *b*, REAL \* *c* )

Compute the product of a 7\*7 matrix *a* and a array *b*, stored in *c*.

## Parameters

<i>a</i>	Pointer to the REAL array which stands a 7*7 matrix
<i>b</i>	Pointer to the REAL array with length 7
<i>c</i>	Pointer to the REAL array with length 7

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 152 of file blas\_smat.c.

**9.16.2.22** void fasp\_blas\_smat\_ymAx ( REAL \* *A*, REAL \* *x*, REAL \* *y*, INT *n* )

Compute  $y := y - Ax$ , where '*A*' is a *n*\**n* dense matrix.

## Parameters

<i>A</i>	Pointer to the <i>n</i> * <i>n</i> dense matrix
<i>x</i>	Pointer to the REAL array with length <i>n</i>
<i>y</i>	Pointer to the REAL array with length <i>n</i>
<i>n</i>	the dimension of the dense matrix

## Author

Zhiyang Zhou, Xiaozhe Hu

## Date

2010/10/25

Definition at line 1205 of file blas\_smat.c.

9.16.2.23 void fasp\_blas\_smat\_ymAx\_nc2 ( REAL \* A, REAL \* x, REAL \* y )

Compute  $y := y - Ax$ , where 'A' is a  $n \times n$  dense matrix.

## Parameters

$A$	Pointer to the 2*2 dense matrix
$x$	Pointer to the REAL array with length 3
$y$	Pointer to the REAL array with length 3

## Author

Xiaozhe Hu

## Date

18/11/2011

## Note

Works for 2-component

Definition at line 1075 of file blas\_smat.c.

9.16.2.24 void fasp\_blas\_smat\_ymAx\_nc3 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y := y - Ax$ , where ' $A$ ' is a  $n \times n$  dense matrix.

## Parameters

$A$	Pointer to the 3*3 dense matrix
$x$	Pointer to the REAL array with length 3
$y$	Pointer to the REAL array with length 3

## Author

Xiaozhe Hu, Zhiyang Zhou

## Date

01/06/2011

## Note

Works for 3-component

Definition at line 1103 of file blas\_smat.c.

9.16.2.25 void fasp\_blas\_smat\_ymAx\_nc5 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y := y - Ax$ , where ' $A$ ' is a  $n \times n$  dense matrix.

## Parameters

$A$	Pointer to the 5*5 dense matrix
$x$	Pointer to the REAL array with length 5
$y$	Pointer to the REAL array with length 5

## Author

Xiaozhe Hu, Zhiyang Zhou

## Date

01/06/2011

## Note

Works for 5-component

Definition at line 1133 of file blas\_smat.c.

9.16.2.26 void fasp\_blas\_smat\_ymAx\_nc7 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y := y - Ax$ , where ' $A$ ' is a 7\*7 dense matrix.

## Parameters

$A$	Pointer to the 7*7 dense matrix
$x$	Pointer to the REAL array with length 7
$y$	Pointer to the REAL array with length 7

## Author

Xiaozhe Hu, Zhiyang Zhou

## Date

01/06/2011

## Note

Works for 7-component

Definition at line 1167 of file blas\_smat.c.

9.16.2.27 void fasp\_blas\_smat\_ymAx\_ns ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$ , const INT  $n$  )

Compute  $y_s := y_s - Ass*xs$ , where ' $A$ ' is a  $n*n$  dense matrix,  $Ass$  is its saturaton part  $(n-1)*(n-1)$ .



## Parameters

$A$	Pointer to the $n \times n$ dense matrix
$x$	Pointer to the REAL array with length $n-1$
$y$	Pointer to the REAL array with length $n-1$
$n$	the dimension of the dense matrix

## Author

Xiaozhe Hu

## Date

2010/10/25

## Note

Only for block smoother for saturation block without explicitly use saturation block!!

Definition at line 1480 of file blas\_smat.c.

9.16.2.28 void fasp\_blas\_smat\_ymAx\_ns2 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y_s := y_s - A_{ss}x_s$ , where ' $A$ ' is a  $2 \times 2$  dense matrix,  $A_{ss}$  is its saturation part  $1 \times 1$ .

## Parameters

$A$	Pointer to the $2 \times 2$ dense matrix
$x$	Pointer to the REAL array with length 1
$y$	Pointer to the REAL array with length 1

## Author

Xiaozhe Hu

## Date

2011/11/18

## Note

Works for 2-component (Xiaozhe) Only for block smoother for saturation block without explicitly use saturation block!!

Definition at line 1356 of file blas\_smat.c.

9.16.2.29 void fasp\_blas\_smat\_ymAx\_ns3 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y_s := y_s - A_{ss}x_s$ , where ' $A$ ' is a  $3 \times 3$  dense matrix,  $A_{ss}$  is its saturation part  $2 \times 2$ .

## Parameters

$A$	Pointer to the 3*3 dense matrix
$x$	Pointer to the REAL array with length 2
$y$	Pointer to the REAL array with length 2

## Author

Xiaozhe Hu

## Date

2010/10/25

## Note

Works for 3-component (Xiaozhe) Only for block smoother for saturation block without explicitly use saturation block!!

Definition at line 1380 of file blas\_smat.c.

9.16.2.30 void fasp\_blas\_smat\_ymAx\_ns5 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y_s := y_s - Ass * x_s$ , where ' $A$ ' is a 5\*5 dense matrix, Ass is its saturaton part 4\*4.

## Parameters

$A$	Pointer to the 5*5 dense matrix
$x$	Pointer to the REAL array with length 4
$y$	Pointer to the REAL array with length 4

## Author

Xiaozhe Hu

## Date

2010/10/25

## Note

Works for 5-component (Xiaozhe) Only for block smoother for saturation block without explicitly use saturation block!!

Definition at line 1408 of file blas\_smat.c.

9.16.2.31 void fasp\_blas\_smat\_ymAx\_ns7 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y_s := y_s - Ass * x_s$ , where ' $A$ ' is a 7\*7 dense matrix, Ass is its saturaton part 6\*6.

## Parameters

$A$	Pointer to the 7*7 dense matrix
$x$	Pointer to the REAL array with length 6
$y$	Pointer to the REAL array with length 6

## Author

Xiaozhe Hu

## Date

2010/10/25

## Note

Works for 7-component (Xiaozhe) Only for block smoother for saturation block without explicitly use saturation block!!

Definition at line 1442 of file blas\_smat.c.

9.16.2.32 void fasp\_blas\_smat\_ypAx ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$ , const INT  $n$  )

Compute  $y := y + Ax$ , where ' $A$ ' is a  $n \times n$  dense matrix.

## Parameters

$A$	Pointer to the $n \times n$ dense matrix
$x$	Pointer to the REAL array with length $n$
$y$	Pointer to the REAL array with length $n$
$n$	Dimension of the dense matrix

## Author

Zhiyang Zhou

## Date

2010/10/25

Definition at line 974 of file blas\_smat.c.

9.16.2.33 void fasp\_blas\_smat\_ypAx\_nc2 ( REAL \*  $A$ , REAL \*  $x$ , REAL \*  $y$  )

Compute  $y := y + Ax$ , where ' $A$ ' is a  $2 \times 2$  dense matrix.

## Parameters

$A$	Pointer to the $3 \times 3$ dense matrix
-----	--

$x$	Pointer to the REAL array with length 3
$y$	Pointer to the REAL array with length 3

**Author**

Xiaozhe Hu

**Date**

2011/11/18

Definition at line 855 of file blas\_smat.c.

**9.16.2.34** void fasp\_blas\_smat\_ypAx\_nc3 ( REAL \* A, REAL \* x, REAL \* y )Compute  $y := y + Ax$ , where 'A' is a 3\*3 dense matrix.**Parameters**

$A$	Pointer to the 3*3 dense matrix
$x$	Pointer to the REAL array with length 3
$y$	Pointer to the REAL array with length 3

**Author**

Zhiyang Zhou, Xiaozhe Hu

**Date**

2010/10/25

Definition at line 881 of file blas\_smat.c.

**9.16.2.35** void fasp\_blas\_smat\_ypAx\_nc5 ( REAL \* A, REAL \* x, REAL \* y )Compute  $y := y + Ax$ , where 'A' is a 5\*5 dense matrix.**Parameters**

$A$	Pointer to the 5*5 dense matrix
$x$	Pointer to the REAL array with length 5
$y$	Pointer to the REAL array with length 5

**Author**

Zhiyang Zhou, Xiaozhe Hu

**Date**

2010/10/25

Definition at line 908 of file blas\_smat.c.

**9.16.2.36** void fasp\_blas\_smat\_ypAx\_nc7 ( REAL \* A, REAL \* x, REAL \* y )Compute  $y := y + Ax$ , where 'A' is a 7\*7 dense matrix.

## Parameters

<i>A</i>	Pointer to the 7*7 dense matrix
<i>x</i>	Pointer to the REAL array with length 7
<i>y</i>	Pointer to the REAL array with length 7

## Author

Zhiyang Zhou, Xiaozhe Hu

## Date

2010/10/25

Definition at line 939 of file blas\_smat.c.

## 9.17 blas\_str.c File Reference

BLAS operations for [dSTRmat](#) matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_blas\\_dstr\\_aAxy](#) (REAL alpha, [dSTRmat](#) \*A, REAL \*x, REAL \*y)  
*Matrix-vector multiplication  $y = \alpha * A * x + y$ .*
- void [fasp\\_blas\\_dstr\\_mxv](#) ([dSTRmat](#) \*A, REAL \*x, REAL \*y)  
*Matrix-vector multiplication  $y = A * x$ .*
- INT [fasp\\_dstr\\_diagscale](#) ([dSTRmat](#) \*A, [dSTRmat](#) \*B)  
 *$B = D^{\{-1\}} A$ .*

### 9.17.1 Detailed Description

BLAS operations for [dSTRmat](#) matrices.

Definition in file [blas\\_str.c](#).

### 9.17.2 Function Documentation

9.17.2.1 void [fasp\\_blas\\_dstr\\_aAxy](#) ( REAL *alpha*, [dSTRmat](#) \* *A*, REAL \* *x*, REAL \* *y* )

Matrix-vector multiplication  $y = \alpha * A * x + y$ .

## Parameters

<i>alpha</i>	REAL factor alpha
<i>A</i>	Pointer to <a href="#">dSTRmat</a> matrix
<i>x</i>	Pointer to REAL array
<i>y</i>	Pointer to REAL array

## Author

Zhiyang Zhou, Xiaozhe Hu, Shiquan Zhang

## Date

2010/10/15

Definition at line 47 of file blas\_str.c.

**9.17.2.2 void fasp\_blas\_dstr\_mxv ( dSTRmat \* *A*, REAL \* *x*, REAL \* *y* )**

Matrix-vector multiplication  $y = A * x$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> matrix
<i>x</i>	Pointer to REAL array
<i>y</i>	Pointer to REAL array

## Author

Chensong Zhang

## Date

04/27/2013

Definition at line 117 of file blas\_str.c.

**9.17.2.3 INT fasp\_dstr\_diagscale ( dSTRmat \* *A*, dSTRmat \* *B* )**

$B = D^{-1}A$ .

## Parameters

<i>A</i>	Pointer to a ' <a href="#">dSTRmat</a> ' type matrix A
<i>B</i>	Pointer to a ' <a href="#">dSTRmat</a> ' type matrix B

## Author

Shiquan Zhang

## Date

2010/10/15

Modified by Chunsheng Feng, Zheng Li

## Date

08/30/2012

Definition at line 142 of file blas\_str.c.

## 9.18 blas\_vec.c File Reference

BLAS operations for vectors.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_blas\\_dvec\\_axpy](#) (const [REAL](#) a, [dvector](#) \*x, [dvector](#) \*y)
  - $y = a*x + y$
- void [fasp\\_blas\\_dvec\\_axpyz](#) (const [REAL](#) a, [dvector](#) \*x, [dvector](#) \*y, [dvector](#) \*z)
  - $z = a*x + y$ ,  $z$  is a third vector ( $z$  is cleared)
- [REAL fasp\\_blas\\_dvec\\_dotprod](#) ([dvector](#) \*x, [dvector](#) \*y)
  - Inner product of two vectors ( $x, y$ )
- [REAL fasp\\_blas\\_dvec\\_relerr](#) ([dvector](#) \*x, [dvector](#) \*y)
  - Relative error of two [dvector](#)  $x$  and  $y$ .
- [REAL fasp\\_blas\\_dvec\\_norm1](#) ([dvector](#) \*x)
  - $L_1$  norm of [dvector](#)  $x$ .
- [REAL fasp\\_blas\\_dvec\\_norm2](#) ([dvector](#) \*x)
  - $L_2$  norm of [dvector](#)  $x$ .
- [REAL fasp\\_blas\\_dvec\\_norminf](#) ([dvector](#) \*x)
  - $L_{inf}$  norm of [dvector](#)  $x$ .

### 9.18.1 Detailed Description

BLAS operations for vectors.

Definition in file [blas\\_vec.c](#).

### 9.18.2 Function Documentation

9.18.2.1 void [fasp\\_blas\\_dvec\\_axpy](#) ( const [REAL](#) a, [dvector](#) \* x, [dvector](#) \* y )

$y = a*x + y$

## Parameters

<i>a</i>	REAL factor a
<i>x</i>	Pointer to dvector x
<i>y</i>	Pointer to dvector y

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 35 of file blas\_vec.c.

**9.18.2.2 void fasp\_blas\_dvec\_axpyz ( const REAL a, dvector \* x, dvector \* y, dvector \* z )**

$z = a*x + y$ ,  $z$  is a third vector ( $z$  is cleared)

## Parameters

<i>a</i>	REAL factor a
<i>x</i>	Pointer to dvector x
<i>y</i>	Pointer to dvector y
<i>z</i>	Pointer to dvector z

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 87 of file blas\_vec.c.

**9.18.2.3 REAL fasp\_blas\_dvec\_dotprod ( dvector \* x, dvector \* y )**

Inner product of two vectors ( $x, y$ )



## Parameters

$x$	Pointer to dvector x
$y$	Pointer to dvector y

## Returns

Inner product

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 123 of file blas\_vec.c.

**9.18.2.4 REAL fasp\_blas\_dvec\_norm1 ( dvector \* x )**

L1 norm of dvector x.

## Parameters

$x$	Pointer to dvector x
-----	----------------------

## Returns

L1 norm of x

## Author

Chensong Zhang

## Date

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 224 of file blas\_vec.c.

**9.18.2.5 REAL fasp\_blas\_dvec\_norm2 ( dvector \* x )**

L2 norm of dvector x.

**Parameters**

$x$	Pointer to dvector $x$
-----	------------------------

**Returns**

L2 norm of  $x$

**Author**

Chensong Zhang

**Date**

07/01/2009

Modified by Chunsheng Feng, Xiaoqiang Yue

**Date**

05/23/2012

Definition at line 267 of file blas\_vec.c.

**9.18.2.6 REAL fasp\_blas\_dvec\_norminf ( dvector \*  $x$  )**

Linf norm of dvector  $x$ .

**Parameters**

$x$	Pointer to dvector $x$
-----	------------------------

**Returns**

L<sub>inf</sub> norm of  $x$

**Author**

Chensong Zhang

**Date**

07/01/2009

Definition at line 307 of file blas\_vec.c.

**9.18.2.7 REAL fasp\_blas\_dvec\_relerr ( dvector \*  $x$ , dvector \*  $y$  )**

Relative error of two dvector  $x$  and  $y$ .

## Parameters

$x$	Pointer to dvector $x$
$y$	Pointer to dvector $y$

## Returns

relative error  $\|x-y\|/\|x\|$

## Author

Chensong Zhang

## Date

07/01/209

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 169 of file blas\_vec.c.

## 9.19 checkmat.c File Reference

Check matrix properties.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- [INT fasp\\_check\\_diagpos](#) ([dCSRmat](#) \*A)  
*Check positivity of diagonal entries of a CSR sparse matrix.*
- [SHORT fasp\\_check\\_diagzero](#) ([dCSRmat](#) \*A)  
*Check whether a CSR sparse matrix has diagonal entries that are very close to zero.*
- [INT fasp\\_check\\_diagdom](#) ([dCSRmat](#) \*A)  
*Check whether a matrix is diagonal dominant.*
- [INT fasp\\_check\\_symm](#) ([dCSRmat](#) \*A)  
*Check symmetry of a sparse matrix of CSR format.*
- [SHORT fasp\\_check\\_dCSRmat](#) ([dCSRmat](#) \*A)  
*Check whether an [dCSRmat](#) matrix is valid or not.*
- [SHORT fasp\\_check\\_iCSRmat](#) ([iCSRmat](#) \*A)  
*Check whether an [iCSRmat](#) matrix is valid or not.*

### 9.19.1 Detailed Description

Check matrix properties.

Definition in file [checkmat.c](#).

### 9.19.2 Function Documentation

#### 9.19.2.1 SHORT fasp\_check\_dCSRmat ( dCSRmat \* A )

Check whether an [dCSRmat](#) matrix is valid or not.

##### Parameters

A	Pointer to the matrix in <a href="#">dCSRmat</a> format
---	---

##### Author

Shuo Zhang

##### Date

03/29/2009

Definition at line 276 of file checkmat.c.

#### 9.19.2.2 INT fasp\_check\_diagdom ( dCSRmat \* A )

Check whether a matrix is diagonal dominant.

INT fasp\_check\_diagdom ([dCSRmat](#) \*A)

##### Parameters

A	Pointer to the <a href="#">dCSRmat</a> matrix
---	---

##### Returns

Number of the rows which are diagonal dominant

##### Note

The routine checks whether the sparse matrix is diagonal dominant on every row. It will print out the percentage of the rows which are diagonal dominant and which are not; the routine will return the number of the rows which are diagonal dominant.

##### Author

Shuo Zhang

##### Date

03/29/2009

Definition at line 109 of file checkmat.c.

### 9.19.2.3 INT fasp\_check\_diagpos ( dCSRmat \* A )

Check positivity of diagonal entries of a CSR sparse matrix.

**Parameters**

<b>A</b>	Pointer to <a href="#">dCSRmat</a> matrix
----------	---

**Returns**

Number of negative diagonal entries

**Author**

Shuo Zhang

**Date**

03/29/2009

Definition at line 27 of file checkmat.c.

**9.19.2.4 SHORT fasp\_check\_diagzero ( dCSRmat \* A )**

Check whether a CSR sparse matrix has diagonal entries that are very close to zero.

**Parameters**

<b>A</b>	pointer to the <a href="#">dCSRmat</a> matrix
----------	---

**Returns**

FASP\_SUCCESS if no diagonal entry is close to zero, else ERROR (negative value)

**Author**

Shuo Zhang

**Date**

03/29/2009

Definition at line 64 of file checkmat.c.

**9.19.2.5 SHORT fasp\_check\_iCSRmat ( iCSRmat \* A )**

Check whether an [iCSRmat](#) matrix is valid or not.

**Parameters**

<b>A</b>	Pointer to the matrix in <a href="#">iCSRmat</a> format
----------	---

**Author**

Shuo Zhang

**Date**

03/29/2009

Definition at line 310 of file checkmat.c.

#### 9.19.2.6 INT fasp\_check\_symm ( dCSRmat \* A )

Check symmetry of a sparse matrix of CSR format.

**Parameters**

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
----------	---

**Returns**

1 and 2 if the structure of the matrix is not symmetric; 0 if the structure of the matrix is symmetric,

**Note**

Print the maximal relative difference between matrix and its transpose.

**Author**

Shuo Zhang

**Date**

03/29/2009

Definition at line 154 of file checkmat.c.

## 9.20 [coarsening\\_cr.c](#) File Reference

Coarsening with Brannick-Falgout strategy.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

**Functions**

- [INT fasp\\_amg\\_coarsening\\_cr](#) (INT *i\_0*, INT *i\_n*, [dCSRmat](#) \**A*, [ivector](#) \**vertices*, [AMG\\_param](#) \**param*)  
*CR coarsening.*

### 9.20.1 Detailed Description

Coarsening with Brannick-Falgout strategy.

Definition in file [coarsening\\_cr.c](#).

### 9.20.2 Function Documentation

9.20.2.1 [INT fasp\\_amg\\_coarsening\\_cr](#) ( INT *i\_0*, INT *i\_n*, [dCSRmat](#) \* *A*, [ivector](#) \* *vertices*, [AMG\\_param](#) \* *param* )

CR coarsening.



## Parameters

<i>i_0</i>	Starting index
<i>i_n</i>	Ending index
<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix (index starts from 0)
<i>vertices</i>	Pointer to CF, 0: fpt (current level) or 1: cpt
<i>param</i>	Pointer to <a href="#">AMG_param</a> : AMG parameters

## Author

James Brannick

## Date

04/21/2010

Modified by Chunsheng Feng, Zheng Li

## Date

10/14/2012

## CR STAGES

Definition at line 41 of file coarsening\_cr.c.

## 9.21 coarsening\_rs.c File Reference

Coarsening with a modified Ruge-Stuben strategy.

```
#include "fasp.h"
#include "fasp_functs.h"
#include "linklist.inl"
```

## Functions

- [SHORT fasp\\_amg\\_coarsening\\_rs](#) ([dCSRmat](#) \*A, [ivector](#) \*vertices, [dCSRmat](#) \*P, [iCSRmat](#) \*S, [AMG\\_param](#) \*param)

*Standard and aggressive coarsening schemes.*

### 9.21.1 Detailed Description

Coarsening with a modified Ruge-Stuben strategy.

## Note

Ref Multigrid by U. Trottenberg, C. W. Oosterlee and A. Schuller Appendix P475 A.7 (by A. Brandt, P. Oswald and K. Stuben) Academic Press Inc., San Diego, CA, 2001.

Definition in file [coarsening\\_rs.c](#).

### 9.21.2 Function Documentation

9.21.2.1 **SHORT** `fasp_amg_coarsening_rs ( dCSRmat * A, ivector * vertices, dCSRmat * P, iCSRmat * S, AMG_param * param )`

Standard and aggressive coarsening schemes.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : Coefficient matrix (index starts from 0)
<i>vertices</i>	Indicator vector for the C/F splitting of the variables
<i>P</i>	Interpolation matrix (nonzero pattern only)
<i>S</i>	Strong connection matrix
<i>param</i>	Pointer to <a href="#">AMG_param</a> : AMG parameters

## Returns

FASP\_SUCCESS or error message

## Author

Xuehai Huang, Chensong Zhang, Xiaozhe Hu, Ludmil Zikatanov

## Date

09/06/2010

## Note

vertices = 0: fine; 1: coarse; 2: isolated or special

Modified by Xiaozhe Hu on 05/23/2011: add strength matrix as an argument Modified by Xiaozhe Hu on 04/24/2013: modify aggressive coarsening Modified by Chensong Zhang on 04/28/2013: remove linked list Modified by Chensong Zhang on 05/11/2013: restructure the code

Definition at line 56 of file coarsening\_rs.c.

## 9.22 convert.c File Reference

Some utilities for format conversion.

```
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- unsigned long [fasp\\_aux\\_change\\_endian4](#) (unsigned long x)  
*Swap order for different endian systems.*
- double [fasp\\_aux\\_change\\_endian8](#) (double x)  
*Swap order for different endian systems.*
- double [fasp\\_aux\\_bbyteToldouble](#) (unsigned char bytes[])  
*Swap order of double-precision float for different endian systems.*
- [INT endian\\_convert\\_int](#) (const [INT](#) inum, const [INT](#) ilength, const [INT](#) endianflag)  
*Swap order of an INT number.*
- [REAL endian\\_convert\\_real](#) (const [REAL](#) rnum, [INT](#) vlength, [INT](#) endianflag)  
*Swap order of a REAL number.*

### 9.22.1 Detailed Description

Some utilities for format conversion.

Definition in file [convert.c](#).

### 9.22.2 Function Documentation

#### 9.22.2.1 `INT endian_convert_int ( const INT inum, const INT ilength, const INT endianflag )`

Swap order of an INT number.

##### Parameters

<i>inum</i>	An INT value
<i>ilength</i>	Length of INT: 2 for short, 4 for int, 8 for long
<i>endianflag</i>	If endianflag = 1, it returns inum itself If endianflag = 2, it returns the swapped inum

##### Returns

Value of inum or swapped inum

##### Author

Ziteng Wang

##### Date

2012-12-24

Definition at line 105 of file convert.c.

#### 9.22.2.2 `REAL endian_convert_real ( const REAL rnum, INT ilength, INT endianflag )`

Swap order of a REAL number.

##### Parameters

<i>rnum</i>	An REAL value
<i>ilength</i>	Length of INT: 2 for short, 4 for int, 8 for long
<i>endianflag</i>	If endianflag = 1, it returns rnum itself If endianflag = 2, it returns the swapped rnum

##### Returns

Value of rnum or swapped rnum

##### Author

Ziteng Wang

##### Date

2012-12-24

Definition at line 137 of file convert.c.

9.22.2.3 double fasp\_aux\_bbyteToldouble ( unsigned char *bytes*[] )

Swap order of double-precision float for different endian systems.

**Parameters**

<i>bytes</i>	A unsigned char
--------------	-----------------

**Returns**

Unsigend long ineger after swapping

**Author**

Chensong Zhang

**Date**

11/16/2009

Definition at line 74 of file convert.c.

**9.22.2.4 unsigned long fasp\_aux\_change\_endian4 ( unsigned long x )**

Swap order for different endian systems.

**Parameters**

<i>x</i>	An unsigned long integer
----------	--------------------------

**Returns**

Unsigend long ineger after swapping

**Author**

Chensong Zhang

**Date**

11/16/2009

Definition at line 25 of file convert.c.

**9.22.2.5 double fasp\_aux\_change\_endian8 ( double x )**

Swap order for different endian systems.

**Parameters**

<i>x</i>	A unsigned long integer
----------	-------------------------

**Returns**

Unsigend long ineger after swapping

**Author**

Chensong Zhang

**Date**

11/16/2009

Definition at line 43 of file convert.c.

## 9.23 doxygen.h File Reference

Main page for Doygen documentation.

### 9.23.1 Detailed Description

Main page for Doygen documentation.

Definition in file [doxygen.h](#).

## 9.24 eigen.c File Reference

Simple subroutines for compute the extreme eigenvalues.

```
#include <math.h>
#include "fasp.h"
#include "fasp_funcs.h"
```

### Functions

- [REAL fasp\\_dcsr\\_eig](#) ([dCSRmat](#) \*A, const [REAL](#) tol, const [INT](#) maxit)  
*Approximate the largest eigenvalue of A by the power method.*

### 9.24.1 Detailed Description

Simple subroutines for compute the extreme eigenvalues.

Definition in file [eigen.c](#).

### 9.24.2 Function Documentation

9.24.2.1 [REAL fasp\\_dcsr\\_eig](#) ( [dCSRmat](#) \* A, const [REAL](#) tol, const [INT](#) maxit )

Approximate the largest eigenvalue of A by the power method.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
<i>tol</i>	Tolerance for stopping the power method
<i>maxit</i>	Max number of iterations

## Returns

Largest eigenvalue

## Author

Xiaozhe Hu

## Date

01/25/2011

Definition at line 29 of file `eigen.c`.

## 9.25 `factor.f` File Reference

LU factorization for CSR matrix.

### Functions/Subroutines

- subroutine **sfactr** (ia, ja, n, iu, ju, ip, nwku)
- subroutine **sfactr\_new** (ia, ja, n, iu, ju, ip, nwku, mem\_chk)
- subroutine **factor** (ia, ja, n, iu, ju, ip, iup, an, ad, un, di)
- subroutine **forbac** (iu, ju, un, di, n, x)

### 9.25.1 Detailed Description

LU factorization for CSR matrix.

## Author

Ludmil Zikatanov

## Date

01/01/2002

Definition in file [factor.f](#).

## 9.26 `famg.c` File Reference

full AMG method as an iterative solver (main file)

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```



## Functions

- void [fasp\\_solver\\_famg](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [AMG\\_param](#) \*param)  
*Solve  $Ax=b$  by full AMG.*

### 9.26.1 Detailed Description

full AMG method as an iterative solver (main file)

Definition in file [famg.c](#).

### 9.26.2 Function Documentation

9.26.2.1 void [fasp\\_solver\\_famg](#) ( [dCSRmat](#) \* A, [dvector](#) \* b, [dvector](#) \* x, [AMG\\_param](#) \* param )

Solve  $Ax=b$  by full AMG.

#### Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to <a href="#">dvector</a> : the right hand side
<i>x</i>	Pointer to <a href="#">dvector</a> : the unknowns
<i>param</i>	Pointer to <a href="#">AMG_param</a> : AMG parameters

#### Author

Xiaozhe Hu

#### Date

02/27/2011

Modified by Chensong Zhang on 01/10/2012 Modified by Chensong Zhang on 05/05/2013: Remove error handling for AMG setup

Definition at line 31 of file [famg.c](#).

## 9.27 fasp.h File Reference

Main header file for FASP.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "messages.h"
```

## Data Structures

- struct [ddenmat](#)  
*Dense matrix of REAL type.*

- struct [idenmat](#)  
*Dense matrix of INT type.*
- struct [dCSRmat](#)  
*Sparse matrix of REAL type in CSR format.*
- struct [iCSRmat](#)  
*Sparse matrix of INT type in CSR format.*
- struct [dCOOmat](#)  
*Sparse matrix of REAL type in COO (or IJ) format.*
- struct [iCOOmat](#)  
*Sparse matrix of INT type in COO (or IJ) format.*
- struct [dCSRLmat](#)  
*Sparse matrix of REAL type in CSRL format.*
- struct [dSTRmat](#)  
*Structure matrix of REAL type.*
- struct [dvector](#)  
*Vector with  $n$  entries of REAL type.*
- struct [ivector](#)  
*Vector with  $n$  entries of INT type.*
- struct [ILU\\_param](#)  
*Parameters for ILU.*
- struct [ILU\\_data](#)  
*Data for ILU setup.*
- struct [Schwarz\\_param](#)  
*Parameters for Schwarz method.*
- struct [Schwarz\\_data](#)  
*Data for Schwarz methods.*
- struct [AMG\\_param](#)  
*Parameters for AMG solver.*
- struct [AMG\\_data](#)  
*Data for AMG solvers.*
- struct [precond\\_data](#)  
*Data passed to the preconditioners.*
- struct [precond\\_data\\_str](#)  
*Data passed to the preconditioner for [dSTRmat](#) matrices.*
- struct [precond\\_diagstr](#)  
*Data passed to diagonal preconditioner for [dSTRmat](#) matrices.*
- struct [precond](#)  
*Preconditioner data and action.*
- struct [mxv\\_matfree](#)  
*Matrix-vector multiplication, replace the actual matrix.*
- struct [input\\_param](#)  
*Input parameters.*
- struct [itsolver\\_param](#)  
*Parameters passed to iterative solvers.*
- struct [grid2d](#)  
*Two dimensional grid data structure.*
- struct [Link](#)  
*Struct for Links.*
- struct [linked\\_list](#)  
*A linked list node.*

## Macros

- #define `__FASP_HEADER__`
- #define `FASP_USE_ILU` ON
  - For external software package support.*
- #define `DLMALLOC` OFF
- #define `NEDMALLOC` OFF
- #define `RS_C1` ON
  - Flags for internal uses (change with caution!!!)*
- #define `DIAGONAL_PREF` OFF
- #define `SHORT` short
  - FASP integer and floating point numbers.*
- #define `INT` int
- #define `LONG` long
- #define `LONGLONG` long long
- #define `REAL` double
- #define `BIGREAL` 1e+20
  - Some global constants.*
- #define `SMALLREAL` 1e-20
- #define `MAX_REFINE_LVL` 20
- #define `MAX_AMG_LVL` 20
- #define `MIN_CDOF` 20
- #define `STAG_RATIO` 1e-4
- #define `MAX_STAG` 20
- #define `MAX_RESTART` 20
- #define `OPENMP_HOLDS` 2000
- #define `MAX(a, b)` (((a)>(b))?(a):(b))
  - Definition of max, min, abs.*
- #define `MIN(a, b)` (((a)<(b))?(a):(b))
- #define `ABS(a)` (((a)>=0.0)?(a):- (a))
- #define `GT(a, b)` (((a)>(b))?(TRUE):(FALSE))
  - Definition of >, >=, <, <=, and isnan.*
- #define `GE(a, b)` (((a)>=(b))?(TRUE):(FALSE))
- #define `LS(a, b)` (((a)<(b))?(TRUE):(FALSE))
- #define `LE(a, b)` (((a)<=(b))?(TRUE):(FALSE))
- #define `ISNAN(a)` (((a) != (a))?(TRUE):(FALSE))
- #define `ISTART` 0
  - Index starting point: C convention or Fortran convention.*
- #define `N2C(ind)` ((ind)-ISTART)
- #define `C2N(ind)` ((ind)+ISTART)
- #define `FASP_GSRB` 1

## Typedefs

- typedef struct `ddenmat` `ddenmat`
- typedef struct `idenmat` `idenmat`
- typedef struct `dCSRmat` `dCSRmat`
- typedef struct `iCSRmat` `iCSRmat`
- typedef struct `dCOOmat` `dCOOmat`

- typedef struct [iCOOmat](#) iCOOmat
- typedef struct [dCSRLmat](#) dCSRLmat
- typedef struct [dSTRmat](#) dSTRmat
- typedef struct [dvector](#) dvector
- typedef struct [ivector](#) ivector
- typedef struct [grid2d](#) grid2d
- typedef [grid2d](#) \* [pgrid2d](#)
- typedef const [grid2d](#) \* [pcgrid2d](#)
- typedef struct [linked\\_list](#) ListElement
- typedef [ListElement](#) \* [LinkList](#)

## Variables

- unsigned [INT](#) [total\\_alloc\\_mem](#)
- unsigned [INT](#) [total\\_alloc\\_count](#)
- [INT](#) [nx\\_rb](#)
- [INT](#) [ny\\_rb](#)
- [INT](#) [nz\\_rb](#)
- [INT](#) \* [IMAP](#)
- [INT](#) [MAXIMAP](#)

### 9.27.1 Detailed Description

Main header file for FASP.

This header file contains general constants and data structures used in FASP.

#### Note

Only define macros and data structures, no function decorations.

Created by Chensong Zhang on 08/12/2010. Modified by Chensong Zhang on 12/13/2011.

Modified by Chensong Zhang on 12/25/2011.

Definition in file [fasp.h](#).

### 9.27.2 Macro Definition Documentation

#### 9.27.2.1 `#define __FASP_HEADER__`

indicate [fasp.h](#) has been included before

Definition at line 23 of file [fasp.h](#).

#### 9.27.2.2 `#define ABS( a ) (((a)>=0.0)?(a):- (a))`

absolute value of a

Definition at line 73 of file [fasp.h](#).

### 9.27.2.3 `#define BIGREAL 1e+20`

Some global constants.

A large real number

Definition at line 58 of file fasp.h.

### 9.27.2.4 `#define C2N( ind ) ((ind)+ISTART)`

map from C index 0,1,... to Natural index 1,2,...

Definition at line 89 of file fasp.h.

### 9.27.2.5 `#define DIAGONAL_PREF OFF`

order each row such that diagonal appears first

Definition at line 42 of file fasp.h.

### 9.27.2.6 `#define DLMALLOC OFF`

use dmalloc instead of standard malloc

Definition at line 33 of file fasp.h.

### 9.27.2.7 `#define FASP_GSRB 1`

MG level 0 use RedBlack Gauss Seidel Smoothing

Definition at line 1100 of file fasp.h.

### 9.27.2.8 `#define FASP_USE_ILU ON`

For external software package support.

enable ILU or not

Definition at line 32 of file fasp.h.

### 9.27.2.9 `#define GE( a, b ) (((a)>=(b))?(TRUE):(FALSE))`

is  $a \geq b$ ?

Definition at line 79 of file fasp.h.

### 9.27.2.10 `#define GT( a, b ) (((a)>(b))?(TRUE):(FALSE))`

Definition of  $>$ ,  $\geq$ ,  $<$ ,  $\leq$ , and `isnan`.

is  $a > b$ ?

Definition at line 78 of file fasp.h.

**9.27.2.11 #define INT int**

regular integer type: int or long

Definition at line 50 of file fasp.h.

**9.27.2.12 #define ISNAN( a ) (((a)!=a)?(TRUE):(FALSE))**

is a == NAN?

Definition at line 82 of file fasp.h.

**9.27.2.13 #define ISTART 0**

Index starting point: C convention or Fortran convention.

0 if in Natural index, 1 if data is in C index

Definition at line 87 of file fasp.h.

**9.27.2.14 #define LE( a, b ) (((a)<=(b))?(TRUE):(FALSE))**

is a <= b?

Definition at line 81 of file fasp.h.

**9.27.2.15 #define LONG long**

long integer type

Definition at line 51 of file fasp.h.

**9.27.2.16 #define LONGLONG long long**

long integer type

Definition at line 52 of file fasp.h.

**9.27.2.17 #define LS( a, b ) (((a)<(b))?(TRUE):(FALSE))**

is a < b?

Definition at line 80 of file fasp.h.

**9.27.2.18 #define MAX( a, b ) (((a)>(b))?(a):(b))**

Definition of max, min, abs.

bigger one in a and b

Definition at line 71 of file fasp.h.

**9.27.2.19 #define MAX\_AMG\_LVL 20**

Maximal AMG coarsening level  
Definition at line 61 of file fasp.h.

**9.27.2.20 #define MAX\_REFINE\_LVL 20**

Maximal refinement level  
Definition at line 60 of file fasp.h.

**9.27.2.21 #define MAX\_RESTART 20**

Maximal number of restarting  
Definition at line 65 of file fasp.h.

**9.27.2.22 #define MAX\_STAG 20**

Maximal number of stagnation times  
Definition at line 64 of file fasp.h.

**9.27.2.23 #define MIN( a, b ) (((a)<(b))?(a):(b))**

smaller one in a and b  
Definition at line 72 of file fasp.h.

**9.27.2.24 #define MIN\_CDOF 20**

Minimal number of coarsest variables  
Definition at line 62 of file fasp.h.

**9.27.2.25 #define N2C( ind ) ((ind)-ISTART)**

map from Natural index 1,2,... to C index 0,1,...  
Definition at line 88 of file fasp.h.

**9.27.2.26 #define NEDMALLOC OFF**

use nedmalloc instead of standard malloc  
Definition at line 34 of file fasp.h.

**9.27.2.27 #define OPENMP\_HOLDS 2000**

Switch to sequence version when size is small  
Definition at line 66 of file fasp.h.

**9.27.2.28 #define REAL double**

float type

Definition at line 53 of file fasp.h.

**9.27.2.29 #define RS\_C1 ON**

Flags for internal uses (change with caution!!!)

CF splitting of RS: check C1 Criterion

Definition at line 39 of file fasp.h.

**9.27.2.30 #define SHORT short**

FASP integer and floating point numbers.

short integer type

Definition at line 49 of file fasp.h.

**9.27.2.31 #define SMALLREAL 1e-20**

A small real number

Definition at line 59 of file fasp.h.

**9.27.2.32 #define STAG\_RATIO 1e-4**

Stagantion tolerance = tol\*STAGRATIO

Definition at line 63 of file fasp.h.

**9.27.3 Typedef Documentation****9.27.3.1 typedef struct dCOOmat dCOOmat**

Sparse matrix of REAL type in COO format

**9.27.3.2 typedef struct dCSRLmat dCSRLmat**

Sparse matrix of REAL type in CSRL format

**9.27.3.3 typedef struct dCSRmat dCSRmat**

Sparse matrix of REAL type in CSR format

**9.27.3.4 typedef struct ddenmat ddenmat**

Dense matrix of REAL type



#### 9.27.3.5 `typedef struct dSTRmat dSTRmat`

Structured matrix of REAL type

#### 9.27.3.6 `typedef struct dvector dvector`

Vector of REAL type

#### 9.27.3.7 `typedef struct grid2d grid2d`

2D grid type for plotting

#### 9.27.3.8 `typedef struct iCOOmat iCOOmat`

Sparse matrix of INT type in COO format

#### 9.27.3.9 `typedef struct iCSRmat iCSRmat`

Sparse matrix of INT type in CSR format

#### 9.27.3.10 `typedef struct idenmat idenmat`

Dense matrix of INT type

#### 9.27.3.11 `typedef struct ivector ivector`

Vector of INT type

#### 9.27.3.12 `typedef ListElement* LinkList`

List of linkslinked list

Definition at line 1095 of file fasp.h.

#### 9.27.3.13 `typedef struct linked_list ListElement`

Linked element in list

#### 9.27.3.14 `typedef const grid2d* pcgrid2d`

Grid in 2d

Definition at line 1049 of file fasp.h.

#### 9.27.3.15 `typedef grid2d* pgrid2d`

Grid in 2d

Definition at line 1047 of file fasp.h.

### 9.27.4 Variable Documentation

#### 9.27.4.1 `INT* IMAP`

Red Black Gs Smoother imap

#### 9.27.4.2 `INT MAXIMAP`

Red Black Gs Smoother max dofs of reservoir

#### 9.27.4.3 `INT nx_rb`

Red Black Gs Smoother Nx

#### 9.27.4.4 `INT ny_rb`

Red Black Gs Smoother Ny

#### 9.27.4.5 `INT nz_rb`

Red Black Gs Smoother Nz

#### 9.27.4.6 `unsigned INT total_alloc_count`

total allocation times

Definition at line 33 of file memory.c.

#### 9.27.4.7 `unsigned INT total_alloc_mem`

total allocated memory

Definition at line 32 of file memory.c.

## 9.28 `fasp_block.h` File Reference

Main header file for FASP (block matrices)

```
#include "fasp.h"
```

## Data Structures

- struct [dBSRmat](#)  
*Block sparse row storage matrix of REAL type.*
- struct [block\\_dCSRmat](#)  
*Block REAL CSR matrix format.*
- struct [block\\_iCSRmat](#)  
*Block INT CSR matrix format.*
- struct [block\\_dvector](#)  
*Block REAL vector structure.*
- struct [block\\_ivec](#)  
*Block INT vector structure.*
- struct [block\\_Reservoir](#)  
*Block REAL matrix format for reservoir simulation.*
- struct [block\\_BSR](#)  
*Block REAL matrix format for reservoir simulation.*
- struct [AMG\\_data\\_bsr](#)  
*Data for multigrid levels. (BSR format)*
- struct [precond\\_diagbsr](#)  
*Data passed to diagonal preconditioner for [dBSRmat](#) matrices.*
- struct [precond\\_data\\_bsr](#)  
*Data passed to the preconditioners.*
- struct [precond\\_block\\_reservoir\\_data](#)  
*Data passed to the preconditioner for preconditioning reservoir simulation problems.*
- struct [precond\\_block\\_data](#)  
*Data passed to the preconditioner for block preconditioning for [block\\_dCSRmat](#) format.*
- struct [precond\\_FASP\\_blkoi\\_data](#)  
*Data passed to the preconditioner for preconditioning reservoir simulation problems.*
- struct [precond\\_sweeping\\_data](#)  
*Data passed to the preconditioner for sweeping preconditioning.*

## Typedefs

- typedef struct [dBSRmat](#) [dBSRmat](#)
- typedef struct [block\\_dCSRmat](#) [block\\_dCSRmat](#)
- typedef struct [block\\_iCSRmat](#) [block\\_iCSRmat](#)
- typedef struct [block\\_dvector](#) [block\\_dvector](#)
- typedef struct [block\\_ivec](#) [block\\_ivec](#)
- typedef struct [block\\_Reservoir](#) [block\\_Reservoir](#)
- typedef struct [block\\_BSR](#) [block\\_BSR](#)
- typedef struct [precond\\_block\\_reservoir\\_data](#) [precond\\_block\\_reservoir\\_data](#)

### 9.28.1 Detailed Description

Main header file for FASP (block matrices)

#### Note

This header file contains definitions of block matrices, including grid-major type and variable-major type. In this header, we only define macros and data structures, not function decorations.

Created by Chensong Zhang on 05/21/2010. Modified by Xiaozhe Hu on 05/28/2010: add [precond\\_block↔reservoir\\_data](#). Modified by Xiaozhe Hu on 06/15/2010: modify [precond\\_block\\_reservoir\\_data](#). Modified by Chensong Zhang on 10/11/2010: add BSR data.

Modified by Chensong Zhang on 10/17/2012: modify comments.

Definition in file [fasp\\_block.h](#).

### 9.28.2 Typedef Documentation

#### 9.28.2.1 typedef struct **block\_BSR** **block\_BSR**

Block of BSR matrices of REAL type

#### 9.28.2.2 typedef struct **block\_dCSRmat** **block\_dCSRmat**

Matrix of REAL type in Block CSR format

#### 9.28.2.3 typedef struct **block\_dvector** **block\_dvector**

Vector of REAL type in Block format

#### 9.28.2.4 typedef struct **block\_iCSRmat** **block\_iCSRmat**

Matrix of INT type in Block CSR format

#### 9.28.2.5 typedef struct **block\_ivec** **block\_ivec**

Vector of INT type in Block format

#### 9.28.2.6 typedef struct **block\_Reservoir** **block\_Reservoir**

Special block matrix for Reservoir Simulation

#### 9.28.2.7 typedef struct **dBSRmat** **dBSRmat**

Matrix of REAL type in BSR format

#### 9.28.2.8 typedef struct **precond\_block\_reservoir\_data** **precond\_block\_reservoir\_data**

Precond data for Reservoir Simulation

## 9.29 fmgcycle.c File Reference

Abstract non-recursive full multigrid cycle.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "forts_ns.h"
#include "mg_util.inl"
```

### Functions

- void [fasp\\_solver\\_fmgcycle](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Solve  $Ax=b$  with non-recursive full multigrid K-cycle.*

#### 9.29.1 Detailed Description

Abstract non-recursive full multigrid cycle.

Definition in file [fmgcycle.c](#).

#### 9.29.2 Function Documentation

9.29.2.1 void [fasp\\_solver\\_fmgcycle](#) ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Solve  $Ax=b$  with non-recursive full multigrid K-cycle.

Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

Author

Chensong Zhang

Date

02/27/2011

Modified by Chensong Zhang on 06/01/2012: fix a bug when there is only one level. Modified by Chensong Zhang on 02/27/2013: update direct solvers.

Definition at line 34 of file fmgcycle.c.

## 9.30 formats.c File Reference

Matrix format conversion routines.

```
#include "fasp.h"
#include "fasp_block.h"
#include "fasp_functs.h"
```

## Functions

- [SHORT fasp\\_format\\_dcoo\\_dcsr](#) ([dCOOmat](#) \*A, [dCSRmat](#) \*B)  
*Transform a REAL matrix from its IJ format to its CSR format.*
- [SHORT fasp\\_format\\_dcsr\\_dcoo](#) ([dCSRmat](#) \*A, [dCOOmat](#) \*B)  
*Transform a REAL matrix from its CSR format to its IJ format.*
- [SHORT fasp\\_format\\_dstr\\_dcsr](#) ([dSTRmat](#) \*A, [dCSRmat](#) \*B)  
*Transfer a 'dSTRmat' type matrix into a 'dCSRmat' type matrix.*
- [dCSRmat fasp\\_format\\_bdcsr\\_dcsr](#) ([block\\_dCSRmat](#) \*Ab)  
*Form the whole dCSRmat A using blocks given in Ab.*
- [dCSRmat \\* fasp\\_format\\_dcsr\\_dcsr](#) ([dCSRmat](#) \*A)  
*Convert a dCSRmat into a dCSRmat.*
- [dCSRmat fasp\\_format\\_dbsr\\_dcsr](#) ([dBSRmat](#) \*B)  
*Transfer a 'dBSRmat' type matrix into a dCSRmat.*
- [dBSRmat fasp\\_format\\_dcsr\\_dbsr](#) ([dCSRmat](#) \*A, [INT](#) nb)  
*Transfer a dCSRmat type matrix into a dBSRmat.*
- [dBSRmat fasp\\_format\\_dstr\\_dbsr](#) ([dSTRmat](#) \*B)  
*Transfer a 'dSTRmat' type matrix to a 'dBSRmat' type matrix.*
- [dCOOmat \\* fasp\\_format\\_dbsr\\_dcoo](#) ([dBSRmat](#) \*B)  
*Transfer a 'dBSRmat' type matrix to a 'dCOOmat' type matrix.*

### 9.30.1 Detailed Description

Matrix format conversion routines.

Definition in file [formats.c](#).

### 9.30.2 Function Documentation

#### 9.30.2.1 [dCSRmat fasp\\_format\\_bdcsr\\_dcsr](#) ( [block\\_dCSRmat](#) \* Ab )

Form the whole [dCSRmat](#) A using blocks given in Ab.

Parameters

<a href="#">Ab</a>	Pointer to <a href="#">block_dCSRmat</a> matrix
--------------------	---

Returns

[dCSRmat](#) matrix if succeed, NULL if fail

Author

Shiquan Zhang

## Date

08/10/2010

Definition at line 293 of file formats.c.

**9.30.2.2 dCOOmat \* fasp\_format\_dbsr\_dcoo ( dBSRmat \* B )**

Transfer a 'dBSRmat' type matrix to a 'dCOOmat' type matrix.

## Parameters

<i>B</i>	Pointer to dBSRmat matrix
----------	---------------------------

## Returns

Pointer to dCOOmat matrix

## Author

Zhiyang Zhou

## Date

2010/10/26

Definition at line 944 of file formats.c.

**9.30.2.3 dCSRmat fasp\_format\_dbsr\_dcsr ( dBSRmat \* B )**

Transfer a 'dBSRmat' type matrix into a dCSRmat.

## Parameters

<i>B</i>	Pointer to dBSRmat matrix
----------	---------------------------

## Returns

dCSRmat matrix

## Author

Zhiyang Zhou

## Date

10/23/2010

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/24/2012

## Note

Works for general nb (Xiaozhe)

Definition at line 496 of file formats.c.

#### 9.30.2.4 **SHORT** fasp\_format\_dcoo\_dcsr ( dCOOmat \* *A*, dCSRmat \* *B* )

Transform a REAL matrix from its IJ format to its CSR format.



## Parameters

<i>A</i>	Pointer to <a href="#">dCOOmat</a> matrix
<i>B</i>	Pointer to <a href="#">dCSRmat</a> matrix

## Returns

FASP\_SUCCESS if succeed

## Author

Xuehai Huang

## Date

08/10/2009

Definition at line 28 of file formats.c.

#### 9.30.2.5 [dBSRmat](#) fasp\_format\_dcsr\_dbsr ( [dCSRmat](#) \* *A*, INT *nb* )

Transfer a [dCSRmat](#) type matrix into a [dBSRmat](#).

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> type matrix
<i>nb</i>	size of each block

## Returns

[dBSRmat](#) matrix

## Author

Zheng Li

## Date

03/27/2014

## Note

modified by Xiaozhe Hu to avoid potential memory leakage problem

Definition at line 722 of file formats.c.

#### 9.30.2.6 [SHORT](#) fasp\_format\_dcsr\_dcoo ( [dCSRmat](#) \* *A*, [dCOOmat](#) \* *B* )

Transform a REAL matrix from its CSR format to its IJ format.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix
<i>B</i>	Pointer to <a href="#">dCOOmat</a> matrix

## Returns

FASP\_SUCCESS if succeed

## Author

Xuehai Huang

## Date

08/10/2009

Modified by Chunsheng Feng, Zheng Li

## Date

10/12/2012

Definition at line 81 of file formats.c.

### 9.30.2.7 [dCSRLmat](#) \* fasp\_format\_dcsr ( [dCSRmat](#) \* *A* )

Convert a [dCSRmat](#) into a [dCSRLmat](#).

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRLmat</a> matrix
----------	--

## Returns

Pointer to [dCSRLmat](#) matrix

## Author

Zhiyang Zhou

## Date

2011/01/07

Definition at line 362 of file formats.c.

### 9.30.2.8 [dBSRmat](#) fasp\_format\_dstr\_dbsr ( [dSTRmat](#) \* *B* )

Transfer a '[dSTRmat](#)' type matrix to a '[dBSRmat](#)' type matrix.

## Parameters

$B$	Pointer to <a href="#">dSTRmat</a> matrix
-----	---

## Returns

[dBSRmat](#) matrix

## Author

Zhiyang Zhou

## Date

2010/10/26

Definition at line 840 of file formats.c.

### 9.30.2.9 SHORT fasp\_format\_dstr\_dcsr ( [dSTRmat](#) \* $A$ , [dCSRmat](#) \* $B$ )

Transfer a '[dSTRmat](#)' type matrix into a '[dCSRmat](#)' type matrix.

## Parameters

$A$	Pointer to <a href="#">dSTRmat</a> matrix
$B$	Pointer to <a href="#">dCSRmat</a> matrix

## Returns

FASP\_SUCCESS if succeed

## Author

Zhiyang Zhou

## Date

2010/04/29

Definition at line 118 of file formats.c.

## 9.31 givens.c File Reference

Givens transformation.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_aux\\_givens](#) (const [REAL](#) beta, [dCSRmat](#) \* $H$ , [dvector](#) \* $y$ , [REAL](#) \*tmp)  
Perform Givens rotations to compute  $y \mid \beta e_1 - H * y$ .

### 9.31.1 Detailed Description

Givens transformation.

Definition in file [givens.c](#).

### 9.31.2 Function Documentation

9.31.2.1 `void fasp_aux_givens ( const REAL beta, dCSRmat * H, dvector * y, REAL * tmp )`

Perform Givens rotations to compute  $y \sqrt{beta * e_1 - H * y}$ .

Parameters

<i>beta</i>	Norm of residual <i>r_0</i>
<i>H</i>	( <i>m</i> +1)* <i>m</i> upper Hessenberg <a href="#">dCSRmat</a> matrix
<i>y</i>	Minimizer of $\sqrt{beta * e_1 - H * y}$
<i>tmp</i>	Temporary work array

Author

Xuehai Huang

Date

10/19/2008

Definition at line 28 of file [givens.c](#).

## 9.32 gmg\_poisson.c File Reference

GMG method as an iterative solver for Poisson Problem.

```
#include <time.h>
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "gmg_util.inl"
```

### Functions

- `INT fasp_poisson_gmg_1D (REAL *u, REAL *b, INT nx, INT maxlevel, REAL rtol, const SHORT prtvl)`  
*Solve  $Ax=b$  of Poisson 1D equation by Geometric Multigrid Method.*
- `INT fasp_poisson_gmg_2D (REAL *u, REAL *b, INT nx, INT ny, INT maxlevel, REAL rtol, const SHORT prtvl)`  
*Solve  $Ax=b$  of Poisson 2D equation by Geometric Multigrid Method.*
- `INT fasp_poisson_gmg_3D (REAL *u, REAL *b, INT nx, INT ny, INT nz, INT maxlevel, REAL rtol, const SHORT prtvl)`  
*Solve  $Ax=b$  of Poisson 3D equation by Geometric Multigrid Method.*
- `void fasp_poisson_fgmg_1D (REAL *u, REAL *b, INT nx, INT maxlevel, REAL rtol, const SHORT prtvl)`  
*Solve  $Ax=b$  of Poisson 1D equation by Geometric Multigrid Method (Full Multigrid)*

- void `fasp_poisson_fgmg_2D` (REAL \*u, REAL \*b, INT nx, INT ny, INT maxlevel, REAL rtol, const SHORT prtlvl)  
*Solve  $Ax=b$  of Poisson 2D equation by Geometric Multigrid Method (Full Multigrid)*
- void `fasp_poisson_fgmg_3D` (REAL \*u, REAL \*b, INT nx, INT ny, INT nz, INT maxlevel, REAL rtol, const SHORT prtlvl)  
*Solve  $Ax=b$  of Poisson 3D equation by Geometric Multigrid Method (Full Multigrid)*
- INT `fasp_poisson_pcg_gmg_1D` (REAL \*u, REAL \*b, INT nx, INT maxlevel, REAL rtol, const SHORT prtlvl)  
*Solve  $Ax=b$  of Poisson 1D equation by Geometric Multigrid Method (GMG preconditioned Conjugate Gradient method)*
- INT `fasp_poisson_pcg_gmg_2D` (REAL \*u, REAL \*b, INT nx, INT ny, INT maxlevel, REAL rtol, const SHORT prtlvl)  
*Solve  $Ax=b$  of Poisson 2D equation by Geometric Multigrid Method (GMG preconditioned Conjugate Gradient method)*
- INT `fasp_poisson_pcg_gmg_3D` (REAL \*u, REAL \*b, INT nx, INT ny, INT nz, INT maxlevel, REAL rtol, const SHORT prtlvl)  
*Solve  $Ax=b$  of Poisson 3D equation by Geometric Multigrid Method (GMG preconditioned Conjugate Gradient method)*

### 9.32.1 Detailed Description

GMG method as an iterative solver for Poisson Problem.

Definition in file [gmg\\_poisson.c](#).

### 9.32.2 Function Documentation

9.32.2.1 void `fasp_poisson_fgmg_1D` ( REAL \* u, REAL \* b, INT nx, INT maxlevel, REAL rtol, const SHORT prtlvl )

Solve  $Ax=b$  of Poisson 1D equation by Geometric Multigrid Method (Full Multigrid)

Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

Author

Ziteng Wang

Date

06/07/2013

Definition at line 417 of file `gmg_poisson.c`.

9.32.2.2 void `fasp_poisson_fgmg_2D` ( REAL \* u, REAL \* b, INT nx, INT ny, INT maxlevel, REAL rtol, const SHORT prtlvl )

Solve  $Ax=b$  of Poisson 2D equation by Geometric Multigrid Method (Full Multigrid)

## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>ny</i>	Number of grids in Y direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 509 of file gmg\_poisson.c.

9.32.2.3 void fasp\_poisson\_fgmg\_3D ( REAL \* *u*, REAL \* *b*, INT *nx*, INT *ny*, INT *nz*, INT *maxlevel*, REAL *rtol*, const SHORT *prtlvl* )

Solve  $Ax=b$  of Poisson 3D equation by Geometric Multigrid Method (Full Multigrid)

## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>ny</i>	NUmber of grids in y direction
<i>nz</i>	NUmber of grids in z direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 616 of file gmg\_poisson.c.

9.32.2.4 INT fasp\_poisson\_gmg\_1D ( REAL \* *u*, REAL \* *b*, INT *nx*, INT *maxlevel*, REAL *rtol*, const SHORT *prtlvl* )

Solve  $Ax=b$  of Poisson 1D equation by Geometric Multigrid Method.

## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 34 of file gmg\_poisson.c.

9.32.2.5 **INT** fasp\_poisson\_gmg\_2D ( **REAL** \* *u*, **REAL** \* *b*, **INT** *nx*, **INT** *ny*, **INT** *maxlevel*, **REAL** *rtol*, **const SHORT** *prtlvl* )

Solve  $Ax=b$  of Poisson 2D equation by Geometric Multigrid Method.

## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>ny</i>	Number of grids in y direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 154 of file gmg\_poisson.c.

9.32.2.6 **INT** fasp\_poisson\_gmg\_3D ( **REAL** \* *u*, **REAL** \* *b*, **INT** *nx*, **INT** *ny*, **INT** *nz*, **INT** *maxlevel*, **REAL** *rtol*, **const SHORT** *prtlvl* )

Solve  $Ax=b$  of Poisson 3D equation by Geometric Multigrid Method.

## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>ny</i>	Number of grids in y direction
<i>nz</i>	Number of grids in z direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 285 of file gmg\_poisson.c.

9.32.2.7 **INT fasp\_poisson\_pcg\_gmg\_1D** ( **REAL \* *u***, **REAL \* *b***, **INT *nx***, **INT *maxlevel***, **REAL *rtol***, **const SHORT *prtlvl*** )

Solve  $Ax=b$  of Poisson 1D equation by Geometric Multigrid Method (GMG preconditioned Conjugate Gradient method)

## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 723 of file gmg\_poisson.c.

9.32.2.8 **INT fasp\_poisson\_pcg\_gmg\_2D** ( **REAL \* *u***, **REAL \* *b***, **INT *nx***, **INT *ny***, **INT *maxlevel***, **REAL *rtol***, **const SHORT *prtlvl*** )

Solve  $Ax=b$  of Poisson 2D equation by Geometric Multigrid Method (GMG preconditioned Conjugate Gradient method)



## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>ny</i>	Number of grids in y direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 813 of file gmg\_poisson.c.

9.32.2.9 INT fasp\_poisson\_pcg\_gmg\_3D ( REAL \* *u*, REAL \* *b*, INT *nx*, INT *ny*, INT *nz*, INT *maxlevel*, REAL *rtol*, const SHORT *prtlvl* )

Solve  $Ax=b$  of Poisson 3D equation by Geometric Multigrid Method (GMG preconditioned Conjugate Gradient method)

## Parameters

<i>u</i>	Pointer to the vector of dofs
<i>b</i>	Pointer to the vector of right hand side
<i>nx</i>	Number of grids in x direction
<i>ny</i>	Number of grids in y direction
<i>nz</i>	Number of grids in z direction
<i>maxlevel</i>	Maximum levels of the multigrid
<i>rtol</i>	Relative tolerance to judge convergence
<i>prtlvl</i>	Print level for output

## Author

Ziteng Wang

## Date

06/07/2013

Definition at line 918 of file gmg\_poisson.c.

## 9.33 gmg\_util.inl File Reference

Routines for GMG solvers.

### 9.33.1 Detailed Description

Routines for GMG solvers.

Definition in file [gmg\\_util.inl](#).

## 9.34 graphics.c File Reference

Functions for graphical output.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_dcsr\\_subplot](#) (const [dCSRmat](#) \*A, const char \*filename, [INT](#) size)  
*Write sparse matrix pattern in BMP file format.*
- void [fasp\\_dbsr\\_subplot](#) (const [dBSRmat](#) \*A, const char \*filename, [INT](#) size)  
*Write sparse matrix pattern in BMP file format.*
- void [fasp\\_grid2d\\_plot](#) ([pgrid2d](#) pg, [INT](#) level)  
*Output grid to a EPS file.*
- [INT](#) [fasp\\_dbsr\\_plot](#) (const [dBSRmat](#) \*A, const char \*fname)  
*Write dBSR sparse matrix pattern in BMP file format.*
- [INT](#) [fasp\\_dcsr\\_plot](#) (const [dCSRmat](#) \*A, const char \*fname)

### 9.34.1 Detailed Description

Functions for graphical output.

Definition in file [graphics.c](#).

### 9.34.2 Function Documentation

#### 9.34.2.1 void [fasp\\_dbsr\\_plot](#) ( const [dBSRmat](#) \* A, const char \* *filename* )

Write dBSR sparse matrix pattern in BMP file format.

Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>filename</i>	File name

Author

Chunsheng Feng

## Date

11/16/2013

## Note

The routine `fasp_dbsr_plot` writes pattern of the specified `dBSRmat` matrix in uncompressed BMP file format (Windows bitmap) to a binary file whose name is specified by the character string `filename`.

Each pixel corresponds to one matrix element. The pixel colors have the following meaning:

White structurally zero element Black zero element Blue positive element Red negative element Brown nearly zero element

Definition at line 463 of file `graphics.c`.

**9.34.2.2** `void fasp_dbsr_subplot ( const dBSRmat * A, const char * filename, INT size )`

Write sparse matrix pattern in BMP file format.

## Parameters

<i>A</i>	Pointer to the <code>dBSRmat</code> matrix
<i>filename</i>	File name
<i>size</i>	<code>size*size</code> is the picture size for the picture

## Author

Chunsheng Feng

## Date

11/16/2013

## Note

The routine `fasp_dbsr_subplot` writes pattern of the specified `dBSRmat` matrix in uncompressed BMP file format (Windows bitmap) to a binary file whose name is specified by the character string `filename`.

Each pixel corresponds to one matrix element. The pixel colors have the following meaning:

White structurally zero element Black zero element Blue positive element Red negative element Brown nearly zero element

Definition at line 105 of file `graphics.c`.

**9.34.2.3** `void fasp_dcsr_subplot ( const dCSRmat * A, const char * filename, INT size )`

Write sparse matrix pattern in BMP file format.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
<i>filename</i>	File name
<i>size</i>	size*size is the picture size for the picture

**Author**

Chensong Zhang

**Date**

03/29/2009

**Note**

The routine `fasp_dcsr_subplot` writes pattern of the specified [dCSRmat](#) matrix in uncompressed BMP file format (Windows bitmap) to a binary file whose name is specified by the character string `filename`.

Each pixel corresponds to one matrix element. The pixel colors have the following meaning:

White structurally zero element Blue positive element Red negative element Brown nearly zero element

Definition at line 44 of file `graphics.c`.

#### 9.34.2.4 void `fasp_grid2d_plot` ( `pgrid2d pg`, `INT level` )

Output grid to a EPS file.

**Parameters**

<i>pg</i>	Pointer to grid in 2d
<i>level</i>	Number of levels

**Author**

Chensong Zhang

**Date**

03/29/2009

Definition at line 172 of file `graphics.c`.

## 9.35 ilu.f File Reference

ILU routines for preconditioning adapted from SPARSEKIT.

**Functions/Subroutines**

- subroutine **iluk** (`n`, `a`, `ja`, `ia`, `lfil`, `alu`, `jlu`, `iwk`, `ierr`, `nzlu`)
- subroutine **ilut** (`n`, `a`, `ja`, `ia`, `lfil`, `droptol`, `alu`, `jlu`, `iwk`, `ierr`, `nz`)
- subroutine **ilutp** (`n`, `a`, `ja`, `ia`, `lfil`, `droptol`, `permtol`, `mbloc`, `alu`, `jlu`, `iwk`, `ierr`, `nz`)
- subroutine **srtr** (`num`, `q`)
- subroutine **qsplrit** (`a`, `ind`, `n`, `ncut`)
- subroutine **symbfactor** (`n`, `colind`, `rwptr`, `levfill`, `nzmax`, `nzlu`, `ijlu`, `uptr`, `ierr`)

### 9.35.1 Detailed Description

ILU routines for preconditioning adapted from SPARSEKIT.

#### Note

Incomplete Factorization Methods: ILUk, ILUt, ILUtp

Definition in file [ilu.f](#).

## 9.36 ilu\_setup\_bsr.c File Reference

Setup Incomplete LU decomposition for [dBSRmat](#) matrices.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void **symbfactor\_** (const [INT](#) \*n, [INT](#) \*colind, [INT](#) \*rowptr, const [INT](#) \*levfill, const [INT](#) \*nzmax, [INT](#) \*nzlu, [INT](#) \*ijlu, [INT](#) \*uptr, [INT](#) \*ierr)
- [SHORT](#) **fasp\_ilu\_dbsr\_setup** ([dBSRmat](#) \*A, [ILU\\_data](#) \*iludata, [ILU\\_param](#) \*iluparam)

*Get ILU decoposition of a BSR matrix A.*

### 9.36.1 Detailed Description

Setup Incomplete LU decomposition for [dBSRmat](#) matrices.

Definition in file [ilu\\_setup\\_bsr.c](#).

### 9.36.2 Function Documentation

#### 9.36.2.1 [SHORT](#) fasp\_ilu\_dbsr\_setup ( [dBSRmat](#) \* A, [ILU\\_data](#) \* *iludata*, [ILU\\_param](#) \* *iluparam* )

Get ILU decoposition of a BSR matrix A.

#### Parameters

<i>A</i>	Pointer to <a href="#">dBSRmat</a> matrix
<i>iludata</i>	Pointer to <a href="#">ILU_data</a>
<i>iluparam</i>	Pointer to <a href="#">ILU_param</a>

#### Author

Shiquan Zhang, Xiaozhe Hu

**Date**

11/08/2010

**Note**

Works for general nb (Xiaozhe)

Definition at line 42 of file `ilu_setup_bsr.c`.

## 9.37 `ilu_setup_csr.c` File Reference

Setup of ILU decomposition for [dCSRmat](#) matrices.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void `iluk_` (const [INT](#) \*n, [REAL](#) \*a, [INT](#) \*ja, [INT](#) \*ia, [INT](#) \*lfil, [REAL](#) \*alu, [INT](#) \*jlu, [INT](#) \*iwk, [INT](#) \*ierr, [INT](#) \*nzlu)
- void `ilut_` (const [INT](#) \*n, [REAL](#) \*a, [INT](#) \*ja, [INT](#) \*ia, [INT](#) \*lfil, const [REAL](#) \*droptol, [REAL](#) \*alu, [INT](#) \*jlu, [INT](#) \*iwk, [INT](#) \*ierr, [INT](#) \*nz)
- void `ilutp_` (const [INT](#) \*n, [REAL](#) \*a, [INT](#) \*ja, [INT](#) \*ia, [INT](#) \*lfil, const [REAL](#) \*droptol, const [REAL](#) \*permtol, const [INT](#) \*mbloc, [REAL](#) \*alu, [INT](#) \*jlu, [INT](#) \*iwk, [INT](#) \*ierr, [INT](#) \*nz)
- [SHORT](#) `fasp_ilu_dcsr_setup` ([dCSRmat](#) \*A, [ILU\\_data](#) \*iludata, [ILU\\_param](#) \*iluparam)

*Get ILU decoposition of a CSR matrix A.*

### 9.37.1 Detailed Description

Setup of ILU decomposition for [dCSRmat](#) matrices.Definition in file [ilu\\_setup\\_csr.c](#).

### 9.37.2 Function Documentation

#### 9.37.2.1 [SHORT](#) `fasp_ilu_dcsr_setup` ( [dCSRmat](#) \* A, [ILU\\_data](#) \* *iludata*, [ILU\\_param](#) \* *iluparam* )

Get ILU decoposition of a CSR matrix A.

**Parameters**

<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix
<i>iludata</i>	Pointer to <a href="#">ILU_data</a>
<i>iluparam</i>	Pointer to <a href="#">ILU_param</a>

**Author**

Shiquan Zhang

## Date

12/27/2009

Definition at line 48 of file ilu\_setup\_csr.c.

## 9.38 ilu\_setup\_str.c File Reference

Setup of ILU decomposition for [dSTRmat](#) matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_ilu\\_dstr\\_setup0](#) ([dSTRmat](#) \*A, [dSTRmat](#) \*LU)  
*Get ILU(0) decomposition of a structured matrix A.*
- void [fasp\\_ilu\\_dstr\\_setup1](#) ([dSTRmat](#) \*A, [dSTRmat](#) \*LU)  
*Get ILU(1) decomposition of a structured matrix A.*

### 9.38.1 Detailed Description

Setup of ILU decomposition for [dSTRmat](#) matrices.Definition in file [ilu\\_setup\\_str.c](#).

### 9.38.2 Function Documentation

#### 9.38.2.1 void [fasp\\_ilu\\_dstr\\_setup0](#) ( [dSTRmat](#) \* A, [dSTRmat](#) \* LU )

Get ILU(0) decomposition of a structured matrix A.

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a>
<i>LU</i>	Pointer to ILU structured matrix of REAL type

## Author

Shiquan Zhang, Xiaozhe Hu

## Date

11/08/2010

## Note

Only works for 5 bands 2D and 7 bands 3D matrix with default offsets (order can be arbitrary)!

Definition at line 28 of file ilu\_setup\_str.c.

9.38.2.2 void fasp\_ilu\_dstr\_setup1 ( dSTRmat \* *A*, dSTRmat \* *LU* )

Get ILU(1) decoposition of a structured matrix *A*.



## Parameters

<i>A</i>	Pointer to original structured matrix of REAL type
<i>LU</i>	Pointer to ILU structured matrix of REAL type

## Author

Shiquan Zhang, Xiaozhe Hu

## Date

11/08/2010

## Note

put L and U in a STR matrix and it has the following structure: the diag is d, the offdiag of L are alpha1 to alpha6, the offdiag of U are beta1 to beta6

Only works for 5 bands 2D and 7 bands 3D matrix with default offsets

Definition at line 319 of file `ilu_setup_str.c`.

## 9.39 init.c File Reference

Initialize important data structures.

```
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void `fasp_precond_data_null` (`precond_data` \*pcdata)  
*Initialize `precond_data`.*
- `AMG_data` \* `fasp_amg_data_create` (`SHORT` max\_levels)  
*Create and initialize `AMG_data` for classical and SA AMG.*
- `AMG_data_bsr` \* `fasp_amg_data_bsr_create` (`SHORT` max\_levels)  
*Create and initialize `AMG_data` data structure for AMG/SAMG (BSR format)*
- void `fasp_ilu_data_alloc` (`INT` iwk, `INT` nwork, `ILU_data` \*iludata)  
*Allocate workspace for ILU factorization.*
- void `fasp_schwarz_data_free` (`Schwarz_data` \*schwarz)  
*Free `Schwarz_data` data memory space.*
- void `fasp_amg_data_free` (`AMG_data` \*mgl, `AMG_param` \*param)  
*Free `AMG_data` data memory space.*
- void `fasp_amg_data_bsr_free` (`AMG_data_bsr` \*mgl)  
*Free `AMG_data_bsr` data memory space.*
- void `fasp_ilu_data_free` (`ILU_data` \*iludata)  
*Create `ILU_data` structure.*
- void `fasp_ilu_data_null` (`ILU_data` \*iludata)  
*Initialize ILU data.*
- void `fasp_precond_null` (`precond` \*pcdata)  
*Initialize precondition data.*

### 9.39.1 Detailed Description

Initialize important data structures.

#### Note

Every structures should be initialized before usage.

Definition in file [init.c](#).

### 9.39.2 Function Documentation

#### 9.39.2.1 `AMG_data_bsr * fasp_amg_data_bsr_create ( SHORT max_levels )`

Create and initialize [AMG\\_data](#) data sturcture for AMG/SAMG (BSR format)

##### Parameters

<i>max_levels</i>	Max number of levels allowed
-------------------	------------------------------

##### Returns

Pointer to the [AMG\\_data](#) data structure

##### Author

Xiaozhe Hu

##### Date

08/07/2011

Definition at line 85 of file `init.c`.

#### 9.39.2.2 `void fasp_amg_data_bsr_free ( AMG_data_bsr * mgl )`

Free [AMG\\_data\\_bsr](#) data memeory space.

##### Parameters

<i>mgl</i>	Pointer to the <a href="#">AMG_data_bsr</a>
------------	---

##### Author

Xiaozhe Hu

##### Date

2013/02/13

Definition at line 219 of file `init.c`.

#### 9.39.2.3 `AMG_data * fasp_amg_data_create ( SHORT max_levels )`

Create and initialize [AMG\\_data](#) for classical and SA AMG.

## Parameters

<i>max_levels</i>	Max number of levels allowed
-------------------	------------------------------

## Returns

Pointer to the [AMG\\_data](#) data structure

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 56 of file init.c.

9.39.2.4 void fasp\_amg\_data\_free ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Free [AMG\\_data](#) data memeory space.

## Parameters

<i>mgl</i>	Pointer to the <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters

## Author

Chensong Zhang

## Date

2010/04/06

Modified by Chensong Zhang on 05/05/2013: Clean up param as well!

Definition at line 171 of file init.c.

9.39.2.5 void fasp\_ilu\_data\_alloc ( INT *iwk*, INT *nwork*, [ILU\\_data](#) \* *iludata* )

Allocate workspace for ILU factorization.

## Parameters

<i>iwk</i>	Size of the index array
<i>nwork</i>	Size of the work array
<i>iludata</i>	Pointer to the <a href="#">ILU_data</a>

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 116 of file init.c.

#### 9.39.2.6 void fasp\_ilu\_data\_free ( ILU\_data \* ILUdata )

Create [ILU\\_data](#) sturcture.

##### Parameters

<i>ILUdata</i>	Pointer to <a href="#">ILU_data</a>
----------------	-------------------------------------

##### Author

Chensong Zhang

##### Date

2010/04/03

Definition at line 264 of file init.c.

#### 9.39.2.7 void fasp\_ilu\_data\_null ( ILU\_data \* ILUdata )

Initialize ILU data.

##### Parameters

<i>ILUdata</i>	Pointer to <a href="#">ILU_data</a>
----------------	-------------------------------------

##### Author

Chensong Zhang

##### Date

2010/03/23

Definition at line 285 of file init.c.

#### 9.39.2.8 void fasp\_precond\_data\_null ( precondition\_data \* pcddata )

Initialize [precond\\_data](#).

##### Parameters

<i>pcdata</i>	Preconditioning data structure
---------------	--------------------------------

##### Author

Chensong Zhang

##### Date

2010/03/23

Definition at line 25 of file init.c.

#### 9.39.2.9 void fasp\_precond\_null ( precondition \* pcddata )

Initialize precondition data.

## Parameters

<i>pcdata</i>	Pointer to precondition
---------------	-------------------------

## Author

Chensong Zhang

## Date

2010/03/23

Definition at line 301 of file init.c.

9.39.2.10 void fasp\_schwarz\_data\_free ( Schwarz\_data \* schwarz )

Free Schwarz\_data data memory space.

## Parameters

*schwarz	pointer to the AMG_data data
----------	------------------------------

## Author

Xiaozhe Hu

## Date

2010/04/06

Definition at line 142 of file init.c.

## 9.40 input.c File Reference

Read input parameters.

```
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- [SHORT fasp\\_param\\_check](#) (input\_param \*inparam)  
*Simple check on input parameters.*
- void [fasp\\_param\\_input](#) (const char \*filenm, input\_param \*inparam)  
*Read input parameters from disk file.*

### 9.40.1 Detailed Description

Read input parameters.

Definition in file [input.c](#).

### 9.40.2 Function Documentation

#### 9.40.2.1 **SHORT** fasp\_param\_check ( input\_param \* inparam )

Simple check on input parameters.

##### Parameters

<i>inparam</i>	Input parameters
----------------	------------------

##### Author

Chensong Zhang

##### Date

09/29/2013

Definition at line 23 of file input.c.

#### 9.40.2.2 **void** fasp\_param\_input ( const char \* *filenm*, input\_param \* *inparam* )

Read input parameters from disk file.

##### Parameters

<i>filenm</i>	File name for input file
<i>inparam</i>	Input parameters

##### Author

Chensong Zhang

##### Date

03/20/2010

Modified by Xiaozhe Hu on 01/23/2011: add AMLI cycle Modified by Chensong Zhang on 01/10/2012 Modified by Ludmil Zikatanov on 02/15/2013 Modified by Chensong Zhang on 05/10/2013: add a new input.

Definition at line 98 of file input.c.

## 9.41 interface\_mumps.c File Reference

Interface to MUMPS direct solvers.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- int [fasp\\_solver\\_mumps](#) ([dCSRmat](#) \*ptrA, [dvector](#) \*b, [dvector](#) \*u, const int print\_level)  
*Solve  $Ax=b$  by MUMPS directly.*
- int [fasp\\_solver\\_mumps\\_steps](#) ([dCSRmat](#) \*ptrA, [dvector](#) \*b, [dvector](#) \*u, const int job)  
*Solve  $Ax=b$  by MUMPS in three steps.*

### 9.41.1 Detailed Description

Interface to MUMPS direct solvers.

Definition in file [interface\\_mumps.c](#).

### 9.41.2 Function Documentation

9.41.2.1 int [fasp\\_solver\\_mumps](#) ( [dCSRmat](#) \* *ptrA*, [dvector](#) \* *b*, [dvector](#) \* *u*, const int *print\_level* )

Solve  $Ax=b$  by MUMPS directly.

Parameters

<i>ptrA</i>	Pointer to a <a href="#">dCSRmat</a> matrix
<i>b</i>	Pointer to the dvector of right-hand side term
<i>u</i>	Pointer to the dvector of solution
<i>print_level</i>	Output level

Author

Chunsheng Feng

Date

02/27/2013

Modified by Chensong Zhang on 02/27/2013 for new FASP function names.

Definition at line 35 of file [interface\\_mumps.c](#).

9.41.2.2 int [fasp\\_solver\\_mumps\\_steps](#) ( [dCSRmat](#) \* *ptrA*, [dvector](#) \* *b*, [dvector](#) \* *u*, const int *job* )

Solve  $Ax=b$  by MUMPS in three steps.

Parameters

<i>ptrA</i>	Pointer to a <a href="#">dCSRmat</a> matrix
<i>b</i>	Pointer to the dvector of right-hand side term
<i>u</i>	Pointer to the dvector of solution
<i>job</i>	1: Setup, 2: Solve, 3 Destroy

Author

Chunsheng Feng

## Date

02/27/2013

Modified by Chensong Zhang on 02/27/2013 for new FASP function names.

Definition at line 161 of file interface\_mumps.c.

## 9.42 interface\_samg.c File Reference

Interface to SAMG.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [dvector2SAMGInput](#) ([dvector](#) \*vec, char \*filename)  
*Write a dvector to disk file in SAMG format (coordinate format)*
- [INT dCSRmat2SAMGInput](#) ([dCSRmat](#) \*A, char \*filefrm, char \*fileamg)  
*Write SAMG Input data from a sparse matrix of CSR format.*

### 9.42.1 Detailed Description

Interface to SAMG.

Add reference for SAMG by K. Stuben here!

Definition in file [interface\\_samg.c](#).

### 9.42.2 Function Documentation

#### 9.42.2.1 [INT dCSRmat2SAMGInput](#) ( [dCSRmat](#) \* A, char \* filefrm, char \* fileamg )

Write SAMG Input data from a sparse matrix of CSR format.

#### Parameters

*A	pointer to the <a href="#">dCSRmat</a> matrix
*filefrm	pointer to the name of the .frm file
*fileamg	pointer to the name of the .amg file

#### Author

Zhiyang Zhou

#### Date

2010/08/25

Definition at line 56 of file interface\_samg.c.



## 9.42.2.2 void dvector2SAMGInput ( dvector \* vec, char \* filename )

Write a dvector to disk file in SAMG format (coordinate format)

Parameters

<i>*vec</i>	pointer to the dvector
<i>*filename</i>	char for vector file name

Author

Zhiyang Zhou

Date

08/25/2010

Definition at line 27 of file interface\_samg.c.

## 9.43 interface\_superlu.c File Reference

Interface to SuperLU direct solvers.

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- int [fasp\\_solver\\_superlu](#) (dCSRmat \*ptrA, dvector \*b, dvector \*u, const int print\_level)  
*Solve  $Au=b$  by SuperLU.*

#### 9.43.1 Detailed Description

Interface to SuperLU direct solvers.

Definition in file [interface\\_superlu.c](#).

#### 9.43.2 Function Documentation

##### 9.43.2.1 int fasp\_solver\_superlu ( dCSRmat \* ptrA, dvector \* b, dvector \* u, const int print\_level )

Solve  $Au=b$  by SuperLU.

**Parameters**

<i>ptrA</i>	Pointer to a <a href="#">dCSRmat</a> matrix
<i>b</i>	Pointer to the dvector of right-hand side term
<i>u</i>	Pointer to the dvector of solution
<i>print_level</i>	Output level

**Author**

Xiaozhe Hu

**Date**

11/05/09

Modified by Chensong Zhang on 11/01/2012 for new FASP function names. Modified by Chensong Zhang on 02/27/2013 for new FASP function names.

Definition at line 39 of file `interface_superlu.c`.

**9.44 interface\_umfpack.c File Reference**

Interface to UMFPACK direct solvers.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

**Functions**

- [INT fasp\\_solver\\_umfpack](#) ([dCSRmat](#) \*ptrA, [dvector](#) \*b, [dvector](#) \*u, const [INT](#) print\_level)  
*Solve  $Au=b$  by UMFPack.*

**9.44.1 Detailed Description**

Interface to UMFPACK direct solvers.

Definition in file [interface\\_umfpack.c](#).

**9.44.2 Function Documentation**

**9.44.2.1** [INT fasp\\_solver\\_umfpack](#) ( [dCSRmat](#) \* ptrA, [dvector](#) \* b, [dvector](#) \* u, const [INT](#) print\_level )

Solve  $Au=b$  by UMFPack.

**Parameters**

<i>ptrA</i>	Pointer to a <a href="#">dCSRmat</a> matrix
<i>b</i>	Pointer to the dvector of right-hand side term
<i>u</i>	Pointer to the dvector of solution
<i>print_level</i>	Output level

**Author**

Chensong Zhang

**Date**

05/20/2010

Modified by Chensong Zhang on 02/27/2013 for new FASP function names.

Definition at line 34 of file `interface_umfpack.c`.

## 9.45 interpolation.c File Reference

Interpolation operators for AMG.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

**Functions**

- void [fasp\\_amg\\_interp](#) ([dCSRmat](#) \*A, [ivector](#) \*vertices, [dCSRmat](#) \*P, [iCSRmat](#) \*S, [AMG\\_param](#) \*param)  
*Generate interpolation operator P.*
- void [fasp\\_amg\\_interp1](#) ([dCSRmat](#) \*A, [ivector](#) \*vertices, [dCSRmat](#) \*P, [AMG\\_param](#) \*param, [iCSRmat](#) \*S, [INT](#) \*icor\_ysk)  
*Generate interpolation operator P.*
- void [fasp\\_amg\\_interp\\_trunc](#) ([dCSRmat](#) \*P, [AMG\\_param](#) \*param)  
*Truncation step for prolongation operators.*

### 9.45.1 Detailed Description

Interpolation operators for AMG.

**Note**

Ref U. Trottenberg, C. W. Oosterlee, and A. Schuller Multigrid (Appendix A: An Intro to Algebraic Multigrid) Academic Press Inc., San Diego, CA, 2001 With contributions by A. Brandt, P. Oswald and K. Stuben.

Definition in file [interpolation.c](#).

### 9.45.2 Function Documentation

9.45.2.1 void fasp\_amg\_interp ( dCSRmat \* *A*, ivector \* *vertices*, dCSRmat \* *P*, iCSRmat \* *S*, AMG\_param \* *param* )

Generate interpolation operator *P*.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix (index starts from 0)
<i>vertices</i>	Indicator vector for the C/F splitting of the variables
<i>P</i>	Prolongation (input: nonzero pattern, output: prolongation)
<i>S</i>	Strong connection matrix
<i>param</i>	AMG parameters

## Author

Xuehai Huang, Chensong Zhang

## Date

04/04/2010

Modified by Xiaozhe Hu on 05/23/2012: add S as input Modified by Chensong Zhang on 09/12/2012: clean up and debug interp\_RS Modified by Chensong Zhang on 05/14/2013: reconstruct the code

Definition at line 48 of file interpolation.c.

9.45.2.2 void fasp\_amg\_interp1 ( dCSRmat \* *A*, ivector \* *vertices*, dCSRmat \* *P*, AMG\_param \* *param*, iCSRmat \* *S*, INT \* *icor\_ysk* )

Generate interpolation operator P.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix (index starts from 0)
<i>vertices</i>	Indicator vector for the C/F splitting of the variables
<i>P</i>	Prolongation (input: nonzero pattern, output: prolongation)
<i>S</i>	Strong connection matrix
<i>param</i>	AMG parameters
<i>icor_ysk</i>	Indices of coarse nodes in fine grid

## Returns

FASP\_SUCCESS or error message

## Author

Chunsheng Feng, Xiaoqiang Yue

## Date

03/01/2011

Modified by Chensong Zhang on 05/14/2013: reconstruct the code

Definition at line 105 of file interpolation.c.

9.45.2.3 void fasp\_amg\_interp\_trunc ( dCSRmat \* *P*, AMG\_param \* *param* )

Truncation step for prolongation operators.

## Parameters

<i>P</i>	Prolongation (input: full, output: truncated)
<i>param</i>	Pointer to <a href="#">AMG_param</a> : AMG parameters

## Author

Chensong Zhang

## Date

05/14/2013

Originally by Xuehai Huang, Chensong Zhang on 01/31/2009 Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012: add OMP support Modified by Chensong Zhang on 05/14/2013: rewritten

Definition at line 159 of file interpolation.c.

## 9.46 interpolation\_em.c File Reference

Interpolation operators for AMG based on energy-min.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_amg\\_interp\\_em](#) ([dCSRmat](#) \*A, [ivector](#) \*vertices, [dCSRmat](#) \*P, [AMG\\_param](#) \*param)  
*Energy-min interpolation.*

#### 9.46.1 Detailed Description

Interpolation operators for AMG based on energy-min.

##### Note

Ref J. Xu and L. Zikatanov "On An Energy Minimizing Basis in Algebraic Multigrid Methods" Computing and visualization in sciences, 2003

Definition in file [interpolation\\_em.c](#).

#### 9.46.2 Function Documentation

9.46.2.1 void [fasp\\_amg\\_interp\\_em](#) ( [dCSRmat](#) \* A, [ivector](#) \* vertices, [dCSRmat](#) \* P, [AMG\\_param](#) \* param )

Energy-min interpolation.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix (index starts from 0)
<i>vertices</i>	Pointer to the indicator of CF splitting on fine or coarse grid
<i>P</i>	Pointer to the <a href="#">dCSRmat</a> matrix of resulted interpolation
<i>param</i>	Pointer to <a href="#">AMG_param</a> : AMG parameters

## Author

Shuo Zhang, Xuehai Huang

## Date

04/04/2010

Modified by Chunsheng Feng, Zheng Li on 10/17/2012: add OMP support Modified by Chensong Zhang on 05/14/2013: reconstruct the code

Definition at line 49 of file interpolation\_em.c.

## 9.47 io.c File Reference

Matrix-vector input/output subroutines.

```
#include "fasp.h"
#include "fasp_functs.h"
#include "hb_io.h"
```

## Functions

- void [fasp\\_dcsrvec1\\_read](#) (const char \*filename, [dCSRmat](#) \*A, [dvector](#) \*b)  
*Read A and b from a SINGLE disk file.*
- void [fasp\\_dcsrvec2\\_read](#) (const char \*filemat, const char \*filerhs, [dCSRmat](#) \*A, [dvector](#) \*b)  
*Read A and b from two disk files.*
- void [fasp\\_dcsr\\_read](#) (const char \*filename, [dCSRmat](#) \*A)  
*Read A from matrix disk file in IJ format.*
- void [fasp\\_dcoo\\_read](#) (const char \*filename, [dCSRmat](#) \*A)  
*Read A from matrix disk file in IJ format – indices starting from 0.*
- void [fasp\\_dcoo1\\_read](#) (const char \*filename, [dCOOmat](#) \*A)  
*Read A from matrix disk file in IJ format – indices starting from 0.*
- void [fasp\\_dcoo\\_shift\\_read](#) (const char \*filename, [dCSRmat](#) \*A)  
*Read A from matrix disk file in IJ format – indices starting from 0.*
- void [fasp\\_dmtx\\_read](#) (const char \*filename, [dCSRmat](#) \*A)  
*Read A from matrix disk file in MatrixMarket general format.*
- void [fasp\\_dmtxsym\\_read](#) (const char \*filename, [dCSRmat](#) \*A)  
*Read A from matrix disk file in MatrixMarket sym format.*
- void [fasp\\_dstr\\_read](#) (const char \*filename, [dSTRmat](#) \*A)  
*Read A from a disk file in dSTRmat format.*
- void [fasp\\_dbsr\\_read](#) (const char \*filename, [dBSRmat](#) \*A)

- Read A from a disk file in dBSRmat format.*

  - void `fasp_dvecind_read` (const char \*filename, `dvector` \*b)
- Read b from matrix disk file.*

  - void `fasp_dvec_read` (const char \*filename, `dvector` \*b)
- Read b from a disk file in array format.*

  - void `fasp_ivecind_read` (const char \*filename, `ivector` \*b)
- Read b from matrix disk file.*

  - void `fasp_ivec_read` (const char \*filename, `ivector` \*b)
- Read b from a disk file in array format.*

  - void `fasp_dcsrvec1_write` (const char \*filename, `dCSRmat` \*A, `dvector` \*b)
- Write A and b to a SINGLE disk file.*

  - void `fasp_dcsrvec2_write` (const char \*filemat, const char \*filerhs, `dCSRmat` \*A, `dvector` \*b)
- Write A and b to two disk files.*

  - void `fasp_dcoo_write` (const char \*filename, `dCSRmat` \*A)
- Write a matrix to disk file in IJ format (coordinate format)*

  - void `fasp_dstr_write` (const char \*filename, `dSTRmat` \*A)
- Write a dSTRmat to a disk file.*

  - void `fasp_dbsr_write` (const char \*filename, `dBSRmat` \*A)
- Write a dBSRmat to a disk file.*

  - void `fasp_dvec_write` (const char \*filename, `dvector` \*vec)
- Write a dvector to disk file.*

  - void `fasp_dvecind_write` (const char \*filename, `dvector` \*vec)
- Write a dvector to disk file in coordinate format.*

  - void `fasp_ivec_write` (const char \*filename, `ivector` \*vec)
- Write a ivector to disk file in coordinate format.*

  - void `fasp_dvec_print` (INT n, `dvector` \*u)
- Print first n entries of a vector of REAL type.*

  - void `fasp_ivec_print` (INT n, `ivector` \*u)
- Print first n entries of a vector of INT type.*

  - void `fasp_dcsr_print` (`dCSRmat` \*A)
- Print out a dCSRmat matrix in coordinate format.*

  - void `fasp_dcoo_print` (`dCOOmat` \*A)
- Print out a dCOOmat matrix in coordinate format.*

  - void `fasp_dbsr_print` (`dBSRmat` \*A)
- Print out a dBSRmat matrix in coordinate format.*

  - void `fasp_dbsr_write_coo` (const char \*filename, const `dBSRmat` \*A)
- Print out a dBSRmat matrix in coordinate format for matlab spy.*

  - void `fasp_dcsr_write_coo` (const char \*filename, const `dCSRmat` \*A)
- Print out a dCSRmat matrix in coordinate format for matlab spy.*

  - void `fasp_dstr_print` (`dSTRmat` \*A)
- Print out a dSTRmat matrix in coordinate format.*

  - void `fasp_matrix_read` (const char \*filename, void \*A)
- Read matrix from different kinds of formats from both ASCII and binary files.*

  - void `fasp_matrix_read_bin` (const char \*filename, void \*A)
- Read matrix in binary format.*

  - void `fasp_matrix_write` (const char \*filename, void \*A, INT flag)
- write matrix from different kinds of formats from both ASCII and binary files*



- void [fasp\\_vector\\_read](#) (const char \*filerhs, void \*b)  
*Read RHS vector from different kinds of formats from both ASCII and binary files.*
- void [fasp\\_vector\\_write](#) (const char \*filerhs, void \*b, [INT](#) flag)  
*write RHS vector from different kinds of formats in both ASCII and binary files*
- void [fasp\\_hb\\_read](#) (char \*input\_file, [dCSRmat](#) \*A, [dvector](#) \*b)  
*Read matrix and right-hans side from a HB format file.*

## Variables

- [INT](#) ilength
- [INT](#) dlength

### 9.47.1 Detailed Description

Matrix-vector input/output subroutines.

#### Note

Read, write or print a matrix or a vector in various formats.

Definition in file [io.c](#).

### 9.47.2 Function Documentation

#### 9.47.2.1 void [fasp\\_dbsr\\_print](#) ( [dBSRmat](#) \* A )

Print out a [dBSRmat](#) matrix in coordinate format.

#### Parameters

<a href="#">A</a>	Pointer to the <a href="#">dBSRmat</a> matrix A
-------------------	---

#### Author

Ziteng Wang

#### Date

12/24/2012

Modified by Chunsheng Feng

#### Date

11/16/2013

Definition at line 1443 of file [io.c](#).

#### 9.47.2.2 void [fasp\\_dbsr\\_read](#) ( const char \* *filename*, [dBSRmat](#) \* A )

Read A from a disk file in [dBSRmat](#) format.

## Parameters

<i>filename</i>	File name for matrix A
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> A

## Note

This routine reads a [dBSRmat](#) matrix from a disk file in the following format:  
File format:

- ROW, COL, NNZ
- nb: size of each block
- storage\_manner: storage manner of each block
- ROW+1: length of IA
- IA(i), i=0:ROW
- NNZ: length of JA
- JA(i), i=0:NNZ-1
- NNZ\*nb\*nb: length of val
- val(i), i=0:NNZ\*nb\*nb-1

## Author

Xiaozhe Hu

## Date

10/29/2010

Definition at line 691 of file io.c.

9.47.2.3 void fasp\_dbsr\_write ( const char \* *filename*, [dBSRmat](#) \* *A* )

Write a [dBSRmat](#) to a disk file.

## Parameters

<i>filename</i>	File name for A
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix A

## Note

The routine writes the specified REAL vector in BSR format.  
Refer to the reading subroutine \ref fasp\_dbsr\_read.

## Author

Shiquan Zhang

## Date

10/29/2010

Definition at line 1202 of file io.c.

9.47.2.4 void fasp\_dbsr\_write\_coo ( const char \* *filename*, const dBSRmat \* *A* )

Print out a dBSRmat matrix in coordinate format for matlab spy.

## Parameters

<i>filename</i>	Name of file to write to
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix <i>A</i>

## Author

Chunsheng Feng

## Date

11/14/2013

Modified by Chensong Zhang on 06/14/2014: Fix index problem.

Definition at line 1480 of file io.c.

9.47.2.5 void fasp\_dcoo1\_read ( const char \* *filename*, dCOOmat \* *A* )

Read *A* from matrix disk file in IJ format – indices starting from 0.

## Parameters

<i>filename</i>	File name for matrix
<i>A</i>	Pointer to the COO matrix

## Note

File format:

- nrow ncol nnz % number of rows, number of columns, and nnz
- i j a\_ij % i, j a\_ij in each line

difference between fasp\_dcoo\_read and this function is this function do not change to CSR format

## Author

Xiaozhe Hu

## Date

03/24/2013

Definition at line 369 of file io.c.

9.47.2.6 void fasp\_dcoo\_print ( dCOOmat \* *A* )

Print out a [dCOOmat](#) matrix in coordinate format.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCOOmat</a> matrix <i>A</i>
----------	--

**Author**

Ziteng Wang

**Date**

12/24/2012

Definition at line 1421 of file io.c.

**9.47.2.7** `void fasp_dcoo_read ( const char * filename, dCSRmat * A )`

Read *A* from matrix disk file in IJ format – indices starting from 0.

**Parameters**

<i>filename</i>	File name for matrix
<i>A</i>	Pointer to the CSR matrix

**Note**

File format:

- *nrow ncol nnz* % number of rows, number of columns, and nnz
- *i j a\_ij* % *i*, *j* *a\_ij* in each line

After reading, it converts the matrix to [dCSRmat](#) format.

**Author**

Xuehai Huang, Chensong Zhang

**Date**

03/29/2009

Definition at line 318 of file io.c.

**9.47.2.8** `void fasp_dcoo_shift_read ( const char * filename, dCSRmat * A )`

Read *A* from matrix disk file in IJ format – indices starting from 0.

**Parameters**

<i>filename</i>	File name for matrix
<i>A</i>	Pointer to the CSR matrix

**Note**

File format:

- nrow ncol nnz % number of rows, number of columns, and nnz
- i j a\_ij % i, j a\_ij in each line

i and j suppose to start with index 1!!!

After read in, it shifts the index to C fashin and converts the matrix to [dCSRmat](#) format.

**Author**

Xiaozhe Hu

**Date**

04/01/2014

Definition at line 420 of file io.c.

**9.47.2.9 void fasp\_dcoo\_write ( const char \* filename, dCSRmat \* A )**

Write a matrix to disk file in IJ format (coordinate format)

**Parameters**

<i>A</i>	pointer to the <a href="#">dCSRmat</a> matrix
<i>filename</i>	char for vector file name

**Note**

The routine writes the specified REAL vector in COO format.  
Refer to the reading subroutine \ref fasp\_dcoo\_read.

File format:

- The first line of the file gives the number of rows, the number of columns, and the number of nonzeros.
- Then gives nonzero values in i j a(i,j) format.

**Author**

Chensong Zhang

**Date**

03/29/2009

Definition at line 1102 of file io.c.

**9.47.2.10 void fasp\_dcsr\_print ( dCSRmat \* A )**

Print out a [dCSRmat](#) matrix in coordinate format.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix <i>A</i>
----------	--

## Author

Xuehai Huang

## Date

03/29/2009

Definition at line 1399 of file io.c.

9.47.2.11 void fasp\_dcsr\_read ( const char \* *filename*, dCSRmat \* *A* )

Read *A* from matrix disk file in IJ format.

## Parameters

<i>*filename</i>	char for matrix file name
<i>*A</i>	pointer to the CSR matrix

## Author

Ziteng Wang

## Date

12/25/2012

Definition at line 257 of file io.c.

9.47.2.12 void fasp\_dcsr\_write\_coo ( const char \* *filename*, const dCSRmat \* *A* )

Print out a [dCSRmat](#) matrix in coordinate format for matlab spy.

## Parameters

<i>filename</i>	Name of file to write to
<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix <i>A</i>

## Author

Chunsheng Feng

## Date

11/14/2013

Definition at line 1529 of file io.c.

9.47.2.13 void fasp\_dcsrvec1\_read ( const char \* *filename*, dCSRmat \* *A*, dvector \* *b* )

Read *A* and *b* from a SINGLE disk file.

## Parameters

<i>filename</i>	File name
<i>A</i>	Pointer to the CSR matrix
<i>b</i>	Pointer to the dvector

## Note

This routine reads a **dCSRmat** matrix and a dvector vector from a single disk file.

The difference between this and `fasp_dcoovec_read` is that this routine support non-square matrices.

File format:

- `nrow ncol` % number of rows and number of columns
- `ia(j), j=0:nrow` % row index
- `ja(j), j=0:nnz-1` % column index
- `a(j), j=0:nnz-1` % entry value
- `n` % number of entries
- `b(j), j=0:n-1` % entry value

## Author

Xuehai Huang

## Date

03/29/2009

Modified by Chensong Zhang on 03/14/2012

Definition at line 86 of file `io.c`.

9.47.2.14 `void fasp_dcsrvec1_write ( const char * filename, dCSRmat * A, dvector * b )`

Write *A* and *b* to a SINGLE disk file.

## Parameters

<i>filename</i>	File name
<i>A</i>	Pointer to the CSR matrix
<i>b</i>	Pointer to the dvector

## Note

This routine writes a **dCSRmat** matrix and a dvector vector to a single disk file.

File format:

- `nrow ncol` % number of rows and number of columns
- `ia(j), j=0:nrow` % row index
- `ja(j), j=0:nnz-1` % column index
- `a(j), j=0:nnz-1` % entry value
- `n` % number of entries
- `b(j), j=0:n-1` % entry value



**Author**

Feiteng Huang

**Date**

05/19/2012

Modified by Chensong on 12/26/2012

Definition at line 953 of file io.c.

9.47.2.15 void fasp\_dcsrvec2\_read ( const char \* *filemat*, const char \* *filerhs*, dCSRmat \* *A*, dvector \* *b* )

Read A and b from two disk files.

**Parameters**

<i>filemat</i>	File name for matrix
<i>filerhs</i>	File name for right-hand side
<i>A</i>	Pointer to the dCSR matrix
<i>b</i>	Pointer to the dvector

**Note**

This routine reads a dCSRmat matrix and a dvector vector from a disk file.

CSR matrix file format:

- nrow % number of columns (rows)
- ia(j), j=0:nrow % row index
- ja(j), j=0:nnz-1 % column index
- a(j), j=0:nnz-1 % entry value

RHS file format:

- n % number of entries
- b(j), j=0:nrow-1 % entry value

Indices start from 1, NOT 0!!!

**Author**

Zhiyang Zhou

**Date**

2010/08/06

Modified by Chensong Zhang on 2011/03/01 Modified by Chensong Zhang on 2012/01/05

Definition at line 178 of file io.c.

9.47.2.16 void fasp\_dcsrvec2\_write ( const char \* *filemat*, const char \* *filerhs*, dCSRmat \* *A*, dvector \* *b* )

Write A and b to two disk files.

## Parameters

<i>filemat</i>	File name for matrix
<i>filerhs</i>	File name for right-hand side
<i>A</i>	Pointer to the dCSR matrix
<i>b</i>	Pointer to the dvector

## Note

This routine writes a dCSRmat matrix and a dvector vector to two disk files.

CSR matrix file format:

- nrow % number of columns (rows)
- ia(j), j=0:nrow % row index
- ja(j), j=0:nnz-1 % column index
- a(j), j=0:nnz-1 % entry value

RHS file format:

- n % number of entries
- b(j), j=0:nrow-1 % entry value

Indices start from 1, NOT 0!!!

## Author

Feiteng Huang

## Date

05/19/2012

Definition at line 1031 of file io.c.

9.47.2.17 void fasp\_dmtx\_read ( const char \* *filename*, dCSRmat \* *A* )

Read *A* from matrix disk file in MatrixMarket general format.

## Parameters

<i>filename</i>	File name for matrix
<i>A</i>	Pointer to the CSR matrix

## Note

File format: This routine reads a MatrixMarket general matrix from a mtx file. And it converts the matrix to dCS↵  
Rmat format. For details of mtx format, please refer to <http://math.nist.gov/MatrixMarket/>.

Indices start from 1, NOT 0!!!

## Author

Chensong Zhang

## Date

09/05/2011

Definition at line 472 of file io.c.

9.47.2.18 void fasp\_dmtxsym\_read ( const char \* *filename*, dCSRmat \* *A* )

Read A from matrix disk file in MatrixMarket sym format.

## Parameters

<i>filename</i>	File name for matrix
<i>A</i>	Pointer to the CSR matrix

## Note

File format: This routine reads a MatrixMarket symmetric matrix from a mtx file. And it converts the matrix to **dCSRmat** format. For details of mtx format, please refer to <http://math.nist.gov/MatrixMarket/>.

Indices start from 1, NOT 0!!!

## Author

Chensong Zhang

## Date

09/02/2011

Definition at line 534 of file io.c.

9.47.2.19 void fasp\_dstr\_print ( **dSTRmat** \* *A* )

Print out a **dSTRmat** matrix in coordinate format.

## Parameters

<i>A</i>	Pointer to the <b>dSTRmat</b> matrix <i>A</i>
----------	---

## Author

Ziteng Wang

## Date

12/24/2012

Definition at line 1569 of file io.c.

9.47.2.20 void fasp\_dstr\_read ( const char \* *filename*, **dSTRmat** \* *A* )

Read *A* from a disk file in **dSTRmat** format.

## Parameters

<i>filename</i>	File name for the matrix
<i>A</i>	Pointer to the <b>dSTRmat</b>

**Note**

This routine reads a [dSTRmat](#) matrix from a disk file. After done, it converts the matrix to [dCSRmat](#) format.  
File format:

- nx, ny, nz
- nc: number of components
- nband: number of bands
- n: size of diagonal, you must have diagonal
- diag(j), j=0:n-1
- offset, length: offset and length of off-diag1
- offdiag(j), j=0:length-1

**Author**

Xuehai Huang

**Date**

03/29/2009

Definition at line 611 of file io.c.

**9.47.2.21** void fasp\_dstr\_write ( const char \* *filename*, dSTRmat \* *A* )

Write a [dSTRmat](#) to a disk file.

**Parameters**

<i>filename</i>	File name for A
<i>A</i>	Pointer to the <a href="#">dSTRmat</a> matrix A

**Note**

The routine writes the specified REAL vector in STR format.  
Refer to the reading subroutine \ref fasp\_dstr\_read.

**Author**

Shiquan Zhang

**Date**

03/29/2010

Definition at line 1142 of file io.c.

**9.47.2.22** void fasp\_dvec\_print ( INT *n*, dvector \* *u* )

Print first n entries of a vector of REAL type.

## Parameters

<i>n</i>	An interger (if n=0, then print all entries)
<i>u</i>	Pointer to a dvector

## Author

Chensong Zhang

## Date

03/29/2009

Definition at line 1360 of file io.c.

9.47.2.23 void fasp\_dvec\_read ( const char \* *filename*, dvector \* *b* )

Read b from a disk file in array format.

## Parameters

<i>filename</i>	File name for vector b
<i>b</i>	Pointer to the dvector b (output)

## Note

File Format:

- nrow
- val\_j, j=0:nrow-1

## Author

Chensong Zhang

## Date

03/29/2009

Definition at line 810 of file io.c.

9.47.2.24 void fasp\_dvec\_write ( const char \* *filename*, dvector \* *vec* )

Write a dvector to disk file.

## Parameters

<i>vec</i>	Pointer to the dvector
<i>filename</i>	File name

## Author

Xuehai Huang

## Date

03/29/2009

Definition at line 1257 of file io.c.

9.47.2.25 void fasp\_dvecind\_read ( const char \* *filename*, dvector \* *b* )

Read *b* from matrix disk file.

Parameters

<i>filename</i>	File name for vector <i>b</i>
<i>b</i>	Pointer to the dvector <i>b</i> (output)

Note

File Format:

- *nrow*
- *ind\_j*, *val\_j*, *j*=0:*nrow*-1

Because the index is given, order is not important!

Author

Chensong Zhang

Date

03/29/2009

Definition at line 760 of file io.c.

9.47.2.26 void fasp\_dvecind\_write ( const char \* *filename*, dvector \* *vec* )

Write a dvector to disk file in coordinate format.

Parameters

<i>vec</i>	Pointer to the dvector
<i>filename</i>	File name

Note

The routine writes the specified REAL vector in IJ format.

- The first line of the file is the length of the vector;
- After that, each line gives index and value of the entries.

Author

Xuehai Huang

Date

03/29/2009

Definition at line 1293 of file io.c.

9.47.2.27 fasp\_hb\_read ( char \* *input\_file*, dCSRmat \* *A*, dvector \* *b* )

Read matrix and right-hans side from a HB format file.

## Parameters

<i>input_file</i>	File name of vector file
<i>A</i>	Pointer to the matrix
<i>b</i>	Pointer to the vector

## Note

Modified from the c code hb\_io\_prb.c by John Burkardt

## Author

Xiaoehe Hu

## Date

05/30/2014

Definition at line 2060 of file io.c.

**9.47.2.28** void fasp\_ivec\_print ( INT *n*, ivector \* *u* )

Print first *n* entries of a vector of INT type.

## Parameters

<i>n</i>	An interger (if <i>n</i> =0, then print all entries)
<i>u</i>	Pointer to an ivector

## Author

Chensong Zhang

## Date

03/29/2009

Definition at line 1380 of file io.c.

**9.47.2.29** void fasp\_ivec\_read ( const char \* *filename*, ivector \* *b* )

Read *b* from a disk file in array format.

## Parameters

<i>filename</i>	File name for vector <i>b</i>
<i>b</i>	Pointer to the dvector <i>b</i> (output)

## Note

File Format:

- *nrow*
- *val\_j*, *j*=0:*nrow*-1



## Author

Xuehai Huang

## Date

03/29/2009

Definition at line 902 of file io.c.

**9.47.2.30 void fasp\_ivec\_write ( const char \* *filename*, ivector \* *vec* )**

Write a ivector to disk file in coordinate format.

## Parameters

<i>vec</i>	Pointer to the dvector
<i>filename</i>	File name

## Note

The routine writes the specified INT vector in IJ format.

- The first line of the file is the length of the vector;
- After that, each line gives index and value of the entries.

## Author

Xuehai Huang

## Date

03/29/2009

Definition at line 1328 of file io.c.

**9.47.2.31 void fasp\_ivecind\_read ( const char \* *filename*, ivector \* *b* )**

Read b from matrix disk file.

## Parameters

<i>filename</i>	File name for vector b
<i>b</i>	Pointer to the dvector b (output)

## Note

File Format:

- nrow
- ind\_j, val\_j ... j=0:nrow-1

## Author

Chensong Zhang

## Date

03/29/2009

Definition at line 862 of file io.c.

**9.47.2.32 fasp\_matrix\_read ( const char \* *filemat*, void \* *A* )**

Read matrix from different kinds of formats from both ASCII and binary files.

**Parameters**

<i>filemat</i>	File name of matrix file
<i>A</i>	Pointer to the matrix

**Note**

Flags for matrix file format:

- fileflag % fileflag = 1: binary, fileflag = 0000: ASCII
- formatflag % a 3-digit number for internal use, see below
- matrix % different types of matrix

Meaning of formatflag:

- matrixflag % first digit of formatflag
  - matrixflag = 1: CSR format
  - matrixflag = 2: BSR format
  - matrixflag = 3: STR format
  - matrixflag = 4: COO format
  - matrixflag = 5: MTX format
  - matrixflag = 6: MTX symmetrical format
- ilength % third digit of formatflag, length of INT
- dlength % fourth digit of formatflag, length of REAL

**Author**

Ziteng Wang

**Date**

12/24/2012

Modified by Chensong Zhang on 05/01/2013

Definition at line 1603 of file io.c.

**9.47.2.33 void fasp\_matrix\_read\_bin ( const char \* *filemat*, void \* *A* )**

Read matrix in binary format.

## Parameters

<i>filemat</i>	File name of matrix file
<i>A</i>	Pointer to the matrix

## Author

Xiaozhe Hu

## Date

04/14/2013

Modified by Chensong Zhang on 05/01/2013: Use it to read binary files!!!

Definition at line 1708 of file io.c.

9.47.2.34 fasp\_matrix\_write ( const char \* *filemat*, void \* *A*, INT *flag* )

write matrix from different kinds of formats from both ASCII and binary files

## Parameters

<i>filemat</i>	File name of matrix file
<i>A</i>	Pointer to the matrix
<i>flag</i>	Type of file and matrix, a 3-digit number

## Note

Meaning of flag:

- fileflag % fileflag = 1: binary, fileflag = 0: ASCII
- matrixflag
  - matrixflag = 1: CSR format
  - matrixflag = 2: BSR format
  - matrixflag = 3: STR format

Matrix file format:

- fileflag % fileflag = 1: binary, fileflag = 0000: ASCII
- formatflag % a 3-digit number
- matrixflag % different kinds of matrix judged by formatflag

## Author

Ziteng Wang

## Date

12/24/2012

Definition at line 1782 of file io.c.

9.47.2.35 fasp\_vector\_read ( const char \* *filerhs*, void \* *b* )

Read RHS vector from different kinds of formats from both ASCII and binary files.

## Parameters

<i>filerhs</i>	File name of vector file
<i>b</i>	Pointer to the vector

## Note

Matrix file format:

- fileflag % fileflag = 1: binary, fileflag = 0000: ASCII
- formatflag % a 3-digit number
- vector % different kinds of vector judged by formatflag

Meaning of formatflag:

- vectorflag % first digit of formatflag
  - vectorflag = 1: dvec format
  - vectorflag = 2: ivec format
  - vectorflag = 3: dvecind format
  - vectorflag = 4: ivecind format
- ilength % second digit of formatflag, length of INT
- dlength % third digit of formatflag, length of REAL

## Author

Ziteng Wang

## Date

12/24/2012

Definition at line 1875 of file io.c.

9.47.2.36 `fasp_vector_write ( const char * filerhs, void * b, INT flag )`

write RHS vector from different kinds of formats in both ASCII and binary files

## Parameters

<i>filerhs</i>	File name of vector file
<i>b</i>	Pointer to the vector
<i>flag</i>	Type of file and vector, a 2-digit number

## Note

Meaning of the flags

- fileflag % fileflag = 1: binary, fileflag = 0: ASCII
- vectorflag
  - vectorflag = 1: dvec format
  - vectorflag = 2: ivec format
  - vectorflag = 3: dvecind format
  - vectorflag = 4: ivecind format

Matrix file format:

- fileflag % fileflag = 1: binary, fileflag = 0000: ASCII
- formatflag % a 2-digit number
- vectorflag % different kinds of vector judged by formatflag

Author

Ziteng Wang

Date

12/24/2012

Modified by Chensong Zhang on 05/02/2013: fix a bug when writing in binary format

Definition at line 1972 of file io.c.

### 9.47.3 Variable Documentation

#### 9.47.3.1 INT dlength

Length of REAL in byte

Definition at line 14 of file io.c.

#### 9.47.3.2 INT ilength

Length of INT in byte

Definition at line 13 of file io.c.

## 9.48 itsolver\_bcsr.c File Reference

Iterative solvers for [block\\_dCSRmat](#) matrices.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_block.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_bdcsr\\_itsolver](#) ([block\\_dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax = b$  by standard Krylov methods.*
- [INT fasp\\_solver\\_bdcsr\\_krylov](#) ([block\\_dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax = b$  by standard Krylov methods.*

- `INT fasp_solver_bdcsl_krylov_block_3` (`block_dCSRmat *A`, `dvector *b`, `dvector *x`, `itsolver_param *itparam`, `AMG_param *amgparam`, `dCSRmat *A_diag`)
- `INT fasp_solver_bdcsl_krylov_block_4` (`block_dCSRmat *A`, `dvector *b`, `dvector *x`, `itsolver_param *itparam`, `AMG_param *amgparam`, `dCSRmat *A_diag`)
- `INT fasp_solver_bdcsl_krylov_sweeping` (`block_dCSRmat *A`, `dvector *b`, `dvector *x`, `itsolver_param *itparam`, `INT NumLayers`, `block_dCSRmat *Ai`, `dCSRmat *local_A`, `ivector *local_index`)

*Solve  $Ax = b$  by standard Krylov methods.*

### 9.48.1 Detailed Description

Iterative solvers for `block_dCSRmat` matrices.

Definition in file `itsolver_bcsr.c`.

### 9.48.2 Function Documentation

9.48.2.1 `INT fasp_solver_bdcsl_itsolver ( block_dCSRmat * A, dvector * b, dvector * x, precondition * pc, itsolver_param * itparam )`

Solve  $Ax = b$  by standard Krylov methods.

Parameters

<code>A</code>	Pointer to the coeff matrix in <code>block_dCSRmat</code> format
<code>b</code>	Pointer to the right hand side in <code>dvector</code> format
<code>x</code>	Pointer to the approx solution in <code>dvector</code> format
<code>pc</code>	Pointer to the preconditioning action
<code>itparam</code>	Pointer to parameters for iterative solvers

Returns

Number of iterations if succeed

Author

Chensong Zhang

Date

11/25/2010

Definition at line 35 of file `itsolver_bcsr.c`.

9.48.2.2 `INT fasp_solver_bdcsl_krylov ( block_dCSRmat * A, dvector * b, dvector * x, itsolver_param * itparam )`

Solve  $Ax = b$  by standard Krylov methods.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">block_dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

## Returns

Number of iterations if succeed

## Author

Xiaozhe Hu

## Date

07/18/2010

Definition at line 123 of file itsolver\_bcsr.c.

**9.48.2.3** `INT fasp_solver_bdcsv_krylov_sweeping ( block_dCSRmat * A, dvector * b, dvector * x, itsolver_param * itparam, INT NumLayers, block_dCSRmat * Ai, dCSRmat * local_A, ivector * local_index )`

Solve  $Ax = b$  by standard Krylov methods.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">block_dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>NumLayers</i>	Number of layers used for sweeping preconditioner
<i>Ai</i>	Pointer to the coeff matrix for the preconditioner in <a href="#">block_dCSRmat</a> format
<i>local_A</i>	Pointer to the local coeff matrices in the <a href="#">dCSRmat</a> format
<i>local_index</i>	Pointer to the local index in ivector format

## Returns

Number of iterations if succeed

## Author

Xiaozhe Hu

## Date

05/01/2014

Definition at line 493 of file itsolver\_bcsr.c.

## 9.49 itsolver\_bsr.c File Reference

Iterative solvers for [dBSRmat](#) matrices.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- void [fasp\\_set\\_GS\\_threads](#) (INT mythreads, INT its)  
*Set threads for CPR. Please add it at the begin of Krylov openmp method function and after iter++.*
- INT [fasp\\_solver\\_dbsr\\_itsolver](#) (dBSRmat \*A, dvector \*b, dvector \*x, precondition \*pc, itsolver\_param \*itparam)  
*Solve  $Ax=b$  by preconditioned Krylov methods for BSR matrices.*
- INT [fasp\\_solver\\_dbsr\\_krylov](#) (dBSRmat \*A, dvector \*b, dvector \*x, itsolver\_param \*itparam)  
*Solve  $Ax=b$  by standard Krylov methods for BSR matrices.*
- INT [fasp\\_solver\\_dbsr\\_krylov\\_diag](#) (dBSRmat \*A, dvector \*b, dvector \*x, itsolver\_param \*itparam)  
*Solve  $Ax=b$  by diagonal preconditioned Krylov methods.*
- INT [fasp\\_solver\\_dbsr\\_krylov\\_ilu](#) (dBSRmat \*A, dvector \*b, dvector \*x, itsolver\_param \*itparam, ILU\_param \*iluparam)  
*Solve  $Ax=b$  by ILUs preconditioned Krylov methods.*
- INT [fasp\\_solver\\_dbsr\\_krylov\\_amg](#) (dBSRmat \*A, dvector \*b, dvector \*x, itsolver\_param \*itparam, AMG\_param \*amgparam)  
*Solve  $Ax=b$  by AMG preconditioned Krylov methods.*
- INT [fasp\\_solver\\_dbsr\\_krylov\\_amg\\_nk](#) (dBSRmat \*A, dvector \*b, dvector \*x, itsolver\_param \*itparam, AMG\_param \*amgparam, dCSRmat \*A\_nk, dCSRmat \*P\_nk, dCSRmat \*R\_nk)
- INT [fasp\\_solver\\_dbsr\\_krylov\\_nk\\_amg](#) (dBSRmat \*A, dvector \*b, dvector \*x, itsolver\_param \*itparam, AMG\_param \*amgparam, const INT nk\_dim, dvector \*nk)  
*Solve  $Ax=b$  by AMG preconditioned Krylov methods.*

### Variables

- INT THDs\_AMG\_GS =0
- INT THDs\_CPR\_IGS =0
- INT THDs\_CPR\_gGS =0

#### 9.49.1 Detailed Description

Iterative solvers for [dBSRmat](#) matrices.

Definition in file [itsolver\\_bsr.c](#).

#### 9.49.2 Function Documentation

##### 9.49.2.1 void fasp\_set\_GS\_threads ( INT threads, INT its )

Set threads for CPR. Please add it at the begin of Krylov openmp method function and after iter++.



## Parameters

<i>threads</i>	Total threads of solver
<i>its</i>	Current its of the Krylov methods

## Author

Feng Chunsheng, Yue Xiaoqiang

## Date

03/20/2011

TODO: Why put it here??? –Chensong

Definition at line 39 of file itsolver\_bsr.c.

**9.49.2.2** `INT fasp_solver_dbsr_itsolver ( dBSRmat * A, dvector * b, dvector * x, precondition * pc, itsolver_param * itparam )`

Solve  $Ax=b$  by preconditioned Krylov methods for BSR matrices.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dBSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>pc</i>	Pointer to the preconditioning action
<i>itparam</i>	Pointer to parameters for iterative solvers

## Returns

Number of iterations if succeed

## Author

Zhiyang Zhou, Xiaozhe Hu

## Date

10/26/2010

Definition at line 100 of file itsolver\_bsr.c.

**9.49.2.3** `INT fasp_solver_dbsr_krylov ( dBSRmat * A, dvector * b, dvector * x, itsolver_param * itparam )`

Solve  $Ax=b$  by standard Krylov methods for BSR matrices.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dBSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

**Returns**

Number of iterations if succeed

**Author**

Zhiyang Zhou, Xiaozhe Hu

**Date**

10/26/2010

Definition at line 189 of file itsolver\_bsr.c.

**9.49.2.4** INT fasp\_solver\_dbsr\_krylov\_amg ( dBSRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam*, AMG\_param \* *amgparam* )

Solve  $Ax=b$  by AMG preconditioned Krylov methods.

**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dBSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>amgparam</i>	Pointer to parameters of AMG

**Returns**

Number of iterations if succeed

**Author**

Xiaozhe Hu

**Date**

03/16/2012

parameters of iterative method

Definition at line 412 of file itsolver\_bsr.c.

**9.49.2.5** INT fasp\_solver\_dbsr\_krylov\_amg\_nk ( dBSRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam*, AMG\_param \* *amgparam*, dCSRmat \* *A\_nk*, dCSRmat \* *P\_nk*, dCSRmat \* *R\_nk* )

parameters of iterative method

Definition at line 555 of file itsolver\_bsr.c.

9.49.2.6 INT fasp\_solver\_dbsr\_krylov\_diag ( dBSRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam* )

Solve  $Ax=b$  by diagonal preconditioned Krylov methods.

**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dBSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

**Returns**

the number of iterations

**Author**

Zhiyang Zhou, Xiaozhe Hu

**Date**

10/26/2010

Modified by Chunsheng Feng, Zheng Li

**Date**

10/15/2012

Definition at line 241 of file itsolver\_bsr.c.

**9.49.2.7** `INT fasp_solver_dbsr_krylov_ilu ( dBSRmat * A, dvector * b, dvector * x, itsolver_param * itparam, ILU_param * iluparam )`

Solve  $Ax=b$  by ILUs preconditioned Krylov methods.

**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dBSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>iluparam</i>	Pointer to parameters of ILU

**Returns**

Number of iterations if succeed

**Author**

Shiquang Zhang, Xiaozhe Hu

**Date**

10/26/2010

Definition at line 345 of file itsolver\_bsr.c.

9.49.2.8 INT fasp\_solver\_dbsr\_krylov\_nk\_amg ( dBSRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam*, AMG\_param \* *amgparam*, const INT *nk\_dim*, dvector \* *nk* )

Solve  $Ax=b$  by AMG preconditioned Krylov methods.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dBSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>amgparam</i>	Pointer to parameters of AMG
<i>nk_dim</i>	Dimension of the near kernel spaces
<i>nk</i>	Pointer to the near kernal spaces

## Returns

Number of iterations if succeed

## Author

Xiaozhe Hu

## Date

05/27/2012

parameters of iterative method

Definition at line 713 of file itsolver\_bsr.c.

### 9.49.3 Variable Documentation

#### 9.49.3.1 INT THDs\_AMG\_GS =0

cpr amg gs smoothing threads

Definition at line 35 of file itsolver\_bsr.c.

#### 9.49.3.2 INT THDs\_CPR\_gGS =0

global matrix gs smoothing threads

Definition at line 37 of file itsolver\_bsr.c.

#### 9.49.3.3 INT THDs\_CPR\_IGS =0

reservoir gs smoothing threads

Definition at line 36 of file itsolver\_bsr.c.

## 9.50 itsolver\_csr.c File Reference

Iterative solvers for [dCSRmat](#) matrices.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- [INT fasp\\_solver\\_dcsr\\_itsolver](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by preconditioned Krylov methods for CSR matrices.*
- [INT fasp\\_solver\\_dcsr\\_krylov](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by standard Krylov methods for CSR matrices.*
- [INT fasp\\_solver\\_dcsr\\_krylov\\_diag](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by diagonal preconditioned Krylov methods.*
- [INT fasp\\_solver\\_dcsr\\_krylov\\_schwarz](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam, [Schwarz\\_param](#) \*schparam)  
*Solve  $Ax=b$  by overlapping schwarz Krylov methods.*
- [INT fasp\\_solver\\_dcsr\\_krylov\\_amg](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam, [AMG\\_param](#) \*amgparam)  
*Solve  $Ax=b$  by AMG preconditioned Krylov methods.*
- [INT fasp\\_solver\\_dcsr\\_krylov\\_ilu](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam, [ILU\\_param](#) \*iluparam)  
*Solve  $Ax=b$  by ILUs preconditioned Krylov methods.*
- [INT fasp\\_solver\\_dcsr\\_krylov\\_ilu\\_M](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam, [ILU\\_param](#) \*iluparam, [dCSRmat](#) \*M)  
*Solve  $Ax=b$  by ILUs preconditioned Krylov methods: ILU of M as preconditioner.*
- [INT fasp\\_solver\\_dcsr\\_krylov\\_amg\\_nk](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam, [AMG\\_param](#) \*amgparam, [dCSRmat](#) \*A\_nk, [dCSRmat](#) \*P\_nk, [dCSRmat](#) \*R\_nk)  
*Solve  $Ax=b$  by AMG preconditioned Krylov methods with an extra near kernel solve.*

### 9.50.1 Detailed Description

Iterative solvers for [dCSRmat](#) matrices.

Definition in file [itsolver\\_csr.c](#).

### 9.50.2 Function Documentation

**9.50.2.1** [INT fasp\\_solver\\_dcsr\\_itsolver](#) ( [dCSRmat](#) \* A, [dvector](#) \* b, [dvector](#) \* x, [precond](#) \* pc, [itsolver\\_param](#) \* itparam )

Solve  $Ax=b$  by preconditioned Krylov methods for CSR matrices.

Parameters

A	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
---	---

<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>pc</i>	Pointer to the preconditioning action
<i>itparam</i>	Pointer to parameters for iterative solvers

**Returns**

Number of iterations if succeed

**Author**

Chensong Zhang

**Date**

09/25/2009

**Note**

This is an abstract interface for iterative methods.

Definition at line 39 of file itsolver\_csr.c.

#### 9.50.2.2 INT fasp\_solver\_dcsr\_krylov ( dCSRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam* )

Solve  $Ax=b$  by standard Krylov methods for CSR matrices.

**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

**Returns**

Number of iterations if succeed

**Author**

Chensong Zhang, Shiquan Zhang

**Date**

09/25/2009

Definition at line 138 of file itsolver\_csr.c.

#### 9.50.2.3 INT fasp\_solver\_dcsr\_krylov\_amg ( dCSRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam*, AMG\_param \* *amgparam* )

Solve  $Ax=b$  by AMG preconditioned Krylov methods.



## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>amgparam</i>	Pointer to parameters for AMG methods

## Returns

Number of iterations if succeed

## Author

Chensong Zhang

## Date

09/25/2009

Definition at line 329 of file itsolver\_csr.c.

**9.50.2.4** `INT fasp_solver_dcsr_krylov_amg_nk ( dCSRmat * A, dvector * b, dvector * x, itsolver_param * itparam, AMG_param * amgparam, dCSRmat * A_nk, dCSRmat * P_nk, dCSRmat * R_nk )`

Solve  $Ax=b$  by AMG preconditioned Krylov methods with an extra near kernel solve.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>amgparam</i>	Pointer to parameters for AMG methods
<i>A_nk</i>	Pointer to the coeff matrix of near kernel space in <a href="#">dCSRmat</a> format
<i>P_nk</i>	Pointer to the prolongation of near kernel space in <a href="#">dCSRmat</a> format
<i>R_nk</i>	Pointer to the restriction of near kernel space in <a href="#">dCSRmat</a> format

## Returns

Number of iterations if succeed

## Author

Xiaozhe Hu

## Date

05/26/2014

Definition at line 605 of file itsolver\_csr.c.

**9.50.2.5** `INT fasp_solver_dcsr_krylov_diag ( dCSRmat * A, dvector * b, dvector * x, itsolver_param * itparam )`

Solve  $Ax=b$  by diagonal preconditioned Krylov methods.

**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

**Returns**

Number of iterations if succeed

**Author**

Chensong Zhang, Shiquan Zhang

**Date**

09/25/2009

Definition at line 188 of file itsolver\_csr.c.

**9.50.2.6** `INT fasp_solver_dcsr_krylov_ilu ( dCSRmat * A, dvector * b, dvector * x, itsolver_param * itparam, ILU_param * iluparam )`

Solve  $Ax=b$  by ILUs preconditioned Krylov methods.

**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>iluparam</i>	Pointer to parameters for ILU

**Returns**

Number of iterations if succeed

**Author**

Chensong Zhang, Shiquan Zhang

**Date**

09/25/2009

Definition at line 434 of file itsolver\_csr.c.

**9.50.2.7** `INT fasp_solver_dcsr_krylov_ilu_M ( dCSRmat * A, dvector * b, dvector * x, itsolver_param * itparam, ILU_param * iluparam, dCSRmat * M )`

Solve  $Ax=b$  by ILUs preconditioned Krylov methods: ILU of M as preconditioner.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>iluparam</i>	Pointer to parameters for ILU
<i>M</i>	Pointer to the preconditioning matrix in <a href="#">dCSRmat</a> format

## Returns

Number of iterations if succeed

## Author

Xiaozhe Hu

## Date

09/25/2009

## Note

This function is specially designed for reservoir simulation. Have not been tested in any other places.

Definition at line 521 of file itsolver\_csr.c.

**9.50.2.8** `INT fasp_solver_dcsr_krylov_schwarz ( dCSRmat * A, dvector * b, dvector * x, itsolver_param * itparam, Schwarz_param * schparam )`

Solve  $Ax=b$  by overlapping schwarz Krylov methods.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dCSRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>schparam</i>	Pointer to parameters for Schwarz methods

## Returns

Number of iterations

## Author

Xiaozhe Hu

## Date

03/21/2011

Modified by Chensong on 07/02/2012: change interface

Definition at line 252 of file itsolver\_csr.c.

## 9.51 itsolver\_mf.c File Reference

Iterative solvers with matrix-free spmv.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "fasp_block.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_itsolver](#) ([mxv\\_matfree](#) \*mf, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by preconditioned Krylov methods for CSR matrices.*
- [INT fasp\\_solver\\_krylov](#) ([mxv\\_matfree](#) \*mf, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by standard Krylov methods – without preconditioner.*
- void [fasp\\_solver\\_itsolver\\_init](#) ([INT](#) matrix\_format, [mxv\\_matfree](#) \*mf, void \*A)  
*Initialize itsolvers.*

### 9.51.1 Detailed Description

Iterative solvers with matrix-free spmv.

Definition in file [itsolver\\_mf.c](#).

### 9.51.2 Function Documentation

**9.51.2.1** [INT fasp\\_solver\\_itsolver](#) ( [mxv\\_matfree](#) \* *mf*, [dvector](#) \* *b*, [dvector](#) \* *x*, [precond](#) \* *pc*, [itsolver\\_param](#) \* *itparam* )

Solve  $Ax=b$  by preconditioned Krylov methods for CSR matrices.

**Parameters**

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> matrix-free spmv operation
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>pc</i>	Pointer to the preconditioning action
<i>itparam</i>	Pointer to parameters for iterative solvers

**Returns**

Number of iterations if succeed

**Author**

Chensong Zhang

## Date

09/25/2009

## Note

This is an abstract interface for iterative methods.

Modified by Feiteng Huang on 09/19/2012: matrix free

Definition at line 50 of file itsolver\_mf.c.

**9.51.2.2** void fasp\_solver\_itsolver\_init ( INT *matrix\_format*, mxv\_matfree \* *mf*, void \* *A* )

Initialize itsolvers.

## Parameters

<i>matrix_format</i>	matrix format
<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> matrix-free spmv operation
<i>A</i>	void pointer to matrix

## Author

Feiteng Huang

## Date

09/18/2012

Modified by Chensong Zhang on 05/10/2013: Change interface of mat-free mv

Definition at line 198 of file itsolver\_mf.c.

**9.51.2.3** INT fasp\_solver\_krylov ( mxv\_matfree \* *mf*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam* )

Solve  $Ax=b$  by standard Krylov methods – without preconditioner.

## Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> matrix-free spmv operation
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

## Returns

Number of iterations if succeed

## Author

Chensong Zhang, Shiquan Zhang

## Date

09/25/2009

Modified by Feiteng Huang on 09/20/2012: matrix free

Definition at line 151 of file itsolver\_mf.c.

## 9.52 itsolver\_str.c File Reference

Iterative solvers for [dSTRmat](#) matrices.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_dstr\\_itsolver](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by standard Krylov methods.*
- [INT fasp\\_solver\\_dstr\\_krylov](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by standard Krylov methods.*
- [INT fasp\\_solver\\_dstr\\_krylov\\_diag](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam)  
*Solve  $Ax=b$  by diagonal preconditioned Krylov methods.*
- [INT fasp\\_solver\\_dstr\\_krylov\\_ilu](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam, [ILU\\_param](#) \*iluparam)  
*Solve  $Ax=b$  by structured ILU preconditioned Krylov methods.*
- [INT fasp\\_solver\\_dstr\\_krylov\\_blockgs](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [itsolver\\_param](#) \*itparam, [ivector](#) \*neigh, [ivector](#) \*order)  
*Solve  $Ax=b$  by diagonal preconditioned Krylov methods.*

### 9.52.1 Detailed Description

Iterative solvers for [dSTRmat](#) matrices.

Definition in file [itsolver\\_str.c](#).

### 9.52.2 Function Documentation

**9.52.2.1** [INT fasp\\_solver\\_dstr\\_itsolver](#) ( [dSTRmat](#) \* A, [dvector](#) \* b, [dvector](#) \* x, [precond](#) \* pc, [itsolver\\_param](#) \* itparam )

Solve  $Ax=b$  by standard Krylov methods.

Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dSTRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>pc</i>	Pointer to the preconditioning action
<i>itparam</i>	Pointer to parameters for iterative solvers

Returns

Number of iterations if succeed

## Author

Chensong Zhang

## Date

09/25/2009

Definition at line 34 of file itsolver\_str.c.

**9.52.2.2 INT fasp\_solver\_dstr\_krylov ( dSTRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam* )**Solve  $Ax=b$  by standard Krylov methods.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dSTRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

## Returns

Number of iterations if succeed

## Author

Zhiyang Zhou

## Date

04/25/2010

Definition at line 118 of file itsolver\_str.c.

**9.52.2.3 INT fasp\_solver\_dstr\_krylov\_blockgs ( dSTRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam*, ivector \* *neigh*, ivector \* *order* )**Solve  $Ax=b$  by diagonal preconditioned Krylov methods.

## Parameters

<i>A</i>	Pointer to the coeff matrix in <a href="#">dSTRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>neigh</i>	Pointer to neighbor vector
<i>order</i>	Pointer to solver ordering

## Returns

Number of iterations if succeed

**Author**

Xiaozhe Hu

**Date**

10/10/2010

Definition at line 324 of file itsolver\_str.c.

**9.52.2.4 INT fasp\_solver\_dstr\_krylov\_diag ( dSTRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam* )**Solve  $Ax=b$  by diagonal preconditioned Krylov methods.**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dSTRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers

**Returns**

Number of iterations if succeed

**Author**

Zhiyang Zhou

**Date**

4/23/2010

Definition at line 166 of file itsolver\_str.c.

**9.52.2.5 INT fasp\_solver\_dstr\_krylov\_ilu ( dSTRmat \* *A*, dvector \* *b*, dvector \* *x*, itsolver\_param \* *itparam*, ILU\_param \* *iluparam* )**Solve  $Ax=b$  by structured ILU preconditioned Krylov methods.**Parameters**

<i>A</i>	Pointer to the coeff matrix in <a href="#">dSTRmat</a> format
<i>b</i>	Pointer to the right hand side in dvector format
<i>x</i>	Pointer to the approx solution in dvector format
<i>itparam</i>	Pointer to parameters for iterative solvers
<i>iluparam</i>	Pointer to parameters for ILU

**Returns**

Number of iterations if succeed



**Author**

Xiaozhe Hu

**Date**

05/01/2010

Definition at line 233 of file itsolver\_str.c.

## 9.53 itsolver\_util.inl File Reference

Routines for iterative solvers.

**Macros**

- #define **ITS\_FACONV** printf("### WARNING: False convergence!\n")  
*Warning for residual false convergence.*
- #define **ITS\_ZEROSOL** printf("### WARNING: Iteration stopped due to the solution is almost zero! %s : %d\n", \_\_FILE\_\_, \_\_LINE\_\_)  
*Warning for solution close to zero.*
- #define **ITS\_RESTART** printf("### WARNING: Iteration restarted due to stagnation! %s : %d\n", \_\_FILE\_\_, \_\_LINE\_\_)  
*Warning for iteration restarted.*
- #define **ITS\_STAGGED** printf("### WARNING: Iteration stopped due to staggnation! %s : %d\n", \_\_FILE\_\_, \_\_LINE\_\_)  
*Warning for stagged iteration.*
- #define **ITS\_ZEROTOL** printf("### WARNING: The tolerance might be too small! %s : %d\n", \_\_FILE\_\_, \_\_LINE\_\_)  
*Warning for tolerance practically close to zero.*
- #define **ITS\_DIVZERO** printf("### WARNING: Divided by zero! %s : %d\n", \_\_FILE\_\_, \_\_LINE\_\_)  
*Warning for divided by zero.*
- #define **ITS\_REALRES**(relres) printf("### WARNING: The actual relative residual = %e!\n", (relres))  
*Warning for actual relative residual.*
- #define **ITS\_COMPRES**(relres) printf("### WARNING: The computed relative residual = %e!\n", (relres))  
*Warning for computed relative residual.*
- #define **ITS\_SMALLSP** printf("### WARNING: The sp is too small! %s : %d\n", \_\_FILE\_\_, \_\_LINE\_\_)  
*Warning for too small sp.*
- #define **ITS\_RESTORE**(iter) printf("### WARNING: Restore iteration %d!", (iter));  
*Warning for restore previous iteration.*
- #define **ITS\_DIFFRES**(reldiff, relres) printf("||u-u'|| = %e and the comp. rel. res. = %e.\n", (reldiff), (relres));  
*Output relative difference and residual.*
- #define **ITS\_PUTNORM**(name, value) printf("L2 norm of %s = %e.\n", (name), (value));  
*Output L2 norm of some variable.*

### 9.53.1 Detailed Description

Routines for iterative solvers.

Definition in file [itsolver\\_util.inl](#).

## 9.54 linklist.inl File Reference

Utilities for link list data structure.

### Macros

- `#define LIST_HEAD -1`
- `#define LIST_TAIL -2`

### 9.54.1 Detailed Description

Utilities for link list data structure.

#### Note

These linked-list operations are adapted from hypre 2.0

Definition in file [linklist.inl](#).

### 9.54.2 Macro Definition Documentation

#### 9.54.2.1 `#define LIST_HEAD -1`

head of the linked list

Definition at line 7 of file linklist.inl.

#### 9.54.2.2 `#define LIST_TAIL -2`

tail of the linked list

Definition at line 8 of file linklist.inl.

## 9.55 lu.c File Reference

LU decomposition and direct solve for dense matrix.

```
#include <math.h>
#include "fasp.h"
#include "fasp_funcs.h"
```

### Functions

- `SHORT fasp_smat_lu_decomp (REAL *A, INT pivot[], INT n)`  
*LU decomposition of A using Doolittle's method.*
- `SHORT fasp_smat_lu_solve (REAL *A, REAL b[], INT pivot[], REAL x[], INT n)`  
*Solving  $Ax=b$  using LU decomposition.*

### 9.55.1 Detailed Description

LU decomposition and direct solve for dense matrix.

Definition in file [lu.c](#).

### 9.55.2 Function Documentation

#### 9.55.2.1 **SHORT** fasp\_smat\_lu\_decomp ( **REAL** \* *A*, **INT** *pivot*[], **INT** *n* )

LU decomposition of *A* using Doolittle's method.

##### Parameters

<i>A</i>	Pointer to the full matrix
<i>pivot</i>	Pivoting positions
<i>n</i>	Size of matrix <i>A</i>

##### Returns

FASP\_SUCCESS if succeed, ERROR\_UNKNOWN if fail

##### Note

Use Doolittle's method to decompose the  $n \times n$  matrix *A* into a unit lower triangular matrix *L* and an upper triangular matrix *U* such that  $A = LU$ . The matrices *L* and *U* replace the matrix *A*. The diagonal elements of *L* are 1 and are not stored.

The Doolittle method with partial pivoting is: Determine the pivot row and interchange the current row with the pivot row, then assuming that row *k* is the current row,  $k = 0, \dots, n - 1$  evaluate in order the following pair of expressions  $U[k][j] = A[k][j] - (L[k][0]*U[0][j] + \dots + L[k][k-1]*U[k-1][j])$  for  $j = k, k+1, \dots, n-1$   $L[i][k] = (A[i][k] - (L[i][0]*U[0][k] + \dots + L[i][k-1]*U[k-1][k])) / U[k][k]$  for  $i = k+1, \dots, n-1$ .

##### Author

Xuehai Huang

##### Date

04/02/2009

Definition at line 46 of file [lu.c](#).

#### 9.55.2.2 **SHORT** fasp\_smat\_lu\_solve ( **REAL** \* *A*, **REAL** *b*[], **INT** *pivot*[], **REAL** *x*[], **INT** *n* )

Solving  $Ax=b$  using LU decomposition.

##### Parameters

<i>A</i>	Pointer to the full matrix
----------	----------------------------

$b$	Right hand side array
$pivot$	Pivoting positions
$x$	Pointer to the solution array
$n$	Size of matrix A

**Returns**

FASP\_SUCCESS if succeed, ERROR\_UNKNOWN if failed

**Note**

This routine uses Doolittle's method to solve the linear equation  $Ax = b$ . This routine is called after the matrix A has been decomposed into a product of a unit lower triangular matrix L and an upper triangular matrix U with pivoting. The solution proceeds by solving the linear equation  $Ly = b$  for y and subsequently solving the linear equation  $Ux = y$  for x.

**Author**

Xuehai Huang

**Date**

04/02/2009

Definition at line 117 of file lu.c.

## 9.56 memory.c File Reference

Memory allocation and deallocation.

```
#include "fasp.h"
```

**Functions**

- void \* [fasp\\_mem\\_calloc](#) (LONGLONG size, INT type)  
*Allocate, initiate, and check memory.*
- void \* [fasp\\_mem\\_realloc](#) (void \*oldmem, LONG tsize)  
*Reallocate, initiate, and check memory.*
- void [fasp\\_mem\\_free](#) (void \*mem)  
*Free up previous allocated memory body.*
- void [fasp\\_mem\\_usage](#) ()  
*Show total allocated memory currently.*
- SHORT [fasp\\_mem\\_check](#) (void \*ptr, const char \*message, INT ERR)  
*Check wether a point is null or not.*
- SHORT [fasp\\_mem\\_iludata\\_check](#) (ILU\_data \*iludata)  
*Check wether a ILU\_data has enough work space.*
- SHORT [fasp\\_mem\\_dcsr\\_check](#) (dCSRmat \*A)  
*Check wether a dCSRmat A has sucessfully allocated memory.*

## Variables

- unsigned INT `total_alloc_mem` = 0
- unsigned INT `total_alloc_count` = 0

### 9.56.1 Detailed Description

Memory allocation and deallocation.

Definition in file [memory.c](#).

### 9.56.2 Function Documentation

#### 9.56.2.1 void \* fasp\_mem\_calloc ( LONGLONG size, INT type )

Allocate, initiate, and check memory.

##### Parameters

<i>size</i>	Number of memory blocks
<i>type</i>	Size of memory blocks

##### Returns

Void pointer to the allocated memory

##### Author

Chensong Zhang

##### Date

2010/08/12

Modified by Chunsheng Feng on 12/20/2013 Modified by Chunsheng Feng on 07/23/2013 Modified by Chunsheng Feng on 07/30/2013 Modified by Chensong Zhang on 07/30/2013: return warning if failed

Definition at line 57 of file memory.c.

#### 9.56.2.2 SHORT fasp\_mem\_check ( void \* ptr, const char \* message, INT ERR )

Check whether a point is null or not.

##### Parameters

<i>ptr</i>	Void pointer to be checked
<i>message</i>	Error message to print
<i>ERR</i>	Integer error code

##### Returns

FASP\_SUCCESS or error code

**Author**

Chensong Zhang

**Date**

11/16/2009

Definition at line 193 of file memory.c.

**9.56.2.3   SHORT fasp\_mem\_dcsr\_check ( dCSRmat \* A )**Check whether a [dCSRmat](#) A has successfully allocated memory.**Parameters**

<i>A</i>	Pointer to be checked
----------	-----------------------

**Returns**

FASP\_SUCCESS if success, else ERROR message (negative value)

**Author**

Xiaozhe Hu

**Date**

11/27/09

Definition at line 243 of file memory.c.

**9.56.2.4   void fasp\_mem\_free ( void \* mem )**

Free up previous allocated memory body.

**Parameters**

<i>mem</i>	Pointer to the memory body need to be freed
------------	---

**Returns**

NULL pointer

**Author**

Chensong Zhang

**Date**

2010/12/24

Definition at line 146 of file memory.c.

**9.56.2.5   SHORT fasp\_mem\_iludata\_check ( ILU\_data \* iludata )**Check whether a [ILU\\_data](#) has enough work space.

## Parameters

<i>iludata</i>	Pointer to be cheked
----------------	----------------------

## Returns

FASP\_SUCCESS if success, else ERROR (negative value)

## Author

Xiaozhe Hu, Chensong Zhang

## Date

11/27/09

Definition at line 217 of file memory.c.

**9.56.2.6 void \* fasp\_mem\_realloc ( void \* *oldmem*, LONG *type* )**

Reallocate, initiate, and check memory.

## Parameters

<i>oldmem</i>	Pointer to the existing mem block
<i>type</i>	Size of memory blocks

## Returns

Void pointer to the reallocated memory

## Author

Chensong Zhang

## Date

2010/08/12

Modified by Chunsheng Feng on 07/23/2013 Modified by Chensong Zhang on 07/30/2013: return warning if failed

Definition at line 112 of file memory.c.

**9.56.2.7 void fasp\_mem\_usage ( )**

Show total allocated memory currently.

## Author

Chensong Zhang

## Date

2010/08/12

Definition at line 171 of file memory.c.

### 9.56.3 Variable Documentation

#### 9.56.3.1 unsigned INT total\_alloc\_count = 0

total allocation times

Definition at line 33 of file memory.c.

#### 9.56.3.2 unsigned INT total\_alloc\_mem = 0

total allocated memory

Definition at line 32 of file memory.c.

## 9.57 message.c File Reference

Output some useful messages.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [print\\_itinfo](#) (const [INT](#) prtvl, const [INT](#) stop\_type, const [INT](#) iter, const [REAL](#) relres, const [REAL](#) absres, const [REAL](#) factor)  
*Print out iteration information for iterative solvers.*
- void [print\\_amgcomplexity](#) ([AMG\\_data](#) \*mgl, const [SHORT](#) prtvl)  
*Print complexities of AMG method.*
- void [print\\_amgcomplexity\\_bsr](#) ([AMG\\_data\\_bsr](#) \*mgl, const [SHORT](#) prtvl)  
*Print complexities of AMG method for BSR matrices.*
- void [print\\_cputime](#) (const char \*message, const [REAL](#) cputime)  
*Print CPU walltime.*
- void [print\\_message](#) (const [INT](#) prtvl, const char \*message)  
*Print output information if necessary.*
- void [fasp\\_chkerr](#) (const [SHORT](#) status, const char \*fctname)  
*Check error status and print out error messages before quit.*

### 9.57.1 Detailed Description

Output some useful messages.

#### Note

These routines are meant for internal use only.

Definition in file [message.c](#).



## 9.57.2 Function Documentation

### 9.57.2.1 void fasp\_chkerr ( const **SHORT** *status*, const char \* *fname* )

Check error status and print out error messages before quit.

## Parameters

<i>status</i>	Error status
<i>fctname</i>	Function name where this routine is called

## Author

Chensong Zhang

## Date

01/10/2012

Definition at line 199 of file message.c.

9.57.2.2 void void print\_amgcomplexity ( **AMG\_data** \* *mgl*, const **SHORT** *prtlvl* )

Print complexities of AMG method.

## Parameters

<i>mgl</i>	Multilevel hierachy for AMG
<i>prtlvl</i>	How much information to print

## Author

Chensong Zhang

## Date

11/16/2009

Definition at line 79 of file message.c.

9.57.2.3 void void print\_amgcomplexity\_bsr ( **AMG\_data\_bsr** \* *mgl*, const **SHORT** *prtlvl* )

Print complexities of AMG method for BSR matrices.

## Parameters

<i>mgl</i>	Multilevel hierachy for AMG
<i>prtlvl</i>	How much information to print

## Author

Chensong Zhang

## Date

05/10/2013

Definition at line 122 of file message.c.

9.57.2.4 void void print\_cputime ( const char \* *message*, const **REAL** *cputime* )

Print CPU walltime.

## Parameters

<i>message</i>	Some string to print out
<i>cputime</i>	Walltime since start to end

## Author

Chensong Zhang

## Date

04/10/2012

Definition at line 165 of file message.c.

**9.57.2.5** void print\_itinfo ( const INT *ptrlvl*, const INT *stop\_type*, const INT *iter*, const REAL *relres*, const REAL *absres*, const REAL *factor* )

Print out iteration information for iterative solvers.

## Parameters

<i>ptrlvl</i>	Level for output
<i>stop_type</i>	Type of stopping criteria
<i>iter</i>	Number of iterations
<i>relres</i>	Relative residual of different kinds
<i>absres</i>	Absolute residual of different kinds
<i>factor</i>	Contraction factor

## Author

Chensong Zhang

## Date

11/16/2009

Modified by Chensong Zhang on 03/28/2013: Output initial guess Modified by Chensong Zhang on 04/05/2013: Fix a typo

Definition at line 36 of file message.c.

**9.57.2.6** void print\_message ( const INT *ptrlvl*, const char \* *message* )

Print output information if necessary.

## Parameters

<i>ptrlvl</i>	Level for output
<i>message</i>	Error message to print

## Author

Chensong Zhang

## Date

11/16/2009

Definition at line 182 of file message.c.

## 9.58 messages.h File Reference

Definition of all kinds of messages, including error messages, solver types, etc.

### Macros

- `#define FASP_SUCCESS 0`  
*Definition of return status and error messages.*
- `#define ERROR_OPEN_FILE -10`
- `#define ERROR_WRONG_FILE -11`
- `#define ERROR_INPUT_PAR -13`
- `#define ERROR_REGRESS -14`
- `#define ERROR_MAT_SIZE -15`
- `#define ERROR_NUM_BLOCKS -18`
- `#define ERROR_MISC -19`
- `#define ERROR_ALLOC_MEM -20`
- `#define ERROR_DATA_STRUCTURE -21`
- `#define ERROR_DATA_ZERODIAG -22`
- `#define ERROR_DUMMY_VAR -23`
- `#define ERROR_AMG_INTERP_TYPE -30`
- `#define ERROR_AMG_SMOOTH_TYPE -31`
- `#define ERROR_AMG_COARSE_TYPE -32`
- `#define ERROR_AMG_COARSEING -33`
- `#define ERROR_SOLVER_TYPE -40`
- `#define ERROR_SOLVER_PRECTYPE -41`
- `#define ERROR_SOLVER_STAG -42`
- `#define ERROR_SOLVER_SOLSTAG -43`
- `#define ERROR_SOLVER_TOLSMALL -44`
- `#define ERROR_SOLVER_ILUSETUP -45`
- `#define ERROR_SOLVER_MISC -46`
- `#define ERROR_SOLVER_MAXIT -48`
- `#define ERROR_SOLVER_EXIT -49`
- `#define ERROR_QUAD_TYPE -60`
- `#define ERROR_QUAD_DIM -61`
- `#define ERROR_LIC_TYPE -80`
- `#define ERROR_UNKNOWN -99`
- `#define TRUE 1`  
*Definition of logic type.*
- `#define FALSE 0`
- `#define ON 1`  
*Definition of switch.*
- `#define OFF 0`
- `#define PRINT_NONE 0`

*Print level for all subroutines – not including DEBUG output.*

- #define `PRINT_MIN` 1
- #define `PRINT_SOME` 2
- #define `PRINT_MORE` 4
- #define `PRINT_MOST` 8
- #define `PRINT_ALL` 10
- #define `MAT_FREE` 0

*Definition of matrix format.*

- #define `MAT_CSR` 1
- #define `MAT_BSR` 2
- #define `MAT_STR` 3
- #define `MAT_bCSR` 4
- #define `MAT_bBSR` 5
- #define `MAT_CSRL` 6
- #define `MAT_SymCSR` 7
- #define `SOLVER_DEFAULT` 0

*Definition of solver types for iterative methods.*

- #define `SOLVER_CG` 1
- #define `SOLVER_BiCGstab` 2
- #define `SOLVER_MinRes` 3
- #define `SOLVER_GMRES` 4
- #define `SOLVER_VGMRES` 5
- #define `SOLVER_VFGMRES` 6
- #define `SOLVER_GCG` 7
- #define `SOLVER_SCG` 11
- #define `SOLVER_SBiCGstab` 12
- #define `SOLVER_SMinRes` 13
- #define `SOLVER_SGMRES` 14
- #define `SOLVER_SVGMRES` 15
- #define `SOLVER_SVFGMRES` 16
- #define `SOLVER_SGCG` 17
- #define `SOLVER_AMG` 21
- #define `SOLVER_FMG` 22
- #define `SOLVER_SUPERLU` 31
- #define `SOLVER_UMFPACK` 32
- #define `SOLVER_MUMPS` 33
- #define `STOP_REL_RES` 1

*Definition of iterative solver stopping criteria types.*

- #define `STOP_REL_PRECRES` 2
- #define `STOP_MOD_REL_RES` 3
- #define `PREC_NULL` 0

*Definition of preconditioner type for iterative methods.*

- #define `PREC_DIAG` 1
- #define `PREC_AMG` 2
- #define `PREC_FMG` 3
- #define `PREC_ILU` 4
- #define `PREC_SCHWARZ` 5
- #define `ILUk` 1

*Type of ILU methods.*

- #define `ILUt` 2

- #define `ILUtp` 3
- #define `CLASSIC_AMG` 1
  - Definition of AMG types.*
- #define `SA_AMG` 2
- #define `UA_AMG` 3
- #define `PAIRWISE` 1
  - Definition of aggregation types.*
- #define `VMB` 2
- #define `V_CYCLE` 1
  - Definition of cycle types.*
- #define `W_CYCLE` 2
- #define `AMLI_CYCLE` 3
- #define `NL_AMLI_CYCLE` 4
- #define `SMOOTHER_JACOBI` 1
  - Definition of standard smoother types.*
- #define `SMOOTHER_GS` 2
- #define `SMOOTHER_SGS` 3
- #define `SMOOTHER_CG` 4
- #define `SMOOTHER_SOR` 5
- #define `SMOOTHER_SSOR` 6
- #define `SMOOTHER_GSOR` 7
- #define `SMOOTHER_SGSOR` 8
- #define `SMOOTHER_POLY` 9
- #define `SMOOTHER_L1DIAG` 10
- #define `SMOOTHER_BLKOL` 11
  - Definition of specialized smoother types.*
- #define `SMOOTHER_SPETEN` 19
- #define `COARSE_RS` 1
  - Definition of coarsening types.*
- #define `COARSE_CR` 3
- #define `COARSE_AC` 4
- #define `INTERP_DIR` 1
  - Definition of interpolation types.*
- #define `INTERP_STD` 2
- #define `INTERP_ENG` 3
- #define `G0PT` -5
  - Type of vertices (dofs) for coarsening.*
- #define `UNPT` -1
- #define `FGPT` 0
- #define `CGPT` 1
- #define `ISPT` 2
- #define `NO_ORDER` 0
  - Definition of smoothing order.*
- #define `CF_ORDER` 1
- #define `USERDEFINED` 0
  - Type of ordering for smoothers.*
- #define `CPFIRST` 1
- #define `FPFIRST` -1
- #define `ASCEND` 12
- #define `DESCEND` 21

### 9.58.1 Detailed Description

Definition of all kinds of messages, including error messages, solver types, etc.

#### Note

This is internal use only.

Created by Chensong Zhang on 03/20/2010. Modified by Chensong Zhang on 12/06/2011. Modified by Chensong Zhang on 12/25/2011. Modified by Chensong Zhang on 04/22/2012. Modified by Ludmil Zikatanov on 02/15/2013: CG -> SMOOTHER\_CG. Modified by Chensong Zhang on 02/16/2013: GS -> SMOOTHER\_GS, etc. Modified by Chensong Zhang on 04/09/2013: Add safe krylov methods.

Modified by Chensong Zhang on 09/22/2013: Clean up Doxygen.

Definition in file [messages.h](#).

### 9.58.2 Macro Definition Documentation

#### 9.58.2.1 #define AMLI\_CYCLE 3

AMLI-cycle

Definition at line 167 of file messages.h.

#### 9.58.2.2 #define ASCEND 12

Asscending order

Definition at line 225 of file messages.h.

#### 9.58.2.3 #define CF\_ORDER 1

C/F order smoothing

Definition at line 217 of file messages.h.

#### 9.58.2.4 #define CGPT 1

Coarse grid points

Definition at line 210 of file messages.h.

#### 9.58.2.5 #define CLASSIC\_AMG 1

Definition of AMG types.

classic AMG

Definition at line 152 of file messages.h.

#### 9.58.2.6 #define COARSE\_AC 4

Aggressive coarsening

Definition at line 195 of file messages.h.

**9.58.2.7 #define COARSE\_CR 3**

Compatible relaxation

Definition at line 194 of file messages.h.

**9.58.2.8 #define COARSE\_RS 1**

Definition of coarsening types.

Classical coarsening

Definition at line 193 of file messages.h.

**9.58.2.9 #define CPFIRST 1**

C-points first order

Definition at line 223 of file messages.h.

**9.58.2.10 #define DESCEND 21**

Dsscending order

Definition at line 226 of file messages.h.

**9.58.2.11 #define ERROR\_ALLOC\_MEM -20**

fail to allocate memory

Definition at line 36 of file messages.h.

**9.58.2.12 #define ERROR\_AMG\_COARSE\_TYPE -32**

unknown coarsening type

Definition at line 43 of file messages.h.

**9.58.2.13 #define ERROR\_AMG\_COARSEING -33**

coarsening step failed to complete

Definition at line 44 of file messages.h.

**9.58.2.14 #define ERROR\_AMG\_INTERP\_TYPE -30**

unknown interpolation type

Definition at line 41 of file messages.h.



**9.58.2.15 #define ERROR\_AMG\_SMOOTH\_TYPE -31**

unknown smoother type

Definition at line 42 of file messages.h.

**9.58.2.16 #define ERROR\_DATA\_STRUCTURE -21**

problem with data structures

Definition at line 37 of file messages.h.

**9.58.2.17 #define ERROR\_DATA\_ZERODIAG -22**

matrix has zero diagonal entries

Definition at line 38 of file messages.h.

**9.58.2.18 #define ERROR\_DUMMY\_VAR -23**

unexpected input data

Definition at line 39 of file messages.h.

**9.58.2.19 #define ERROR\_INPUT\_PAR -13**

wrong input argument

Definition at line 30 of file messages.h.

**9.58.2.20 #define ERROR\_LIC\_TYPE -80**

wrong license type

Definition at line 59 of file messages.h.

**9.58.2.21 #define ERROR\_MAT\_SIZE -15**

wrong problem size

Definition at line 32 of file messages.h.

**9.58.2.22 #define ERROR\_MISC -19**

other error

Definition at line 34 of file messages.h.

**9.58.2.23 #define ERROR\_NUM\_BLOCKS -18**

wrong number of blocks

Definition at line 33 of file messages.h.

**9.58.2.24 #define ERROR\_OPEN\_FILE -10**

fail to open a file

Definition at line 28 of file messages.h.

**9.58.2.25 #define ERROR\_QUAD\_DIM -61**

unsupported quadrature dim

Definition at line 57 of file messages.h.

**9.58.2.26 #define ERROR\_QUAD\_TYPE -60**

unknown quadrature type

Definition at line 56 of file messages.h.

**9.58.2.27 #define ERROR\_REGRESS -14**

regression test fail

Definition at line 31 of file messages.h.

**9.58.2.28 #define ERROR\_SOLVER\_EXIT -49**

solver does not quit successfully

Definition at line 54 of file messages.h.

**9.58.2.29 #define ERROR\_SOLVER\_ILUSETUP -45**

ILU setup error

Definition at line 51 of file messages.h.

**9.58.2.30 #define ERROR\_SOLVER\_MAXIT -48**

maximal iteration number exceeded

Definition at line 53 of file messages.h.

**9.58.2.31 #define ERROR\_SOLVER\_MISC -46**

misc solver error during run time

Definition at line 52 of file messages.h.

**9.58.2.32 #define ERROR\_SOLVER\_PRECTYPE -41**

unknow precond type

Definition at line 47 of file messages.h.

**9.58.2.33 #define ERROR\_SOLVER\_SOLSTAG -43**

solver's solution is too small

Definition at line 49 of file messages.h.

**9.58.2.34 #define ERROR\_SOLVER\_STAG -42**

solver stagnates

Definition at line 48 of file messages.h.

**9.58.2.35 #define ERROR\_SOLVER\_TOLSMALL -44**

solver's tolerance is too small

Definition at line 50 of file messages.h.

**9.58.2.36 #define ERROR\_SOLVER\_TYPE -40**

unknown solver type

Definition at line 46 of file messages.h.

**9.58.2.37 #define ERROR\_UNKNOWN -99**

an unknown error type

Definition at line 61 of file messages.h.

**9.58.2.38 #define ERROR\_WRONG\_FILE -11**

input contains wrong format

Definition at line 29 of file messages.h.

**9.58.2.39 #define FALSE 0**

logic FALSE

Definition at line 67 of file messages.h.

**9.58.2.40 #define FASP\_SUCCESS 0**

Definition of return status and error messages.

return from function successfully

Definition at line 26 of file messages.h.

**9.58.2.41 #define FGPT 0**

Fine grid points

Definition at line 209 of file messages.h.

**9.58.2.42 #define FPFIRST -1**

F-points first order

Definition at line 224 of file messages.h.

**9.58.2.43 #define G0PT -5**

Type of vertices (dofs) for coarsening.

Cannot fit in aggregates

Definition at line 207 of file messages.h.

**9.58.2.44 #define ILUk 1**

Type of ILU methods.

ILUk

Definition at line 145 of file messages.h.

**9.58.2.45 #define ILUt 2**

ILUt

Definition at line 146 of file messages.h.

**9.58.2.46 #define ILUtp 3**

ILUtp

Definition at line 147 of file messages.h.

**9.58.2.47 #define INTERP\_DIR 1**

Definition of interpolation types.

Direct interpolation

Definition at line 200 of file messages.h.

**9.58.2.48 #define INTERP\_ENG 3**

energy minimization interp in C

Definition at line 202 of file messages.h.

**9.58.2.49 #define INTERP\_STD 2**

Standard interpolation

Definition at line 201 of file messages.h.

**9.58.2.50 #define ISPT 2**

Isolated points

Definition at line 211 of file messages.h.

**9.58.2.51 #define MAT\_bBSR 5**

block matrix of BSR for bordered systems

Definition at line 93 of file messages.h.

**9.58.2.52 #define MAT\_bCSR 4**

block matrix of CSR

Definition at line 92 of file messages.h.

**9.58.2.53 #define MAT\_BSR 2**

blockwise compressed sparse row

Definition at line 90 of file messages.h.

**9.58.2.54 #define MAT\_CSR 1**

compressed sparse row

Definition at line 89 of file messages.h.

**9.58.2.55 #define MAT\_CSRL 6**

modified CSR to reduce cache missing

Definition at line 94 of file messages.h.

**9.58.2.56 #define MAT\_FREE 0**

Definition of matrix format.

matrix-free format: only mxv action

Definition at line 88 of file messages.h.

**9.58.2.57 #define MAT\_STR 3**

structured sparse matrix

Definition at line 91 of file messages.h.

**9.58.2.58 #define MAT\_SymCSR 7**

symmetric CSR format

Definition at line 95 of file messages.h.

**9.58.2.59 #define NL\_AMLI\_CYCLE 4**

Nonlinear AMLI-cycle

Definition at line 168 of file messages.h.

**9.58.2.60 #define NO\_ORDER 0**

Definition of smoothing order.

Natural order smoothing

Definition at line 216 of file messages.h.

**9.58.2.61 #define OFF 0**

turn off certain parameter

Definition at line 73 of file messages.h.

**9.58.2.62 #define ON 1**

Definition of switch.

turn on certain parameter

Definition at line 72 of file messages.h.

**9.58.2.63 #define PAIRWISE 1**

Definition of aggregation types.

pairwise aggregation

Definition at line 159 of file messages.h.

**9.58.2.64 #define PREC\_AMG 2**

with AMG precondition

Definition at line 137 of file messages.h.

**9.58.2.65 #define PREC\_DIAG 1**

with diagonal precondition

Definition at line 136 of file messages.h.

**9.58.2.66 #define PREC\_FMG 3**

with full AMG precondition

Definition at line 138 of file messages.h.

**9.58.2.67 #define PREC\_ILU 4**

with ILU precondition

Definition at line 139 of file messages.h.

**9.58.2.68 #define PREC\_NULL 0**

Definition of preconditioner type for iterative methods.

with no precondition

Definition at line 135 of file messages.h.

**9.58.2.69 #define PREC\_SCHWARZ 5**

with Schwarz preconditioner

Definition at line 140 of file messages.h.

**9.58.2.70 #define PRINT\_ALL 10**

everything: all printouts allowed

Definition at line 83 of file messages.h.

**9.58.2.71 #define PRINT\_MIN 1**

quiet: minimal print, like convergence

Definition at line 79 of file messages.h.

**9.58.2.72 #define PRINT\_MORE 4**

more: print more useful information

Definition at line 81 of file messages.h.

**9.58.2.73 #define PRINT\_MOST 8**

most: maximal printouts, no disk files  
Definition at line 82 of file messages.h.

**9.58.2.74 #define PRINT\_NONE 0**

Print level for all subroutines – not including DEBUG output.  
silent: no printout at all  
Definition at line 78 of file messages.h.

**9.58.2.75 #define PRINT\_SOME 2**

some: print cpu time, iteration number  
Definition at line 80 of file messages.h.

**9.58.2.76 #define SA\_AMG 2**

smoothed aggregation AMG  
Definition at line 153 of file messages.h.

**9.58.2.77 #define SMOOTHER\_BLKOil 11**

Definition of specialized smoother types.  
Used in monolithic AMG for black-oil  
Definition at line 187 of file messages.h.

**9.58.2.78 #define SMOOTHER\_CG 4**

CG as a smoother  
Definition at line 176 of file messages.h.

**9.58.2.79 #define SMOOTHER\_GS 2**

Gauss-Seidel smoother  
Definition at line 174 of file messages.h.

**9.58.2.80 #define SMOOTHER\_GSOR 7**

GS + SOR smoother  
Definition at line 179 of file messages.h.



**9.58.2.81 #define SMOOTHER\_JACOBI 1**

Definition of standard smoother types.

Jacobi smoother

Definition at line 173 of file messages.h.

**9.58.2.82 #define SMOOTHER\_L1DIAG 10**

L1 norm diagonal scaling smoother

Definition at line 182 of file messages.h.

**9.58.2.83 #define SMOOTHER\_POLY 9**

Polynomial smoother

Definition at line 181 of file messages.h.

**9.58.2.84 #define SMOOTHER\_SGS 3**

symm Gauss-Seidel smoother

Definition at line 175 of file messages.h.

**9.58.2.85 #define SMOOTHER\_SGSOR 8**

SGS + SSOR smoother

Definition at line 180 of file messages.h.

**9.58.2.86 #define SMOOTHER\_SOR 5**

SOR smoother

Definition at line 177 of file messages.h.

**9.58.2.87 #define SMOOTHER\_SPETEN 19**

Used in monolithic AMG for black-oil

Definition at line 188 of file messages.h.

**9.58.2.88 #define SMOOTHER\_SSOR 6**

SSOR smoother

Definition at line 178 of file messages.h.

9.58.2.89 `#define SOLVER_AMG 21`

AMG as an iterative solver

Definition at line 118 of file messages.h.

9.58.2.90 `#define SOLVER_BiCGstab 2`

Biconjugate Gradient Stabilized

Definition at line 103 of file messages.h.

9.58.2.91 `#define SOLVER_CG 1`

Conjugate Gradient

Definition at line 102 of file messages.h.

9.58.2.92 `#define SOLVER_DEFAULT 0`

Definition of solver types for iterative methods.

Use default solver in FASP

Definition at line 100 of file messages.h.

9.58.2.93 `#define SOLVER_FMG 22`

Full AMG as an solver

Definition at line 119 of file messages.h.

9.58.2.94 `#define SOLVER_GCG 7`

Generalized Conjugate Gradient

Definition at line 108 of file messages.h.

9.58.2.95 `#define SOLVER_GMRES 4`

Generalized Minimal Residual

Definition at line 105 of file messages.h.

9.58.2.96 `#define SOLVER_MinRes 3`

Minimal Residual

Definition at line 104 of file messages.h.

**9.58.2.97 #define SOLVER\_MUMPS 33**

MUMPS Direct Solver

Definition at line 123 of file messages.h.

**9.58.2.98 #define SOLVER\_SBiCGstab 12**

BiCGstab with safe net

Definition at line 111 of file messages.h.

**9.58.2.99 #define SOLVER\_SCG 11**

Conjugate Gradient with safe net

Definition at line 110 of file messages.h.

**9.58.2.100 #define SOLVER\_SGCG 17**

GCG with safe net

Definition at line 116 of file messages.h.

**9.58.2.101 #define SOLVER\_SGMRES 14**

GMRes with safe net

Definition at line 113 of file messages.h.

**9.58.2.102 #define SOLVER\_SMinRes 13**

MinRes with safe net

Definition at line 112 of file messages.h.

**9.58.2.103 #define SOLVER\_SUPERLU 31**

SuperLU Direct Solver

Definition at line 121 of file messages.h.

**9.58.2.104 #define SOLVER\_SVFGMRES 16**

Variable-restart FGMRES with safe net

Definition at line 115 of file messages.h.

**9.58.2.105 #define SOLVER\_SVGMRES 15**

Variable-restart GMRES with safe net

Definition at line 114 of file messages.h.

9.58.2.106 `#define SOLVER_UMFPACK 32`

UMFPack Direct Solver

Definition at line 122 of file messages.h.

9.58.2.107 `#define SOLVER_VFGMRES 6`

Variable Restarting Flexible GMRES

Definition at line 107 of file messages.h.

9.58.2.108 `#define SOLVER_VGMRES 5`

Variable Restarting GMRES

Definition at line 106 of file messages.h.

9.58.2.109 `#define STOP_MOD_REL_RES 3`

modified relative residual  $\|r\|/\|x\|$

Definition at line 130 of file messages.h.

9.58.2.110 `#define STOP_REL_PRECRES 2`

relative B-residual  $\|r\|_B/\|b\|_B$

Definition at line 129 of file messages.h.

9.58.2.111 `#define STOP_REL_RES 1`

Definition of iterative solver stopping criteria types.

relative residual  $\|r\|/\|b\|$

Definition at line 128 of file messages.h.

9.58.2.112 `#define TRUE 1`

Definition of logic type.

logic TRUE

Definition at line 66 of file messages.h.

9.58.2.113 `#define UA_AMG 3`

unsmoothed aggregation AMG

Definition at line 154 of file messages.h.

**9.58.2.114 #define UNPT -1**

Undetermined points

Definition at line 208 of file messages.h.

**9.58.2.115 #define USERDEFINED 0**

Type of ordering for smoothers.

USERDEFINED order

Definition at line 222 of file messages.h.

**9.58.2.116 #define V\_CYCLE 1**

Definition of cycle types.

V-cycle

Definition at line 165 of file messages.h.

**9.58.2.117 #define VMB 2**

VMB aggregation

Definition at line 160 of file messages.h.

**9.58.2.118 #define W\_CYCLE 2**

W-cycle

Definition at line 166 of file messages.h.

## 9.59 mg\_util.inl File Reference

Routines for algebraic multigrid cycles.

### 9.59.1 Detailed Description

Routines for algebraic multigrid cycles.

Definition in file [mg\\_util.inl](#).

## 9.60 mgcycle.c File Reference

Abstract non-recursive multigrid cycle.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "forts_ns.h"
#include "mg_util.inl"
```

## Functions

- void [fasp\\_solver\\_mgcycle](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Solve  $Ax=b$  with non-recursive multigrid cycle.*
- void [fasp\\_solver\\_mgcycle\\_bsr](#) ([AMG\\_data\\_bsr](#) \*mgl, [AMG\\_param](#) \*param)  
*Solve  $Ax=b$  with non-recursive multigrid cycle.*

### 9.60.1 Detailed Description

Abstract non-recursive multigrid cycle.

Definition in file [mgcycle.c](#).

### 9.60.2 Function Documentation

9.60.2.1 void [fasp\\_solver\\_mgcycle](#) ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Solve  $Ax=b$  with non-recursive multigrid cycle.

Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

Author

Chensong Zhang

Date

10/06/2010

Modified by Chensong Zhang on 12/13/2011 Modified by Chensong Zhang on 02/27/2013: update direct solvers.

Definition at line 41 of file mgcycle.c.

9.60.2.2 void [fasp\\_solver\\_mgcycle\\_bsr](#) ( [AMG\\_data\\_bsr](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Solve  $Ax=b$  with non-recursive multigrid cycle.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data_bsr</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>

## Author

Xiaozhe Hu

## Date

08/07/2011

Definition at line 316 of file mgcycle.c.

## 9.61 mgrecur.c File Reference

Abstract multigrid cycle – recursive version.

```
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "mg_util.inl"
```

## Functions

- void [fasp\\_solver\\_mgrecur](#) ([AMG\\_data](#) \**mgl*, [AMG\\_param](#) \**param*, INT *level*)  
Solve  $Ax=b$  with recursive multigrid  $K$ -cycle.

### 9.61.1 Detailed Description

Abstract multigrid cycle – recursive version.

Definition in file [mgrecur.c](#).

### 9.61.2 Function Documentation

9.61.2.1 void [fasp\\_solver\\_mgrecur](#) ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param*, INT *level* )

Solve  $Ax=b$  with recursive multigrid  $K$ -cycle.

## Parameters

<i>mgl</i>	Pointer to AMG data: <a href="#">AMG_data</a>
<i>param</i>	Pointer to AMG parameters: <a href="#">AMG_param</a>
<i>level</i>	Index of the current level

## Author

Xuehai Huang, Chensong Zhang

Date

04/06/2010

Modified by Chensong Zhang on 01/10/2012 Modified by Chensong Zhang on 02/27/2013: update direct solvers.

Definition at line 31 of file mgrecur.c.

## 9.62 ordering.c File Reference

A collection of ordering, merging, removing duplicated integers functions.

```
#include "fasp.h"
```

### Functions

- [INT fasp\\_BinarySearch](#) ([INT](#) \*list, [INT](#) value, [INT](#) list\_length)  
*Binary Search.*
- [INT fasp\\_aux\\_unique](#) ([INT](#) numbers[], [INT](#) size)  
*Remove duplicates in an sorted (ascending order) array.*
- void [fasp\\_aux\\_merge](#) ([INT](#) numbers[], [INT](#) work[], [INT](#) left, [INT](#) mid, [INT](#) right)  
*Merge two sorted arraies.*
- void [fasp\\_aux\\_msort](#) ([INT](#) numbers[], [INT](#) work[], [INT](#) left, [INT](#) right)  
*Sort the INT array ascendingly with the merge sort algorithm.*
- void [fasp\\_aux\\_iQuickSort](#) ([INT](#) \*a, [INT](#) left, [INT](#) right)  
*Sort the array (INT type) ascendingly with the quick sorting algorithm.*
- void [fasp\\_aux\\_dQuickSort](#) ([REAL](#) \*a, [INT](#) left, [INT](#) right)  
*Sort the array (REAL type) ascendingly with the quick sorting algorithm.*
- void [fasp\\_aux\\_iQuickSortIndex](#) ([INT](#) \*a, [INT](#) left, [INT](#) right, [INT](#) \*index)  
*Reorder the index of (INT type) so that 'a' is in ascending order.*
- void [fasp\\_aux\\_dQuickSortIndex](#) ([REAL](#) \*a, [INT](#) left, [INT](#) right, [INT](#) \*index)  
*Reorder the index of (REAL type) so that 'a' is ascending in such order.*

### 9.62.1 Detailed Description

A collection of ordering, merging, removing duplicated integers functions.

Definition in file [ordering.c](#).

### 9.62.2 Function Documentation

#### 9.62.2.1 void fasp\_aux\_dQuickSort ( [REAL](#) \* a, [INT](#) left, [INT](#) right )

Sort the array (REAL type) ascendingly with the quick sorting algorithm.



## Parameters

<i>a</i>	Pointer to the array needed to be sorted
<i>left</i>	Starting index
<i>right</i>	Ending index

## Author

Zhiyang Zhou

## Date

2009/11/28

## Note

'left' and 'right' are usually set to be 0 and n-1, respectively where n is the length of 'a'.

Definition at line 238 of file ordering.c.

**9.62.2.2** void fasp\_aux\_dQuickSortIndex ( REAL \* *a*, INT *left*, INT *right*, INT \* *index* )

Reorder the index of (REAL type) so that 'a' is ascending in such order.

## Parameters

<i>a</i>	Pointer to the array
<i>left</i>	Starting index
<i>right</i>	Ending index
<i>index</i>	Index of 'a' (out)

## Author

Zhiyang Zhou

## Date

2009/12/02

## Note

'left' and 'right' are usually set to be 0 and n-1, respectively, where n is the length of 'a'. 'index' should be initialized in the nature order and it has the same length as 'a'.

Definition at line 319 of file ordering.c.

**9.62.2.3** void fasp\_aux\_iQuickSort ( INT \* *a*, INT *left*, INT *right* )

Sort the array (INT type) ascendingly with the quick sorting algorithm.

## Parameters

<i>a</i>	Pointer to the array needed to be sorted
<i>left</i>	Starting index
<i>right</i>	Ending index

## Author

Zhiyang Zhou

## Date

11/28/2009

## Note

'left' and 'right' are usually set to be 0 and n-1, respectively where n is the length of 'a'.

Definition at line 200 of file ordering.c.

**9.62.2.4** void fasp\_aux\_iQuickSortIndex ( INT \* *a*, INT *left*, INT *right*, INT \* *index* )

Reorder the index of (INT type) so that 'a' is in ascending order.

## Parameters

<i>a</i>	Pointer to the array
<i>left</i>	Starting index
<i>right</i>	Ending index
<i>index</i>	Index of 'a' (out)

## Author

Zhiyang Zhou

## Date

2009/12/02

## Note

'left' and 'right' are usually set to be 0 and n-1, respectively, where n is the length of 'a'. 'index' should be initialized in the nature order and it has the same length as 'a'.

Definition at line 278 of file ordering.c.

**9.62.2.5** void fasp\_aux\_merge ( INT *numbers*[], INT *work*[], INT *left*, INT *mid*, INT *right* )

Merge two sorted arrays.

## Parameters

<i>numbers</i>	Pointer to the array needed to be sorted
<i>work</i>	Pointer to the work array with same size as numbers
<i>left</i>	Starting index of array 1
<i>mid</i>	Starting index of array 2
<i>right</i>	Ending index of array 1 and 2

## Author

Chensong Zhang

## Date

11/21/2010

## Note

Both arraies are stored in numbers! Arraies should be pre-sorted!

Definition at line 107 of file ordering.c.

9.62.2.6 void fasp\_aux\_msort ( INT *numbers*[], INT *work*[], INT *left*, INT *right* )

Sort the INT array ascendingly with the merge sort algorithm.

## Parameters

<i>numbers</i>	Pointer to the array needed to be sorted
<i>work</i>	Pointer to the work array with same size as numbers
<i>left</i>	Starting index
<i>right</i>	Ending index

## Author

Chensong Zhang

## Date

11/21/2010

## Note

'left' and 'right' are usually set to be 0 and n-1, respectively

Definition at line 169 of file ordering.c.

9.62.2.7 INT fasp\_aux\_unique ( INT *numbers*[], INT *size* )

Remove duplicates in an sorted (ascending order) array.

**Parameters**

<i>numbers</i>	Pointer to the array needed to be sorted (in/out)
<i>size</i>	Length of the target array

**Returns**

New size after removing duplicates

**Author**

Chensong Zhang

**Date**

11/21/2010

**Note**

Operation is in place. Does not use any extra or temporary storage.

Definition at line 74 of file ordering.c.

**9.62.2.8 INT fasp\_BinarySearch ( INT \* *list*, INT *value*, INT *list\_length* )**

Binary Search.

**Parameters**

<i>list</i>	Pointer to a set of values
<i>value</i>	The target
<i>list_length</i>	Length of the array list

**Returns**

The location of value in array list if succeeded, otherwise, return -1.

**Author**

Chunsheng Feng

**Date**

03/01/2011

Definition at line 29 of file ordering.c.

## 9.63 parameters.c File Reference

Initialize, set, or print input data and parameters.

```
#include <stdio.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_param\\_set](#) (int argc, const char \*argv[], [input\\_param](#) \*iniparam)  
*Read input from command-line arguments.*
- void [fasp\\_param\\_init](#) ([input\\_param](#) \*iniparam, [itsolver\\_param](#) \*itsparam, [AMG\\_param](#) \*amgparam, [ILU\\_param](#) \*iluparam, [Schwarz\\_param](#) \*schparam)  
*Initialize parameters, global variables, etc.*
- void [fasp\\_param\\_input\\_init](#) ([input\\_param](#) \*iniparam)  
*Initialize input parameters.*
- void [fasp\\_param\\_amg\\_init](#) ([AMG\\_param](#) \*amgparam)  
*Initialize AMG parameters.*
- void [fasp\\_param\\_solver\\_init](#) ([itsolver\\_param](#) \*itsparam)  
*Initialize [itsolver\\_param](#).*
- void [fasp\\_param\\_ilu\\_init](#) ([ILU\\_param](#) \*iluparam)  
*Initialize ILU parameters.*
- void [fasp\\_param\\_schwarz\\_init](#) ([Schwarz\\_param](#) \*schparam)  
*Initialize Schwarz parameters.*
- void [fasp\\_param\\_amg\\_set](#) ([AMG\\_param](#) \*param, [input\\_param](#) \*iniparam)  
*Set [AMG\\_param](#) from INPUT.*
- void [fasp\\_param\\_ilu\\_set](#) ([ILU\\_param](#) \*iluparam, [input\\_param](#) \*iniparam)  
*Set [ILU\\_param](#) with INPUT.*
- void [fasp\\_param\\_schwarz\\_set](#) ([Schwarz\\_param](#) \*schparam, [input\\_param](#) \*iniparam)  
*Set [Schwarz\\_param](#) with INPUT.*
- void [fasp\\_param\\_solver\\_set](#) ([itsolver\\_param](#) \*itsparam, [input\\_param](#) \*iniparam)  
*Set [itsolver\\_param](#) with INPUT.*
- void [fasp\\_param\\_amg\\_to\\_prec](#) ([precond\\_data](#) \*pcdata, [AMG\\_param](#) \*amgparam)  
*Set [precond\\_data](#) with [AMG\\_param](#).*
- void [fasp\\_param\\_prec\\_to\\_amg](#) ([AMG\\_param](#) \*amgparam, [precond\\_data](#) \*pcdata)  
*Set [AMG\\_param](#) with [precond\\_data](#).*
- void [fasp\\_param\\_amg\\_to\\_prec\\_bsr](#) ([precond\\_data\\_bsr](#) \*pcdata, [AMG\\_param](#) \*amgparam)  
*Set [precond\\_data\\_bsr](#) with [AMG\\_param](#).*
- void [fasp\\_param\\_prec\\_to\\_amg\\_bsr](#) ([AMG\\_param](#) \*amgparam, [precond\\_data\\_bsr](#) \*pcdata)  
*Set [AMG\\_param](#) with [precond\\_data](#).*
- void [fasp\\_param\\_amg\\_print](#) ([AMG\\_param](#) \*param)  
*Print out AMG parameters.*
- void [fasp\\_param\\_ilu\\_print](#) ([ILU\\_param](#) \*param)  
*Print out ILU parameters.*
- void [fasp\\_param\\_schwarz\\_print](#) ([Schwarz\\_param](#) \*param)  
*Print out Schwarz parameters.*
- void [fasp\\_param\\_solver\\_print](#) ([itsolver\\_param](#) \*param)  
*Print out itsolver parameters.*

### 9.63.1 Detailed Description

Initialize, set, or print input data and parameters.

Definition in file [parameters.c](#).

### 9.63.2 Function Documentation

9.63.2.1 void fasp\_param\_amg\_init ( AMG\_param \* *amgparam* )

Initialize AMG parameters.

## Parameters

<i>amgparam</i>	Parameters for AMG
-----------------	--------------------

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 387 of file parameters.c.

9.63.2.2 void fasp\_param\_amg\_print ( AMG\_param \* param )

Print out AMG parameters.

## Parameters

<i>param</i>	Parameters for AMG
--------------	--------------------

## Author

Chensong Zhang

## Date

2010/03/22

Definition at line 787 of file parameters.c.

9.63.2.3 void fasp\_param\_amg\_set ( AMG\_param \* param, input\_param \* iniparam )

Set [AMG\\_param](#) from INPUT.

## Parameters

<i>param</i>	Parameters for AMG
<i>iniparam</i>	Input parameters

## Author

Chensong Zhang

## Date

2010/03/23

Definition at line 510 of file parameters.c.

9.63.2.4 void fasp\_param\_amg\_to\_prec ( precondition\_data \* pcddata, AMG\_param \* amgparam )

Set [precond\\_data](#) with [AMG\\_param](#).

## Parameters

<i>pcdata</i>	Preconditioning data structure
<i>amgparam</i>	Parameters for AMG

## Author

Chensong Zhang

## Date

2011/01/10

Definition at line 656 of file parameters.c.

9.63.2.5 void fasp\_param\_amg\_to\_prec\_bsr ( precondition\_data\_bsr \* *pcdata*, AMG\_param \* *amgparam* )

Set [precond\\_data\\_bsr](#) with [AMG\\_param](#).

## Parameters

<i>pcdata</i>	Preconditioning data structure
<i>amgparam</i>	Parameters for AMG

## Author

Xiaozhe Hu

## Date

02/06/2012

Definition at line 723 of file parameters.c.

9.63.2.6 void fasp\_param\_ilu\_init ( ILU\_param \* *iluparam* )

Initialize ILU parameters.

## Parameters

<i>iluparam</i>	Parameters for ILU
-----------------	--------------------

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 471 of file parameters.c.

9.63.2.7 void fasp\_param\_ilu\_print ( ILU\_param \* *param* )

Print out ILU parameters.



## Parameters

<i>param</i>	Parameters for ILU
--------------	--------------------

## Author

Chensong Zhang

## Date

2011/12/20

Definition at line 887 of file parameters.c.

9.63.2.8 void fasp\_param\_ilu\_set ( ILU\_param \* *iluparam*, input\_param \* *iniparam* )

Set [ILU\\_param](#) with INPUT.

## Parameters

<i>iluparam</i>	Parameters for ILU
<i>iniparam</i>	Input parameters

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 584 of file parameters.c.

9.63.2.9 void fasp\_param\_init ( input\_param \* *iniparam*, itsolver\_param \* *itsparam*, AMG\_param \* *amgparam*, ILU\_param \* *iluparam*, Schwarz\_param \* *schparam* )

Initialize parameters, global variables, etc.

## Parameters

<i>iniparam</i>	Input parameters
<i>itsparam</i>	Iterative solver parameters
<i>amgparam</i>	AMG parameters
<i>iluparam</i>	ILU parameters
<i>schparam</i>	Schwarz parameters

## Author

Chensong Zhang

## Date

2010/08/12

Modified by Xiaozhe Hu (01/23/2011): initialize, then set value Modified by Chensong Zhang (09/12/2012): find a bug during debugging in VS08 Modified by Chensong Zhang (12/29/2013): rewritten

Definition at line 270 of file parameters.c.

9.63.2.10 void fasp\_param\_input\_init ( input\_param \* *iniparam* )

Initialize input parameters.

Parameters

<i>iniparam</i>	Input parameters
-----------------	------------------

Author

Chensong Zhang

Date

2010/03/20

Definition at line 310 of file parameters.c.

9.63.2.11 void fasp\_param\_prec\_to\_amg ( AMG\_param \* *amgparam*, precondition\_data \* *pcdata* )

Set [AMG\\_param](#) with [precond\\_data](#).

Parameters

<i>amgparam</i>	Parameters for AMG
<i>pcdata</i>	Preconditioning data structure

Author

Chensong Zhang

Date

2011/01/10

Definition at line 691 of file parameters.c.

9.63.2.12 void fasp\_param\_prec\_to\_amg\_bsr ( AMG\_param \* *amgparam*, precondition\_data\_bsr \* *pcdata* )

Set [AMG\\_param](#) with [precond\\_data](#).

Parameters

<i>amgparam</i>	Parameters for AMG
<i>pcdata</i>	Preconditioning data structure

Author

Xiaozhe Hu

Date

02/06/2012

Definition at line 757 of file parameters.c.

9.63.2.13 void fasp\_param\_schwarz\_init ( **Schwarz\_param** \* *schparam* )

Initialize Schwarz parameters.

## Parameters

<i>schparam</i>	Parameters for Schwarz method
-----------------	-------------------------------

## Author

Xiaozhe Hu

## Date

05/22/2012

Definition at line 491 of file parameters.c.

9.63.2.14 void fasp\_param\_schwarz\_print ( **Schwarz\_param** \* *param* )

Print out Schwarz parameters.

## Parameters

<i>param</i>	Parameters for Schwarz
--------------	------------------------

## Author

Xiaozhe Hu

## Date

05/22/2012

Definition at line 917 of file parameters.c.

9.63.2.15 void fasp\_param\_schwarz\_set ( **Schwarz\_param** \* *schparam*, **input\_param** \* *iniparam* )

Set [Schwarz\\_param](#) with INPUT.

## Parameters

<i>schparam</i>	Parameters for Schwarz method
<i>iniparam</i>	Input parameters

## Author

Xiaozhe Hu

## Date

05/22/2012

Definition at line 606 of file parameters.c.

9.63.2.16 void fasp\_param\_set ( int *argc*, const char \* *argv*[], **input\_param** \* *iniparam* )

Read input from command-line arguments.

## Parameters

<i>argc</i>	Number of arg input
<i>argv</i>	Input arguments
<i>iniparam</i>	Parameters to be set

## Author

Chensong Zhang

## Date

12/29/2013

Definition at line 27 of file parameters.c.

9.63.2.17 void fasp\_param\_solver\_init ( itsolver\_param \* *itsparam* )

Initialize [itsolver\\_param](#).

## Parameters

<i>itsparam</i>	Parameters for iterative solvers
-----------------	----------------------------------

## Author

Chensong Zhang

## Date

2010/03/23

Definition at line 450 of file parameters.c.

9.63.2.18 void fasp\_param\_solver\_print ( itsolver\_param \* *param* )

Print out itsolver parameters.

## Parameters

<i>param</i>	Parameters for iterative solvers
--------------	----------------------------------

## Author

Chensong Zhang

## Date

2011/12/20

Definition at line 946 of file parameters.c.

9.63.2.19 void fasp\_param\_solver\_set ( itsolver\_param \* *itsparam*, input\_param \* *iniparam* )

Set [itsolver\\_param](#) with INPUT.

## Parameters

<i>itsparam</i>	Parameters for iterative solvers
<i>iniparam</i>	Input parameters

## Author

Chensong Zhang

## Date

2010/03/23

Definition at line 626 of file parameters.c.

## 9.64 pbcgs.c File Reference

Krylov subspace methods – Preconditioned BiCGstab.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- `INT fasp_solver_dcsr_pbcgs (dCSRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*Preconditioned BiCGstab method for solving  $Au=b$ .*
- `INT fasp_solver_dbsr_pbcgs (dBSRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*Preconditioned BiCGstab method for solving  $Au=b$ .*
- `INT fasp_solver_bdcsr_pbcgs (block_dCSRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*A preconditioned BiCGstab method for solving  $Au=b$ .*
- `INT fasp_solver_dstr_pbcgs (dSTRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*Preconditioned BiCGstab method for solving  $Au=b$ .*

### 9.64.1 Detailed Description

Krylov subspace methods – Preconditioned BiCGstab.

Abstract algorithm

PBICGStab method to solve  $A*x=b$  is to generate  $\{x_k\}$  to approximate  $x$ Note: We generate a series of  $\{p_k\}$  such that  $V_k=\text{span}\{p_1, \dots, p_k\}$ .Step 0. Given  $A, b, x_0, M$ Step 1. Compute residual  $r_0 = b - A*x_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}r_0$ ,  $p_0 = z_0$ ;

Step 3. Main loop ...

FOR  $k = 0:MaxIt$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha p_k$ ;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha(Ap_k)$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of  $k$ -th iteration; END FOR

Convergence check:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check:

- IF  $\text{norm}(\alpha p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
See [spbcgs.c](#) for a safer version

Definition in file [pbcgs.c](#).

### 9.64.2 Function Documentation

9.64.2.1 **INT fasp\_solver\_bdcsr\_pbcgs ( block\_dCSRmat \* A, dvector \* b, dvector \* u, precondition \* pc, const REAL tol, const INT MaxIt, const SHORT stop\_type, const SHORT print\_level )**

A preconditioned BiCGstab method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to the coefficient matrix
<i>b</i>	Pointer to the dvector of right hand side
<i>u</i>	Pointer to the dvector of DOFs
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Xiaozhe Hu

## Date

05/24/2010

Rewritten by Chensong Zhang on 04/30/2012 Modified by Feiteng Huang on 06/01/2012: fix restart param-init Modified by Chensong Zhang on 03/31/2013

Definition at line 767 of file pbcgs.c.

**9.64.2.2** `INT fasp_solver_dbsr_pbcgs ( dBSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned BiCGstab method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to the coefficient matrix
<i>b</i>	Pointer to the dvector of right hand side
<i>u</i>	Pointer to the dvector of DOFs
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang



## Date

09/09/2009

Rewritten by Chensong Zhang on 04/30/2012 Modified by Feiteng Huang on 06/01/2012: fix restart param-init Modified by Chensong Zhang on 03/31/2013

Definition at line 428 of file pbcgs.c.

**9.64.2.3** `INT fasp_solver_dcsr_pbcgs ( dCSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned BiCGstab method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to the coefficient matrix
<i>b</i>	Pointer to the dvector of right hand side
<i>u</i>	Pointer to the dvector of DOFs
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

09/09/2009

Rewritten by Chensong Zhang on 04/30/2012 Modified by Feiteng Huang on 06/01/2012: fix restart param-init Modified by Chensong Zhang on 03/31/2013

Definition at line 89 of file pbcgs.c.

**9.64.2.4** `INT fasp_solver_dstr_pbcgs ( dSTRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned BiCGstab method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to the coefficient matrix
----------	-----------------------------------

<i>b</i>	Pointer to the dvector of right hand side
<i>u</i>	Pointer to the dvector of DOFs
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Zhiyang Zhou

#### Date

04/25/2010

Rewritten by Chensong Zhang on 04/30/2012 Modified by Feiteng Huang on 06/01/2012: fix restart param-init Modified by Chensong Zhang on 03/31/2013

Definition at line 1106 of file pbcgs.c.

## 9.65 pbcgs\_mf.c File Reference

Krylov subspace methods – Preconditioned BiCGstab (matrix free)

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_pbcgs](#) ([mxv\\_matfree](#) \*mf, [dvector](#) \*b, [dvector](#) \*u, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)

*Preconditioned BiCGstab method for solving  $Au=b$ .*

#### 9.65.1 Detailed Description

Krylov subspace methods – Preconditioned BiCGstab (matrix free)

Abstract algorithm of Krylov method

Krylov method to solve  $A*x=b$  is to generate  $\{x_k\}$  to approximate  $x$ , where  $x_k$  is the optimal solution in Krylov space

$V_k = \text{span}\{r_0, A*r_0, A^2*r_0, \dots, A^{k-1}*r_0\}$ ,

under some inner product.

For the implementation, we generate a series of  $\{p_k\}$  such that  $V_k = \text{span}\{p_1, \dots, p_k\}$ . Details:

Step 0. Given  $A, b, x_0, M$

Step 1. Compute residual  $r_0 = b - A \cdot x_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1} \cdot r_0, p_0 = z_0$ ;

Step 3. Main loop ...

FOR  $k = 0 : \text{MaxIt}$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha \cdot p_k$ ;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha \cdot (A \cdot p_k)$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of  $k$ -th iteration; END FOR

Convergence check is:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check is like following:

- IF  $\text{norm}(\alpha \cdot p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A \cdot x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check is like following:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A \cdot x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM

Definition in file [pbcgs\\_mf.c](#).

## 9.65.2 Function Documentation

**9.65.2.1** `INT fasp_solver_pbcgs ( mxv_matfree * mf, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned BiCGstab method for solving  $Au=b$ .

## Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> : the spmv operation
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

09/09/2009

Rewritten by Chensong Zhang on 04/30/2012 Modified by Feiteng Huang on 06/01/2012: fix restart param-init Modified by Feiteng Huang on 09/26/2012, (mmatrix free)

Definition at line 91 of file pbcgs\_mf.c.

## 9.66 pcg.c File Reference

Krylov subspace methods – Preconditioned conjugate gradient.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- [INT fasp\\_solver\\_dcsr\\_pcg](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned conjugate gradient method for solving  $Au=b$ .*
- [INT fasp\\_solver\\_dbsr\\_pcg](#) ([dBSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned conjugate gradient method for solving  $Au=b$ .*
- [INT fasp\\_solver\\_bdcsr\\_pcg](#) ([block\\_dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned conjugate gradient method for solving  $Au=b$ .*
- [INT fasp\\_solver\\_dstr\\_pcg](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned conjugate gradient method for solving  $Au=b$ .*

### 9.66.1 Detailed Description

Krylov subspace methods – Preconditioned conjugate gradient.

Abstract algorithm

PCG method to solve  $A*x=b$  is to generate  $\{x_k\}$  to approximate  $x$

Step 0. Given  $A, b, x_0, M$

Step 1. Compute residual  $r_0 = b - A*x_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}*r_0, p_0=z_0$ ;

Step 3. Main loop ...

FOR  $k = 0:MaxIt$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha*p_k$ ;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha*(A*p_k)$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of  $k$ -th iteration; END FOR

Convergence check:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check:

- IF  $\text{norm}(\alpha*p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r=b-A*x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A*x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
See [spcg.c](#) for a safer version

Definition in file [pcg.c](#).

## 9.66.2 Function Documentation

9.66.2.1 **INT fasp\_solver\_bdcsr\_pcg ( block\_dCSRmat \* *A*, dvector \* *b*, dvector \* *u*, precondition \* *pc*, const REAL *tol*, const INT *MaxIt*, const SHORT *stop\_type*, const SHORT *print\_level* )**

Preconditioned conjugate gradient method for solving  $Au=b$ .

### Parameters

<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

### Returns

Number of iterations if converged, error message otherwise

### Author

Xiaozhe Hu

### Date

05/24/2010

Modified by Chensong Zhang on 04/30/2012 Modified by Chensong Zhang on 03/28/2013

Definition at line 646 of file pcg.c.

9.66.2.2 **INT fasp\_solver\_dbsr\_pcg ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, precondition \* *pc*, const REAL *tol*, const INT *MaxIt*, const SHORT *stop\_type*, const SHORT *print\_level* )**

Preconditioned conjugate gradient method for solving  $Au=b$ .

### Parameters

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

### Returns

Number of iterations if converged, error message otherwise

## Author

Xiaozhe Hu

## Date

05/26/2014

Definition at line 364 of file pcg.c.

**9.66.2.3** `INT fasp_solver_dcsr_pcg ( dCSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned conjugate gradient method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang, Xiaozhe Hu, Shiquan Zhang

## Date

05/06/2010

Modified by Chensong Zhang on 04/30/2012 Modified by Chensong Zhang on 03/28/2013

Definition at line 85 of file pcg.c.

**9.66.2.4** `INT fasp_solver_dstr_pcg ( dSTRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned conjugate gradient method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
----------	---

<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Zhiyang Zhou

#### Date

04/25/2010

Modified by Chensong Zhang on 04/30/2012 Modified by Chensong Zhang on 03/28/2013

Definition at line 927 of file pcg.c.

## 9.67 pcg\_mf.c File Reference

Krylov subspace methods – Preconditioned conjugate gradient (matrix free)

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- **INT fasp\_solver\_pcg** (**mxv\_matfree** \*mf, **dvector** \*b, **dvector** \*u, **precond** \*pc, const **REAL** tol, const **INT** MaxIt, const **SHORT** stop\_type, const **SHORT** print\_level)

*Preconditioned conjugate gradient (CG) method for solving  $Au=b$ .*

#### 9.67.1 Detailed Description

Krylov subspace methods – Preconditioned conjugate gradient (matrix free)

Abstract algorithm

PCG method to solve  $Ax=b$  is to generate  $\{x_k\}$  to approximate  $x$

Step 0. Given  $A$ ,  $b$ ,  $x_0$ ,  $M$

Step 1. Compute residual  $r_0 = b - Ax_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}r_0$ ,  $p_0 = z_0$ ;



Step 3. Main loop ...

FOR k = 0:MaxIt

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha * p_k$ ;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha * (A * p_k)$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of k-th iteration; END FOR

Convergence check is:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check is like following:

- IF  $\text{norm}(\alpha * p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A * x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check is like following:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A * x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM

Definition in file [pcg\\_mf.c](#).

## 9.67.2 Function Documentation

9.67.2.1 **INT fasp\_solver\_pcg ( mxv\_matfree \* mf, dvector \* b, dvector \* u, precondition \* pc, const REAL tol, const INT MaxIt, const SHORT stop\_type, const SHORT print\_level )**

Preconditioned conjugate gradient (CG) method for solving  $Au=b$ .

## Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> : the spmv operation
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang, Xiaozhe Hu, Shiquan Zhang

## Date

05/06/2010

Modified by Chensong Zhang on 04/30/2012 Modified by Feiteng Huang on 09/19/2012: matrix free

Definition at line 87 of file `pcg_mf.c`.

## 9.68 `pgcg.c` File Reference

Krylov subspace methods – Preconditioned Generalized CG.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- [INT fasp\\_solver\\_dcsr\\_pgcg](#) (dCSRmat \*A, dvector \*b, dvector \*u, precondition \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)

*Preconditioned generalized conjugate gradient (GCG) method for solving  $Au=b$ .*

### 9.68.1 Detailed Description

Krylov subspace methods – Preconditioned Generalized CG.

## Note

Refer to Concus, P. and Golub, G.H. and O'Leary, D.P. A Generalized Conjugate Gradient Method for the Numerical: Solution of Elliptic Partial Differential Equations, Computer Science Department, Stanford University, 1976

Definition in file [pgcg.c](#).

### 9.68.2 Function Documentation

9.68.2.1 **INT** fasp\_solver\_dcsr\_pgcg ( **dCSRmat** \* *A*, **dvector** \* *b*, **dvector** \* *u*, **precond** \* *pc*, const **REAL** *tol*, const **INT** *MaxIt*, const **SHORT** *stop\_type*, const **SHORT** *print\_level* )

Preconditioned generalized conjugate gradient (GCG) method for solving  $Au=b$ .

#### Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Xiaozhe Hu

#### Date

01/01/2012

#### Note

Not completely implemented yet! —Chensong

Modified by Chensong Zhang on 05/01/2012

Definition at line 46 of file pgcg.c.

## 9.69 pgcg\_mf.c File Reference

Krylov subspace methods – Preconditioned Generalized CG (matrix free)

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- **INT** fasp\_solver\_pgcg (**mxv\_matfree** \**mf*, **dvector** \**b*, **dvector** \**u*, **precond** \**pc*, const **REAL** *tol*, const **INT** *MaxIt*, const **SHORT** *stop\_type*, const **SHORT** *print\_level*)

*Preconditioned generalized conjugate gradient (GCG) method for solving  $Au=b$ .*

### 9.69.1 Detailed Description

Krylov subspace methods – Preconditioned Generalized CG (matrix free)

#### Note

Refer to Concus, P. and Golub, G.H. and O'Leary, D.P. A Generalized Conjugate Gradient Method for the Numerical: Solution of Elliptic Partial Differential Equations, Computer Science Department, Stanford University, 1976

Definition in file [pgcg\\_mf.c](#).

### 9.69.2 Function Documentation

**9.69.2.1** `INT fasp_solver_pgcg ( mxv_matfree * mf, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned generalized conjugate gradient (GCG) method for solving  $Au=b$ .

#### Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> : the spmv operation
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type – Not implemented
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Xiaozhe Hu

#### Date

01/01/2012

#### Note

Not completely implemented yet! –Chensong

Modified by Chensong Zhang on 05/01/2012 Modified by Feiteng Huang on 09/26/2012: matrix free

Definition at line 47 of file [pgcg\\_mf.c](#).

## 9.70 pgmres.c File Reference

Krylov subspace methods – Preconditioned GMRes.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_dcsr\\_pgmres](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$ .*
- [INT fasp\\_solver\\_bdcsr\\_pgmres](#) ([block\\_dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$ .*
- [INT fasp\\_solver\\_dbsr\\_pgmres](#) ([dBSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$ .*
- [INT fasp\\_solver\\_dstr\\_pgmres](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$ .*

### 9.70.1 Detailed Description

Krylov subspace methods – Preconditioned GMRes.

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
See also [pvgmres.c](#) for a variable restarting version.  
See [spgmres.c](#) for a safer version

Definition in file [pgmres.c](#).

### 9.70.2 Function Documentation

9.70.2.1 [INT fasp\\_solver\\_bdcsr\\_pgmres](#) ( [block\\_dCSRmat](#) \* A, [dvector](#) \* b, [dvector](#) \* x, [precond](#) \* pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level )

Preconditioned GMRES method for solving  $Au=b$ .

#### Parameters

A	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
---	---

<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Xiaozhe Hu

**Date**

05/24/2010

Modified by Chensong Zhang on 05/01/2012 Modified by Chensong Zhang on 04/05/2013: add stop\_type and safe check

Definition at line 350 of file pgmres.c.

**9.70.2.2** `INT fasp_solver_dbsr_pgmres ( dBSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Preconditioned GMRES method for solving  $Au=b$ .

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Zhiyang Zhou

## Date

2010/12/21

Modified by Chensong Zhang on 05/01/2012 Modified by Chensong Zhang on 04/05/2013: add stop\_type and safe check

Definition at line 650 of file pgmres.c.

**9.70.2.3** `INT fasp_solver_dcsr_pgmres ( dCSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Preconditioned GMRES method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Zhiyang Zhou

## Date

2010/11/28

Modified by Chensong Zhang on 05/01/2012 Modified by Chensong Zhang on 04/05/2013: Add stop\_type and safe check Modified by Chunsheng Feng on 07/22/2013: Add adapt memory allocate Modified by Chensong Zhang on 07/30/2014: Make memory allocation size long int

Definition at line 50 of file pgmres.c.

**9.70.2.4** `INT fasp_solver_dstr_pgmres ( dSTRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Preconditioned GMRES method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Zhiyang Zhou

#### Date

2010/11/28

Modified by Chensong Zhang on 05/01/2012 Modified by Chensong Zhang on 04/05/2013: add stop\_type and safe check

Definition at line 950 of file pgmres.c.

## 9.71 pgmres\_mf.c File Reference

Krylov subspace methods – Preconditioned GMRes (matrix free)

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_pgmres](#) ([mxv\\_matfree](#) \*mf, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Solve "Ax=b" using PGMRES (right preconditioned) iterative method.*

#### 9.71.1 Detailed Description

Krylov subspace methods – Preconditioned GMRes (matrix free)

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
Refer to A.H. Baker, E.R. Jessup, and Tz.V. Kolev A Simple Strategy for Varying the Restart Parameter in GMR↔ES(m) Journal of Computational and Applied Mathematics, 230 (2009) pp. 751-761. UCRL-JRNL-235266.

Definition in file [pgmres\\_mf.c](#).



### 9.71.2 Function Documentation

9.71.2.1 **INT** fasp\_solver\_pgmres ( **mxv\_matfree** \* *mf*, **dvector** \* *b*, **dvector** \* *x*, **precond** \* *pc*, **const REAL** *tol*, **const INT** *MaxIt*, **const SHORT** *restart*, **const SHORT** *stop\_type*, **const SHORT** *print\_level* )

Solve "Ax=b" using PGMRES (right preconditioned) iterative method.

#### Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> : the spmv operation
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type – DOES not support this parameter
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Zhiyang Zhou

#### Date

2010/11/28

Modified by Chensong Zhang on 05/01/2012 Modified by Feiteng Huang on 09/26/2012: matrix free Modified by Chunsheng Feng on 07/22/2013: Add adapt memory allocate

Definition at line 51 of file pgmres\_mf.c.

## 9.72 pminres.c File Reference

Krylov subspace methods – Preconditioned minimal residual.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- **INT** fasp\_solver\_dcsr\_pminres (**dCSRmat** \**A*, **dvector** \**b*, **dvector** \**u*, **precond** \**pc*, **const REAL** *tol*, **const INT** *MaxIt*, **const SHORT** *stop\_type*, **const SHORT** *print\_level*)

*A preconditioned minimal residual (Minres) method for solving  $Au=b$ .*

- `INT fasp_solver_bdcsr_pminres (block_dCSRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`

*A preconditioned minimal residual (Minres) method for solving  $Au=b$ .*

- `INT fasp_solver_dstr_pminres (dSTRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`

*A preconditioned minimal residual (Minres) method for solving  $Au=b$ .*

### 9.72.1 Detailed Description

Krylov subspace methods – Preconditioned minimal residual.

Abstract algorithm of Krylov method

Krylov method to solve  $Ax=b$  is to generate  $\{x_k\}$  to approximate  $x$ , where  $x_k$  is the optimal solution in Krylov space

$V_k = \text{span}\{r_0, A*r_0, A^2*r_0, \dots, A^{k-1}*r_0\}$ ,

under some inner product.

For the implementation, we generate a series of  $\{p_k\}$  such that  $V_k = \text{span}\{p_1, \dots, p_k\}$ . Details:

Step 0. Given  $A$ ,  $b$ ,  $x_0$ ,  $M$

Step 1. Compute residual  $r_0 = b - A*x_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}*r_0$ ,  $p_0 = z_0$ ;

Step 3. Main loop ...

FOR  $k = 0:\text{MaxIt}$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha*p_k$ ;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha*(A*p_k)$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of  $k$ -th iteration; END FOR

Convergence check:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check:

- IF  $\text{norm}(\alpha*p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A*x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A * x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

**Note**

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
 See [spminres.c](#) for a safer version

Definition in file [pminres.c](#).

**9.72.2 Function Documentation**

**9.72.2.1** `INT fasp_solver_bdcsr_pminres ( block_dCSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

A preconditioned minimal residual (Minres) method for solving  $Au=b$ .

**Parameters**

<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Chensong Zhang

**Date**

05/01/2012

**Note**

Rewritten based on the original version by Xiaozhe Hu 05/24/2010

Modified by Chensong Zhang on 04/09/2013

Definition at line 499 of file pminres.c.

**9.72.2.2** `INT fasp_solver_dcsr_pminres ( dCSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

A preconditioned minimal residual (Minres) method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

05/01/2012

## Note

Rewritten based on the original version by Shiquan Zhang 05/10/2010

Modified by Chensong Zhang on 04/09/2013

Definition at line 93 of file pminres.c.

**9.72.2.3** `INT fasp_solver_dstr_pminres ( dSTRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

A preconditioned minimal residual (Minres) method for solving  $Au=b$ .

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

04/09/2013

Definition at line 901 of file pminres.c.

## 9.73 pminres\_mf.c File Reference

Krylov subspace methods – Preconditioned minimal residual (matrix free)

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- `INT fasp_solver_pminres (mxv_matfree *mf, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*A preconditioned minimal residual (Minres) method for solving  $Au=b$ .*

#### 9.73.1 Detailed Description

Krylov subspace methods – Preconditioned minimal residual (matrix free)

Abstract algorithm of Krylov method

Krylov method to solve  $A*x=b$  is to generate  $\{x_k\}$  to approximate  $x$ , where  $x_k$  is the optimal solution in Krylov space

$V_k = \text{span}\{r_0, A*r_0, A^2*r_0, \dots, A^{k-1}*r_0\}$ ,

under some inner product.

For the implementation, we generate a series of  $\{p_k\}$  such that  $V_k = \text{span}\{p_1, \dots, p_k\}$ . Details:

Step 0. Given  $A$ ,  $b$ ,  $x_0$ ,  $M$

Step 1. Compute residual  $r_0 = b - A*x_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}*r_0$ ,  $p_0 = z_0$ ;

Step 3. Main loop ...

FOR  $k = 0:\text{MaxIt}$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha*p_k$ ;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha*(A*p_k)$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;

- print the result of k-th iteration; END FOR

Convergence check is:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check is like following:

- IF  $\text{norm}(\alpha * p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A * x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check is like following:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A * x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM

Definition in file [pminres\\_mf.c](#).

## 9.73.2 Function Documentation

**9.73.2.1** `INT fasp_solver_pminres ( mxv_matfree * mf, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

A preconditioned minimal residual (Minres) method for solving  $Au=b$ .

#### Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> : the spmv operation
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

**Author**

Shiquan Zhang

**Date**

10/24/2010

Rewritten by Chensong Zhang on 05/01/2012 Modified by Feiteng Huang on 09/26/2012: matrix free

Definition at line 90 of file pminres\_mf.c.

## 9.74 precondition\_bcsr.c File Reference

Preconditioners.

```
#include "fasp.h"
#include "fasp_block.h"
#include "fasp_functs.h"
```

**Functions**

- void [fasp\\_precond\\_block\\_diag\\_3](#) (double \*r, double \*z, void \*data)  
*block diagonal preconditioning*
- void [fasp\\_precond\\_block\\_diag\\_3\\_amg](#) (double \*r, double \*z, void \*data)  
*block diagonal preconditioning reservoir-reservoir block: AMG for pressure-pressure block, Jacobi for saturation-saturation block*
- void [fasp\\_precond\\_block\\_diag\\_4](#) (double \*r, double \*z, void \*data)  
*block diagonal preconditioning*
- void [fasp\\_precond\\_block\\_lower\\_3](#) (double \*r, double \*z, void \*data)  
*block lower triangular preconditioning*
- void [fasp\\_precond\\_block\\_lower\\_3\\_amg](#) (double \*r, double \*z, void \*data)
- void [fasp\\_precond\\_block\\_lower\\_4](#) (double \*r, double \*z, void \*data)  
*block lower triangular preconditioning*
- void [fasp\\_precond\\_sweeping](#) (double \*r, double \*z, void \*data)  
*sweeping preconditioner for Maxwell equations*

### 9.74.1 Detailed Description

Preconditioners.

Definition in file [precond\\_bcsr.c](#).

### 9.74.2 Function Documentation

**9.74.2.1** void [fasp\\_precond\\_block\\_diag\\_3](#) ( double \* r, double \* z, void \* data )

block diagonal preconditioning

**Parameters**

<i>*r</i>	pointer to residual
<i>*z</i>	pointer to preconditioned residual
<i>*data</i>	pointer to precondition data

**Author**

Xiaozhe Hu

**Date**

07/10/2014

back up r, setup z;

prepare

Preconditioning A00 block

Preconditioning A11 block

Preconditioning A22 block

restore r

Definition at line 26 of file precondition\_bcsr.c.

9.74.2.2 void fasp\_precond\_block\_diag\_3\_amg ( double \* r, double \* z, void \* data )

block diagonal preconditioning reservoir-reservoir block: AMG for pressure-pressure block, Jacobi for saturation-saturation block

**Parameters**

<i>*r</i>	pointer to residual
<i>*z</i>	pointer to preconditioned residual
<i>*data</i>	pointer to precondition data

**Author**

Xiaozhe Hu

back up r, setup z;

prepare

Preconditioning A00 block

Preconditioning A11 block

Preconditioning A22 block

restore r

Definition at line 104 of file precondition\_bcsr.c.

9.74.2.3 void fasp\_precond\_block\_diag\_4 ( double \* r, double \* z, void \* data )

block diagonal preconditioning



## Parameters

<i>*r</i>	pointer to residual
<i>*z</i>	pointer to preconditioned residual
<i>*data</i>	pointer to precondition data

## Author

Xiaozhe Hu

back up r, setup z;

prepare

Preconditioning A00 block

Preconditioning A11 block

Preconditioning A22 block

Preconditioning A33 block

restore r

Definition at line 167 of file precondition\_bcsr.c.

## 9.74.2.4 void fasp\_precond\_block\_lower\_3 ( double \* r, double \* z, void \* data )

block lower triangular preconditioning

block diagonal preconditioning reservoir-reservoir block: AMG for pressure-pressure block, Jacobi for saturation-saturation block

## Parameters

<i>*r</i>	pointer to residual
<i>*z</i>	pointer to preconditioned residual
<i>*data</i>	pointer to precondition data

## Author

Xiaozhe Hu

## Date

07/10/2014

## Parameters

<i>*r</i>	pointer to residual
<i>*z</i>	pointer to preconditioned residual
<i>*data</i>	pointer to precondition data

## Author

Xiaozhe Hu

back up r, setup z;

prepare

Preconditioning A00 block

Preconditioning A11 block

Preconditioning A22 block

restore r

Definition at line 257 of file precondition\_bcsr.c.

**9.74.2.5 void fasp\_precond\_block\_lower\_3\_amg ( double \* r, double \* z, void \* data )**

back up r, setup z;

prepare

Preconditioning A00 block

Preconditioning A11 block

Preconditioning A22 block

restore r

Definition at line 342 of file precondition\_bcsr.c.

**9.74.2.6 void fasp\_precond\_block\_lower\_4 ( double \* r, double \* z, void \* data )**

block lower triangular preconditioning

Parameters

*r	pointer to residual
*z	pointer to preconditioned residual
*data	pointer to precondition data

Author

Xiaozhe Hu

back up r, setup z;

prepare

Preconditioning A00 block

Preconditioning A11 block

Preconditioning A22 block

Preconditioning A33 block

restore r

Definition at line 413 of file precondition\_bcsr.c.

**9.74.2.7 void fasp\_precond\_sweeping ( double \* r, double \* z, void \* data )**

sweeping preconditioner for Maxwell equations

## Parameters

<code>*r</code>	pointer to residual
<code>*z</code>	pointer to preconditioned residual
<code>*data</code>	pointer to precondition data

## Author

Xiaozhe Hu

## Date

05/01/2014

back up r, setup z;

restore r

Definition at line 516 of file precondition\_bcsr.c.

## 9.75 precondition\_bsr.c File Reference

Preconditioners for [dBSRmat](#) matrices.

```
#include "fasp.h"
#include "fasp_functs.h"
#include "mg_util.inl"
```

## Functions

- void [fasp\\_precond\\_dbsr\\_diag](#) (REAL \*r, REAL \*z, void \*data)  
*Diagonal preconditioner  $z=inv(D)*r$ .*
- void [fasp\\_precond\\_dbsr\\_diag\\_nc2](#) (REAL \*r, REAL \*z, void \*data)  
*Diagonal preconditioner  $z=inv(D)*r$ .*
- void [fasp\\_precond\\_dbsr\\_diag\\_nc3](#) (REAL \*r, REAL \*z, void \*data)  
*Diagonal preconditioner  $z=inv(D)*r$ .*
- void [fasp\\_precond\\_dbsr\\_diag\\_nc5](#) (REAL \*r, REAL \*z, void \*data)  
*Diagonal preconditioner  $z=inv(D)*r$ .*
- void [fasp\\_precond\\_dbsr\\_diag\\_nc7](#) (REAL \*r, REAL \*z, void \*data)  
*Diagonal preconditioner  $z=inv(D)*r$ .*
- void [fasp\\_precond\\_dbsr\\_ilu](#) (REAL \*r, REAL \*z, void \*data)  
*ILU preconditioner.*
- void [fasp\\_precond\\_dbsr\\_amg](#) (REAL \*r, REAL \*z, void \*data)  
*AMG preconditioner.*
- void [fasp\\_precond\\_dbsr\\_nl\\_amli](#) (REAL \*r, REAL \*z, void \*data)  
*Nonlinear AMLI-cycle AMG preconditioner.*
- void [fasp\\_precond\\_dbsr\\_amg\\_nk](#) (REAL \*r, REAL \*z, void \*data)  
*AMG with extra near kernel solve preconditioner.*

### 9.75.1 Detailed Description

Preconditioners for [dBSRmat](#) matrices.

Definition in file [precond\\_bsr.c](#).

### 9.75.2 Function Documentation

#### 9.75.2.1 void fasp\_precond\_dbsr\_amg ( REAL \* *r*, REAL \* *z*, void \* *data* )

AMG preconditioner.

Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

Author

Xiaozhe Hu

Date

08/07/2011

Definition at line 563 of file [precond\\_bsr.c](#).

#### 9.75.2.2 void fasp\_precond\_dbsr\_amg\_nk ( REAL \* *r*, REAL \* *z*, void \* *data* )

AMG with extra near kernel solve preconditioner.

Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

Author

Xiaozhe Hu

Date

05/26/2014

Definition at line 642 of file [precond\\_bsr.c](#).

#### 9.75.2.3 void fasp\_precond\_dbsr\_diag ( REAL \* *r*, REAL \* *z*, void \* *data* )

Diagonal preconditioner  $z = \text{inv}(D) * r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Zhou Zhiyang, Xiaozhe Hu

## Date

10/26/2010

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/24/2012

## Note

Works for general nb (Xiaozhe)

Definition at line 37 of file precondition\_bsr.c.

9.75.2.4 void fasp\_precond\_dbsr\_diag\_nc2 ( REAL \* *r*, REAL \* *z*, void \* *data* )

Diagonal preconditioner  $z = \text{inv}(D) * r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Zhou Zhiyang, Xiaozhe Hu

## Date

11/18/2011

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/24/2012

## Note

Works for 2-component (Xiaozhe)

Definition at line 111 of file precondition\_bsr.c.

9.75.2.5 void fasp\_precond\_dbsr\_diag\_nc3 ( REAL \* *r*, REAL \* *z*, void \* *data* )

Diagonal preconditioner  $z = \text{inv}(D) * r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Zhou Zhiyang, Xiaozhe Hu

## Date

01/06/2011

Modified by Chunsheng Feng Xiaoqiang Yue

## Date

05/24/2012

## Note

Works for 3-component (Xiaozhe)

Definition at line 161 of file precondition\_bsr.c.

9.75.2.6 void fasp\_precond\_dbsr\_diag\_nc5 ( REAL \* *r*, REAL \* *z*, void \* *data* )

Diagonal preconditioner  $z = \text{inv}(D) * r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Zhou Zhiyang, Xiaozhe Hu

## Date

01/06/2011

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/24/2012

## Note

Works for 5-component (Xiaozhe)

Definition at line 211 of file precondition\_bsr.c.

9.75.2.7 void fasp\_precond\_dbsr\_diag\_nc7 ( REAL \* *r*, REAL \* *z*, void \* *data* )

Diagonal preconditioner  $z = \text{inv}(D) * r$ .



## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Zhou Zhiyang, Xiaozhe Hu

## Date

01/06/2011

Modified by Chunsheng Feng Xiaoqiang Yue

## Date

05/24/2012

## Note

Works for 7-component (Xiaozhe)

Definition at line 260 of file precondition\_bsr.c.

9.75.2.8 void fasp\_precond\_dbsr\_ilu ( REAL \* *r*, REAL \* *z*, void \* *data* )

ILU preconditioner.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

11/09/2010

## Note

Works for general nb (Xiaozhe)

Definition at line 306 of file precondition\_bsr.c.

9.75.2.9 void fasp\_precond\_dbsr\_nl\_amli ( REAL \* *r*, REAL \* *z*, void \* *data* )

Nonlinear AMLI-cycle AMG preconditioner.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Xiaozhe Hu

## Date

02/06/2012

Definition at line 606 of file `precond_bsr.c`.

## 9.76 `precond_csr.c` File Reference

Preconditioners for `dCSRmat` matrices.

```
#include "fasp.h"
#include "fasp_functs.h"
#include "forts_ns.h"
#include "mg_util.inl"
```

## Functions

- `precond * fasp_precond_setup` (`SHORT` `precond_type`, `AMG_param` `*amgparam`, `ILU_param` `*iluparam`, `dCSRmat` `*A`)  
*Setup preconditioner interface for iterative methods.*
- `void fasp_precond_diag` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*Diagonal preconditioner  $z = \text{inv}(D) * r$ .*
- `void fasp_precond_ilu` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*ILU preconditioner.*
- `void fasp_precond_ilu_forward` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*ILU preconditioner: only forward sweep.*
- `void fasp_precond_ilu_backward` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*ILU preconditioner: only backward sweep.*
- `void fasp_precond_schwarz` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*get  $z$  from  $r$  by schwarz*
- `void fasp_precond_amg` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*AMG preconditioner.*
- `void fasp_precond_famg` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*Full AMG preconditioner.*
- `void fasp_precond_amli` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*AMLI AMG preconditioner.*
- `void fasp_precond_nl_amli` (`REAL` `*r`, `REAL` `*z`, `void` `*data`)  
*Nonlinear AMLI AMG preconditioner.*

- void [fasp\\_precond\\_amg\\_nk](#) ([REAL](#) \**r*, [REAL](#) \**z*, void \**data*)  
*AMG with extra near kernel solve as preconditioner.*
- void [fasp\\_precond\\_free](#) ([SHORT](#) *precond\_type*, [precond](#) \**pc*)  
*free preconditioner*

### 9.76.1 Detailed Description

Preconditioners for [dCSRmat](#) matrices.

Definition in file [precond\\_csr.c](#).

### 9.76.2 Function Documentation

#### 9.76.2.1 void [fasp\\_precond\\_amg](#) ( [REAL](#) \* *r*, [REAL](#) \* *z*, void \* *data* )

AMG preconditioner.

Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

Author

Chensong Zhang

Date

04/06/2010

Definition at line 411 of file [precond\\_csr.c](#).

#### 9.76.2.2 void [fasp\\_precond\\_amg\\_nk](#) ( [REAL](#) \* *r*, [REAL](#) \* *z*, void \* *data* )

AMG with extra near kernel solve as preconditioner.

Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

Author

Xiaozhe Hu

Date

05/26/2014

Definition at line 548 of file [precond\\_csr.c](#).

9.76.2.3 void fasp\_precond\_amli ( REAL \* *r*, REAL \* *z*, void \* *data* )

AMLI AMG preconditioner.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Xiaozhe Hu

## Date

01/23/2011

Definition at line 480 of file precondition\_csr.c.

#### 9.76.2.4 void fasp\_precond\_diag ( REAL \* *r*, REAL \* *z*, void \* *data* )

Diagonal preconditioner  $z = \text{inv}(D) * r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Chensong Zhang

## Date

04/06/2010

Definition at line 159 of file precondition\_csr.c.

#### 9.76.2.5 void fasp\_precond\_famg ( REAL \* *r*, REAL \* *z*, void \* *data* )

Full AMG preconditioner.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Xiaozhe Hu

## Date

02/27/2011

Definition at line 447 of file precondition\_csr.c.

9.76.2.6 void fasp\_precond\_free ( SHORT *precond\_type*, precondition \* *pc* )

free preconditioner

## Parameters

<i>precond_type</i>	Preconditioner type
<i>*pc</i>	precondition data & fct

## Returns

void

## Author

Feiteng Huang

## Date

12/24/2012

Definition at line 633 of file precondition\_csr.c.

### 9.76.2.7 void fasp\_precond\_ilu ( REAL \* *r*, REAL \* *z*, void \* *data* )

ILU preconditioner.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

04/06/2010

Definition at line 185 of file precondition\_csr.c.

### 9.76.2.8 void fasp\_precond\_ilu\_backward ( REAL \* *r*, REAL \* *z*, void \* *data* )

ILU preconditioner: only backward sweep.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

04/06/2010

Definition at line 307 of file precondition\_csr.c.

9.76.2.9 void fasp\_precond\_ilu\_forward ( REAL \* *r*, REAL \* *z*, void \* *data* )

ILU preconditioner: only forward sweep.

Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

Author

Xiaozhe Hu, Shiquang Zhang

Date

04/06/2010

Definition at line 254 of file precondition\_csr.c.

9.76.2.10 void fasp\_precond\_nl\_amli ( REAL \* *r*, REAL \* *z*, void \* *data* )

Nonlinear AMLI AMG preconditioner.

Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

Author

Xiaozhe Hu

Date

04/25/2011

Definition at line 513 of file precondition\_csr.c.

9.76.2.11 void fasp\_precond\_schwarz ( REAL \* *r*, REAL \* *z*, void \* *data* )

get *z* from *r* by schwarz

Parameters

* <i>r</i>	pointer to residual
* <i>z</i>	pointer to preconditioned residual
* <i>data</i>	pointer to precondition data

Author

Xiaozhe Hu



## Date

03/22/2010

Definition at line 357 of file precondition\_csr.c.

9.76.2.12 `precond * fasp_precond_setup ( SHORT precond_type, AMG_param * amgparam, ILU_param * iluparam, dCSRmat * A )`

Setup preconditioner interface for iterative methods.

## Parameters

<i>precond_type</i>	Preconditioner type
* <i>amgparam</i>	AMG parameters
* <i>iluparam</i>	ILU parameters
* <i>A</i>	Pointer to coefficient matrix

## Returns

Pointer to preconditioner

## Author

Feiteng Huang

## Date

05/18/2009

Definition at line 32 of file precondition\_csr.c.

## 9.77 precondition\_str.c File Reference

Preconditioners for [dSTRmat](#) matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_precond\\_dstr\\_diag](#) (REAL \**r*, REAL \**z*, void \**data*)  
*Diagonal preconditioner  $z = \text{inv}(D) * r$ .*
- void [fasp\\_precond\\_dstr\\_ilu0](#) (REAL \**r*, REAL \**z*, void \**data*)  
*Preconditioning using STR\_ILU(0) decomposition.*
- void [fasp\\_precond\\_dstr\\_ilu1](#) (REAL \**r*, REAL \**z*, void \**data*)  
*Preconditioning using STR\_ILU(1) decomposition.*
- void [fasp\\_precond\\_dstr\\_ilu0\\_forward](#) (REAL \**r*, REAL \**z*, void \**data*)  
*Preconditioning using STR\_ILU(0) decomposition:  $Lz = r$ .*

- void `fasp_precond_dstr_ilu0_backward` (`REAL *r`, `REAL *z`, void `*data`)  
Preconditioning using `STR_ILU(0)` decomposition:  $Uz = r$ .
- void `fasp_precond_dstr_ilu1_forward` (`REAL *r`, `REAL *z`, void `*data`)  
Preconditioning using `STR_ILU(1)` decomposition:  $Lz = r$ .
- void `fasp_precond_dstr_ilu1_backward` (`REAL *r`, `REAL *z`, void `*data`)  
Preconditioning using `STR_ILU(1)` decomposition:  $Uz = r$ .
- void `fasp_precond_dstr_blockgs` (`REAL *r`, `REAL *z`, void `*data`)  
CPR-type preconditioner (`STR` format)

### 9.77.1 Detailed Description

Preconditioners for `dSTRmat` matrices.

Definition in file `precond_str.c`.

### 9.77.2 Function Documentation

#### 9.77.2.1 void `fasp_precond_dstr_blockgs` ( `REAL * r`, `REAL * z`, void `* data` )

CPR-type preconditioner (`STR` format)

Parameters

<code>r</code>	Pointer to the vector needs preconditioning
<code>z</code>	Pointer to preconditioned vector
<code>data</code>	Pointer to precondition data

Author

Shiquan Zhang

Date

10/17/2010

Definition at line 1707 of file `precond_str.c`.

#### 9.77.2.2 void `fasp_precond_dstr_diag` ( `REAL * r`, `REAL * z`, void `* data` )

Diagonal preconditioner  $z = \text{inv}(D) * r$ .

Parameters

<code>r</code>	Pointer to the vector needs preconditioning
<code>z</code>	Pointer to preconditioned vector
<code>data</code>	Pointer to precondition data

Author

Shiquan Zhang

## Date

04/06/2010

Definition at line 27 of file precondition\_str.c.

**9.77.2.3 void fasp\_precond\_dstr\_ilu0 ( REAL \* r, REAL \* z, void \* data )**

Preconditioning using STR\_ILU(0) decomposition.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

04/21/2010

Definition at line 55 of file precondition\_str.c.

**9.77.2.4 void fasp\_precond\_dstr\_ilu0\_backward ( REAL \* r, REAL \* z, void \* data )**Preconditioning using STR\_ILU(0) decomposition:  $Uz = r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

06/07/2010

Definition at line 979 of file precondition\_str.c.

**9.77.2.5 void fasp\_precond\_dstr\_ilu0\_forward ( REAL \* r, REAL \* z, void \* data )**Preconditioning using STR\_ILU(0) decomposition:  $Lz = r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

06/07/2010

Definition at line 816 of file precondition\_str.c.

9.77.2.6 void fasp\_precond\_dstr\_ilu1 ( REAL \* *r*, REAL \* *z*, void \* *data* )

Preconditioning using STR\_ILU(1) decomposition.

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

04/21/2010

Definition at line 337 of file precondition\_str.c.

9.77.2.7 void fasp\_precond\_dstr\_ilu1\_backward ( REAL \* *r*, REAL \* *z*, void \* *data* )

Preconditioning using STR\_ILU(1) decomposition:  $Uz = r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

04/21/2010

Definition at line 1426 of file precondition\_str.c.

9.77.2.8 void fasp\_precond\_dstr\_ilu1\_forward ( REAL \* *r*, REAL \* *z*, void \* *data* )

Preconditioning using STR\_ILU(1) decomposition:  $Lz = r$ .

## Parameters

<i>r</i>	Pointer to the vector needs preconditioning
<i>z</i>	Pointer to preconditioned vector
<i>data</i>	Pointer to precondition data

## Author

Shiquan Zhang

## Date

04/21/2010

Definition at line 1160 of file `precond_str.c`.

## 9.78 pvfgmres.c File Reference

Krylov subspace methods – Preconditioned variable-restarting flexible GMRes.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- **INT fasp\_solver\_dcsr\_pvfgmres** (**dCSRmat** \*A, **dvector** \*b, **dvector** \*x, **precond** \*pc, const **REAL** tol, const **INT** MaxIt, const **SHORT** restart, const **SHORT** stop\_type, const **SHORT** print\_level)  
Solve " $Ax=b$ " using PFGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.
- **INT fasp\_solver\_dbsr\_pvfgmres** (**dBSRmat** \*A, **dvector** \*b, **dvector** \*x, **precond** \*pc, const **REAL** tol, const **INT** MaxIt, const **SHORT** restart, const **SHORT** stop\_type, const **SHORT** print\_level)  
Solve " $Ax=b$ " using PFGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.
- **INT fasp\_solver\_bdcsr\_pvfgmres** (**block\_dCSRmat** \*A, **dvector** \*b, **dvector** \*x, **precond** \*pc, const **REAL** tol, const **INT** MaxIt, const **SHORT** restart, const **SHORT** stop\_type, const **SHORT** print\_level)  
Solve " $Ax=b$ " using PFGMRES (right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.

### 9.78.1 Detailed Description

Krylov subspace methods – Preconditioned variable-restarting flexible GMRes.

## Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
Refer to A.H. Baker, E.R. Jessup, and Tz.V. Kolev A Simple Strategy for Varying the Restart Parameter in GMR<sub>ES</sub>(m) Journal of Computational and Applied Mathematics, 230 (2009) pp. 751-761. UCRL-JRNL-235266.  
This file is modified from [pvgmres.c](#)

Definition in file [pvfgmres.c](#).

## 9.78.2 Function Documentation

**9.78.2.1** `INT fasp_solver_bdcsv_pvfgmres ( block_dCSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Solve " $Ax=b$ " using PFGMRES (right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.

### Parameters

<i>*A</i>	pointer to the coefficient matrix
<i>*b</i>	pointer to the right hand side vector
<i>*x</i>	pointer to the solution vector
<i>MaxIt</i>	maximal iteration number allowed
<i>tol</i>	tolerance
<i>*pre</i>	pointer to preconditioner data
<i>print_level</i>	how much of the SOLVE-INFORMATION be printed
<i>stop_type</i>	default stopping criterion, i.e. $\ r_k\ /\ r_0\  < tol$ , is used.
<i>restart</i>	number of restart for GMRES

### Returns

number of iteration if succeed

### Author

Xiaozhe Hu

### Date

01/04/2012

### Note

Based on Zhiyang Zhou's [pvgmres.c](#)

Definition at line 691 of file pvfgmres.c.

**9.78.2.2** `INT fasp_solver_dbsr_pvfgmres ( dBSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Solve " $Ax=b$ " using PFGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.

### Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns

<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type – DOES not support this parameter
<i>print_level</i>	How much information to print out

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Xiaozhe Hu

**Date**

02/05/2012

Modified by Chensong Zhang on 05/01/2012

Definition at line 372 of file pvfgmres.c.

**9.78.2.3** `INT fasp_solver_dcsr_pvfgmres ( dCSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Solve "Ax=b" using PFGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.

**Parameters**

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type – DOES not support this parameter
<i>print_level</i>	How much information to print out

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Xiaozhe Hu

**Date**

01/04/2012

Modified by Chensong Zhang on 05/01/2012 Modified by Chunsheng Feng on 07/22/2013: Add adaptive memory allocate

Definition at line 54 of file pvfgmres.c.



## 9.79 pvfgmres\_mf.c File Reference

Krylov subspace methods – Preconditioned variable-restarting flexible GMRes (matrix free)

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_pvfgmres](#) ([mxv\\_matfree](#) \*mf, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) *MaxIt*, const [SHORT](#) *restart*, const [SHORT](#) *stop\_type*, const [SHORT](#) *print\_level*)

*Solve "Ax=b" using PFGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.*

### 9.79.1 Detailed Description

Krylov subspace methods – Preconditioned variable-restarting flexible GMRes (matrix free)

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM

Refer to A.H. Baker, E.R. Jessup, and Tz.V. Kolev A Simple Strategy for Varying the Restart Parameter in GMR↔ES(m) Journal of Computational and Applied Mathematics, 230 (2009) pp. 751-761. UCRL-JRNL-235266.

This file is modified from [pvgmres.c](#)

Definition in file [pvfgmres\\_mf.c](#).

### 9.79.2 Function Documentation

**9.79.2.1** [INT fasp\\_solver\\_pvfgmres](#) ( [mxv\\_matfree](#) \* *mf*, [dvector](#) \* *b*, [dvector](#) \* *x*, [precond](#) \* *pc*, const [REAL](#) *tol*, const [INT](#) *MaxIt*, const [SHORT](#) *restart*, const [SHORT](#) *stop\_type*, const [SHORT](#) *print\_level* )

Solve "Ax=b" using PFGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration and flexible preconditioner can be used.

#### Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> : the spmv operation
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps

<i>stop_type</i>	Stopping criteria type – DOES not support this parameter
<i>print_level</i>	How much information to print out

### Returns

Number of iterations if converged, error message otherwise

### Author

Xiaozhe Hu

### Date

01/04/2012

Modified by Chensong Zhang on 05/01/2012 Modified by Feiteng Huang on 09/26/2012: matrix free Modified by Chunsheng Feng on 07/22/2013: Add adapt memory allocate

Definition at line 56 of file pvfgmres\_mf.c.

## 9.80 pvgmres.c File Reference

Krylov subspace methods – Preconditioned variable-restart GMRes.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_dcsr\\_pvgmres](#) (dCSRmat \*A, dvector \*b, dvector \*x, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop\_type, const SHORT print\_level)  
*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*
- [INT fasp\\_solver\\_bdcsr\\_pvgmres](#) (block\_dCSRmat \*A, dvector \*b, dvector \*x, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop\_type, const SHORT print\_level)  
*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*
- [INT fasp\\_solver\\_dbsr\\_pvgmres](#) (dBSRmat \*A, dvector \*b, dvector \*x, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop\_type, const SHORT print\_level)  
*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*
- [INT fasp\\_solver\\_dstr\\_pvgmres](#) (dSTRmat \*A, dvector \*b, dvector \*x, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop\_type, const SHORT print\_level)  
*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*

### 9.80.1 Detailed Description

Krylov subspace methods – Preconditioned variable-restart GMRes.

#### Note

Refer to A.H. Baker, E.R. Jessup, and Tz.V. Kolev A Simple Strategy for Varying the Restart Parameter in GMRES(m) Journal of Computational and Applied Mathematics, 230 (2009) pp. 751-761. UCRL-JRNL-235266.  
See [spvgmres.c](#) for a safer version

Definition in file [pvgmres.c](#).

### 9.80.2 Function Documentation

**9.80.2.1** `INT fasp_solver_bdcsr_pvgmres ( block_dCSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

#### Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Chensong Zhang

#### Date

04/05/2013

Definition at line 385 of file pvgmres.c.

**9.80.2.2** `INT fasp_solver_dbsr_pvgmres ( dBSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Zhiyang Zhou

## Date

12/21/2011

Modified by Chensong Zhang on 05/01/2012 Modified by Chensong Zhang on 04/06/2013: Add stop type support

Definition at line 721 of file pvgmres.c.

**9.80.2.3** `INT fasp_solver_dcsr_pvgmres ( dCSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Solve " $Ax=b$ " using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Zhiyang Zhou

## Date

2010/12/14

Modified by Chensong Zhang on 12/13/2011 Modified by Chensong Zhang on 05/01/2012 Modified by Chensong Zhang on 04/06/2013: Add stop type support Modified by Chunsheng Feng on 07/22/2013: Add adapt memory allocate

Definition at line 52 of file pvgmres.c.

**9.80.2.4** `INT fasp_solver_dstr_pvgmres ( dSTRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, const SHORT restart, const SHORT stop_type, const SHORT print_level )`

Solve " $Ax=b$ " using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Zhiyang Zhou

## Date

2010/12/14

Modified by Chensong Zhang on 05/01/2012 Modified by Chensong Zhang on 04/06/2013: Add stop type support

Definition at line 1057 of file pvgmres.c.

## 9.81 pvgmres\_mf.c File Reference

Krylov subspace methods – Preconditioned variable-restarting GMRes (matrix free)

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- **INT fasp\_solver\_pvgmres** (**mxv\_matfree** \*mf, **dvector** \*b, **dvector** \*x, **precond** \*pc, const **REAL** tol, const **INT** MaxIt, **SHORT** restart, const **SHORT** stop\_type, const **SHORT** print\_level)

*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*

### 9.81.1 Detailed Description

Krylov subspace methods – Preconditioned variable-restarting GMRes (matrix free)

#### Note

Refer to A.H. Baker, E.R. Jessup, and Tz.V. Kolev A Simple Strategy for Varying the Restart Parameter in GMR↵ES(m) Journal of Computational and Applied Mathematics, 230 (2009) pp. 751-761. UCRL-JRNL-235266.

Definition in file [pvgmres\\_mf.c](#).

### 9.81.2 Function Documentation

- 9.81.2.1 INT fasp\_solver\_pvgmres** ( **mxv\_matfree** \* mf, **dvector** \* b, **dvector** \* x, **precond** \* pc, const **REAL** tol, const **INT** MaxIt, **SHORT** restart, const **SHORT** stop\_type, const **SHORT** print\_level )

Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

#### Parameters

<i>mf</i>	Pointer to <a href="#">mxv_matfree</a> : the spmv operation
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to precondition: the structure of precondition
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type – DOES not support this parameter
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Zhiyang Zhou

#### Date

2010/12/14

Modified by Chensong Zhang on 12/13/2011 Modified by Chensong Zhang on 05/01/2012 Modified by Feiteng Huang on 09/26/2012: matrix free Modified by Chunsheng Feng on 07/22/2013: Add adapt memory allocate

Definition at line 54 of file [pvgmres\\_mf.c](#).

## 9.82 quadrature.c File Reference

Quadrature rules.

```
#include <stdio.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_quad2d](#) (INT num\_qp, INT ncoor, REAL(\*quad)[3])  
*Initialize Lagrange quadrature points and weights.*
- void [fasp\\_gauss2d](#) (INT num\_qp, INT ncoor, REAL(\*gauss)[3])  
*Initialize Gauss quadrature points and weights.*

### 9.82.1 Detailed Description

Quadrature rules.

Definition in file [quadrature.c](#).

### 9.82.2 Function Documentation

9.82.2.1 void [fasp\\_gauss2d](#) ( INT num\_qp, INT ncoor, REAL(\*) gauss[3] )

Initialize Gauss quadrature points and weights.

Parameters

<i>num_qp</i>	Number of quadrature points
<i>ncoor</i>	Dimension of space
<i>gauss</i>	Quadrature points and weight

Author

Xuehai Huang, Chensong Zhang, Ludmil Zikatanov

Date

10/21/2008

Note

gauss[\*][0] – quad point x in ref coor gauss[\*][1] – quad point y in ref coor gauss[\*][2] – quad weight

Definition at line 210 of file quadrature.c.

9.82.2.2 void [fasp\\_quad2d](#) ( INT num\_qp, INT ncoor, REAL(\*) quad[3] )

Initialize Lagrange quadrature points and weights.

## Parameters

<i>num_qp</i>	Number of quadrature points
<i>ncoor</i>	Dimension of space
<i>quad</i>	Quadrature points and weights

## Author

Xuehai Huang, Chensong Zhang, Ludmil Zikatanov

## Date

10/21/2008

## Note

quad[\*][0] – quad point x in ref coor quad[\*][1] – quad point y in ref coor quad[\*][2] – quad weight

Definition at line 31 of file quadrature.c.

## 9.83 rap.c File Reference

R\*A\*P driver.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- [dCSRmat fasp\\_blas\\_dcsr\\_rap2](#) ([INT](#) \*ir, [INT](#) \*jr, [REAL](#) \*r, [INT](#) \*ia, [INT](#) \*ja, [REAL](#) \*a, [INT](#) \*ipt, [INT](#) \*jpt, [REAL](#) \*pt, [INT](#) n, [INT](#) nc, [INT](#) \*maxrpout, [INT](#) \*ipin, [INT](#) \*jpin)  
Compute  $R*A*P$ .

#### 9.83.1 Detailed Description

R\*A\*P driver.

C-version by Ludmil Zikatanov 2010-04-08

tested 2010-04-08

Definition in file [rap.c](#).

#### 9.83.2 Function Documentation

9.83.2.1 [dCSRmat fasp\\_blas\\_dcsr\\_rap2](#) ( [INT](#) \*ir, [INT](#) \*jr, [REAL](#) \*r, [INT](#) \*ia, [INT](#) \*ja, [REAL](#) \*a, [INT](#) \*ipt, [INT](#) \*jpt, [REAL](#) \*pt, [INT](#) n, [INT](#) nc, [INT](#) \*maxrpout, [INT](#) \*ipin, [INT](#) \*jpin )

Compute  $R*A*P$ .



**Author**

Ludmil Zikatanov

**Date**

04/08/2010

**Note**

It uses [dCSRmat](#) only. The functions called from here are in [sparse\\_util.c](#)

Definition at line 33 of file rap.c.

## 9.84 schwarz.f File Reference

Schwarz smoothers.

### Functions/Subroutines

- subroutine **cut0** (n, ia, ja, a, iaw, jaw, jblk, iblk, nblk, lwork1, lwork2, lwork3, msize)
- subroutine **chsize** (a, b, tol, imin)
- subroutine **shift** (nxadj, nadj, n)
- subroutine **dfs** (n, ia, ja, nblk, iblk, jblk, lowlink, iedge, numb)
- subroutine **permat** (iord, ia, ja, an, n, m, iat, jat, ant)
- subroutine **pervec** (iord, u1, u2, n)
- subroutine **perback** (iord, u1, u2, n)
- subroutine **perm0** (iord, ia, ja, an, n, m, iat, jat, ant)
- subroutine **icopyv** (iu, iv, n)
- subroutine **mxfrm2** (n, ia, ja, nblk, iblock, jblock, mask, maxa, memt, maxbs)
- subroutine **sky2ns** (n, ia, ja, a, nblk, iblock, jblock, mask, maxa, au, al)
- subroutine **fbgs2ns** (n, ia, ja, a, x, b, nblk, iblock, jblock, mask, maxa, au, al, rhsloc, memt)
- subroutine **bbgs2ns** (n, ia, ja, a, x, b, nblk, iblock, jblock, mask, maxa, au, al, rhsloc, memt)
- subroutine **doluns** (au, al, maxa, nn)
- subroutine **sluns** (au, al, v, maxa, nn)
- subroutine **dolu** (a, maxa, nn)
- subroutine **slvlu** (a, v, maxa, nn)
- subroutine **ijacrs** (ln, ia, ja, a, n, nnz, ir, ic, aij)
- subroutine **sympat** (ln, ia, ja, n, ir, ic, aij)
- subroutine **levels** (inroot, ia, ja, mask, nlvl, iblock, jblock, maxlev)

### 9.84.1 Detailed Description

Schwarz smoothers.

**Author**

Ludmil Zikatanov

**Date**

01/01/2007

**Note**

These routines are part of the matching MG method

Definition in file [schwarz.f](#).

## 9.85 schwarz\_setup.c File Reference

Setup phase for the Schwarz methods.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "forts_ns.h"
```

**Functions**

- [INT fasp\\_schwarz\\_setup](#) ([Schwarz\\_data](#) \*schwarz, [INT](#) mmsize, [INT](#) maxlev, [INT](#) schwarz\_type)  
*Setup phase for the Schwarz methods.*

### 9.85.1 Detailed Description

Setup phase for the Schwarz methods.

Definition in file [schwarz\\_setup.c](#).

### 9.85.2 Function Documentation

#### 9.85.2.1 INT fasp\_schwarz\_setup ( Schwarz\_data \* schwarz, INT mmsize, INT maxlev, INT schwarz\_type )

Setup phase for the Schwarz methods.

**Parameters**

<i>schwarz</i>	Pointer to the showwarz data
<i>mmsize</i>	Max block size
<i>maxlev</i>	Max number of levels
<i>schwarz_type</i>	Type of the Schwarz method

**Returns**

FASP\_SUCCESS if succeed

**Author**

Ludmil, Xiaozhe Hu

**Date**

03/22/2011

Modified by Chunsheng Feng, Zheng Li on 08/28/2012

Definition at line 35 of file schwarz\_setup.c.

## 9.86 smat.c File Reference

Simple operations for *small* full matrices in row-major format.

```
#include "fasp.h"
#include "fasp_functs.h"
```

**Functions**

- void [fasp\\_blas\\_smat\\_inv\\_nc2](#) (REAL \*a)  
*Compute the inverse matrix of a 2\*2 full matrix A (in place)*
- void [fasp\\_blas\\_smat\\_inv\\_nc3](#) (REAL \*a)  
*Compute the inverse matrix of a 3\*3 full matrix A (in place)*
- void [fasp\\_blas\\_smat\\_inv\\_nc4](#) (REAL \*a)  
*Compute the inverse matrix of a 4\*4 full matrix A (in place)*
- void [fasp\\_blas\\_smat\\_inv\\_nc5](#) (REAL \*a)  
*Compute the inverse matrix of a 5\*5 full matrix A (in place)*
- void [fasp\\_blas\\_smat\\_inv\\_nc7](#) (REAL \*a)  
*Compute the inverse matrix of a 7\*7 matrix a.*
- INT [fasp\\_blas\\_smat\\_inv](#) (REAL \*a, const INT n)  
*Compute the inverse matrix of a small full matrix a.*
- void [fasp\\_iden\\_free](#) (idenmat \*A)  
*Free idenmat sparse matrix data memeory space.*
- void [fasp\\_smat\\_identity\\_nc2](#) (REAL \*a)  
*Set a 2\*2 full matrix to be a identity.*
- void [fasp\\_smat\\_identity\\_nc3](#) (REAL \*a)  
*Set a 3\*3 full matrix to be a identity.*
- void [fasp\\_smat\\_identity\\_nc5](#) (REAL \*a)  
*Set a 5\*5 full matrix to be a identity.*
- void [fasp\\_smat\\_identity\\_nc7](#) (REAL \*a)  
*Set a 7\*7 full matrix to be a identity.*
- void [fasp\\_smat\\_identity](#) (REAL \*a, INT n, INT n2)  
*Set a n\*n full matrix to be a identity.*
- REAL [fasp\\_blas\\_smat\\_Linfinity](#) (REAL \*A, const INT n)  
*Compute the L infinity norm of A.*

### 9.86.1 Detailed Description

Simple operations for *small* full matrices in row-major format.

Definition in file [smat.c](#).

### 9.86.2 Function Documentation

#### 9.86.2.1 `INT fasp_blas_smat_inv ( REAL * a, const INT n )`

Compute the inverse matrix of a small full matrix *a*.

Parameters

<i>a</i>	Pointer to the REAL array which stands a <i>n</i> * <i>n</i> matrix
<i>n</i>	Dimension of the matrix

Author

Xiaozhe Hu, Shiquan Zhang

Date

04/21/2010

Definition at line 403 of file *smat.c*.

#### 9.86.2.2 `void fasp_blas_smat_inv_nc2 ( REAL * a )`

Compute the inverse matrix of a 2\*2 full matrix *A* (in place)

Parameters

<i>a</i>	Pointer to the REAL array which stands a 2*2 matrix
----------	---

Author

Xiaozhe Hu

Date

18/11/2011

Definition at line 23 of file *smat.c*.

#### 9.86.2.3 `void fasp_blas_smat_inv_nc3 ( REAL * a )`

Compute the inverse matrix of a 3\*3 full matrix *A* (in place)

## Parameters

$a$	Pointer to the REAL array which stands a 3*3 matrix
-----	---

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 59 of file smat.c.

#### 9.86.2.4 void fasp\_blas\_smat\_inv\_nc4 ( REAL \* $a$ )

Compute the inverse matrix of a 4\*4 full matrix A (in place)

## Parameters

$a$	Pointer to the REAL array which stands a 4*4 matrix
-----	---

## Author

Xiaozhe Hu

## Date

01/12/2013

Modified by Hongxuan Zhang on 06/13/2014: Fix a bug in M23.

Definition at line 113 of file smat.c.

#### 9.86.2.5 void fasp\_blas\_smat\_inv\_nc5 ( REAL \* $a$ )

Compute the inverse matrix of a 5\*5 full matrix A (in place)

## Parameters

$a$	Pointer to the REAL array which stands a 5*5 matrix
-----	---

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 171 of file smat.c.

#### 9.86.2.6 void fasp\_blas\_smat\_inv\_nc7 ( REAL \* $a$ )

Compute the inverse matrix of a 7\*7 matrix a.

## Parameters

$a$	Pointer to the REAL array which stands a 7*7 matrix
-----	---

## Note

This is NOT implemented yet!

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 387 of file smat.c.

**9.86.2.7 REAL fasp\_blas\_smat\_Linfinity ( REAL \* A, const INT  $n$  )**

Compute the L infinity norm of A.

## Parameters

$A$	Pointer to the $n \times n$ dense matrix
$n$	the dimension of the dense matrix

## Author

Xiaozhe Hu

## Date

05/26/2014

Definition at line 672 of file smat.c.

**9.86.2.8 void fasp\_iden\_free ( idenmat \* A )**

Free idenmat sparse matrix data memeory space.

## Parameters

$A$	Pointer to the idenmat matrix
-----	-------------------------------

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 492 of file smat.c.

9.86.2.9 void fasp\_smat\_identity ( REAL \* *a*, INT *n*, INT *n2* )

Set a  $n \times n$  full matrix to be a identity.

## Parameters

$a$	Pointer to the REAL vector which stands for a $n \times n$ full matrix
$n$	Size of full matrix
$n2$	Length of the REAL vector which stores the $n \times n$ full matrix

## Author

Xiaozhe Hu

## Date

2010/12/25

Definition at line 592 of file smat.c.

9.86.2.10 void fasp\_smat\_identity\_nc2 ( REAL \*  $a$  )

Set a  $2 \times 2$  full matrix to be a identity.

## Parameters

$a$	Pointer to the REAL vector which stands for a $2 \times 2$ full matrix
-----	--

## Author

Xiaozhe Hu

## Date

2011/11/18

Definition at line 512 of file smat.c.

9.86.2.11 void fasp\_smat\_identity\_nc3 ( REAL \*  $a$  )

Set a  $3 \times 3$  full matrix to be a identity.

## Parameters

$a$	Pointer to the REAL vector which stands for a $3 \times 3$ full matrix
-----	--

## Author

Xiaozhe Hu

## Date

2010/12/25

Definition at line 529 of file smat.c.

9.86.2.12 void fasp\_smat\_identity\_nc5 ( REAL \*  $a$  )

Set a  $5 \times 5$  full matrix to be a identity.



## Parameters

<i>a</i>	Pointer to the REAL vector which stands for a 5*5 full matrix
----------	---

## Author

Xiaozhe Hu

## Date

2010/12/25

Definition at line 546 of file smat.c.

9.86.2.13 void fasp\_smat\_identity\_nc7 ( REAL \* *a* )

Set a 7\*7 full matrix to be a identity.

## Parameters

<i>a</i>	Pointer to the REAL vector which stands for a 7*7 full matrix
----------	---

## Author

Xiaozhe Hu

## Date

2010/12/25

Definition at line 567 of file smat.c.

## 9.87 smoother\_bsr.c File Reference

Smoother for [dBSRmat](#) matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_smoother\\_dbsr\\_jacobi](#) (dBSRmat \*A, dvector \*b, dvector \*u)  
*Jacobi relaxation.*
- void [fasp\\_smoother\\_dbsr\\_jacobi\\_setup](#) (dBSRmat \*A, dvector \*b, dvector \*u, REAL \*diaginv)  
*Setup for jacobi relaxation, fetch the diagonal sub-block matrixes and make them inverse first.*
- void [fasp\\_smoother\\_dbsr\\_jacobi1](#) (dBSRmat \*A, dvector \*b, dvector \*u, REAL \*diaginv)  
*Jacobi relaxation.*
- void [fasp\\_smoother\\_dbsr\\_gs](#) (dBSRmat \*A, dvector \*b, dvector \*u, INT order, INT \*mark)  
*Gauss-Seidel relaxation.*

- void `fasp_smoother_dbsr_gs1` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `INT order`, `INT *mark`, `REAL *diaginv`)  
*Gauss-Seidel relaxation.*
- void `fasp_smoother_dbsr_gs_ascend` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`)  
*Gauss-Seidel relaxation in the ascending order.*
- void `fasp_smoother_dbsr_gs_ascend1` (`dBSRmat *A`, `dvector *b`, `dvector *u`)  
*Gauss-Seidel relaxation in the ascending order.*
- void `fasp_smoother_dbsr_gs_descend` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`)  
*Gauss-Seidel relaxation in the descending order.*
- void `fasp_smoother_dbsr_gs_descend1` (`dBSRmat *A`, `dvector *b`, `dvector *u`)  
*Gauss-Seidel relaxation in the descending order.*
- void `fasp_smoother_dbsr_gs_order1` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `INT *mark`)  
*Gauss-Seidel relaxation in the user-defined order.*
- void `fasp_smoother_dbsr_gs_order2` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `INT *mark`, `REAL *work`)  
*Gauss-Seidel relaxation in the user-defined order.*
- void `fasp_smoother_dbsr_sor` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `INT order`, `INT *mark`, `REAL weight`)  
*SOR relaxation.*
- void `fasp_smoother_dbsr_sor1` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `INT order`, `INT *mark`, `REAL *diaginv`, `REAL weight`)  
*SOR relaxation.*
- void `fasp_smoother_dbsr_sor_ascend` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `REAL weight`)  
*SOR relaxation in the ascending order.*
- void `fasp_smoother_dbsr_sor_descend` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `REAL weight`)  
*SOR relaxation in the descending order.*
- void `fasp_smoother_dbsr_sor_order` (`dBSRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `INT *mark`, `REAL weight`)  
*SOR relaxation in the user-defined order.*
- void `fasp_smoother_dbsr_ilu` (`dBSRmat *A`, `dvector *b`, `dvector *x`, `void *data`)  
*ILU method as the smoother in solving  $Au=b$  with multigrid method.*

### 9.87.1 Detailed Description

Smoothers for `dBSRmat` matrices.

Definition in file `smoother_bsr.c`.

### 9.87.2 Function Documentation

#### 9.87.2.1 void `fasp_smoother_dbsr_gs` ( `dBSRmat * A`, `dvector * b`, `dvector * u`, `INT order`, `INT * mark` )

Gauss-Seidel relaxation.

Parameters

<i>A</i>	Pointer to <code>dBSRmat</code> : the coefficient matrix
<i>b</i>	Pointer to <code>dvector</code> : the right hand side

<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending order DESCEND 21: in descending order If mark != NULL: in the user-defined order
<i>mark</i>	Pointer to NULL or to the user-defined ordering

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Modified by Chunsheng Feng, Zheng Li on 08/03/2012

Definition at line 415 of file smoother\_bsr.c.

9.87.2.2 void fasp\_smoother\_dbsr\_gs1 ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, INT *order*, INT \* *mark*, REAL \* *diaginv* )

Gauss-Seidel relaxation.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending order DESCEND 21: in descending order If mark != NULL: in the user-defined order
<i>mark</i>	Pointer to NULL or to the user-defined ordering
<i>diaginv</i>	Inverses for all the diagonal blocks of <i>A</i>

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Definition at line 535 of file smoother\_bsr.c.

9.87.2.3 void fasp\_smoother\_dbsr\_gs\_ascend ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv* )

Gauss-Seidel relaxation in the ascending order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side

<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)
<i>diaginv</i>	Inverses for all the diagonal blocks of A

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Definition at line 572 of file smoother\_bsr.c.

9.87.2.4 void fasp\_smoother\_dbsr\_gs\_ascend1 ( dBSRmat \* A, dvector \* b, dvector \* u )

Gauss-Seidel relaxation in the ascending order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)

**Author**

Xiaozhe

**Date**

01/01/2014

**Note**

The only difference between the functions 'fasp\_smoother\_dbsr\_gs\_ascend1' and 'fasp\_smoother\_dbsr\_gs\_↔ascend' is that we don't have to multiply by the inverses of the diagonal blocks in each ROW since matrix A has been such scaled that all the diagonal blocks become identity matrices.

Definition at line 645 of file smoother\_bsr.c.

9.87.2.5 void fasp\_smoother\_dbsr\_gs\_descend ( dBSRmat \* A, dvector \* b, dvector \* u, REAL \* diaginv )

Gauss-Seidel relaxation in the descending order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)

<i>diaginv</i>	Inverses for all the diagonal blocks of A
----------------	---

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Definition at line 716 of file smoother\_bsr.c.

9.87.2.6 void fasp\_smoother\_dbsr\_gs\_descend1 ( dBSRmat \* A, dvector \* b, dvector \* u )

Gauss-Seidel relaxation in the descending order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)

**Author**

Xiaozhe Hu

**Date**

01/01/2014

**Note**

The only difference between the functions 'fasp\_smoother\_dbsr\_gs\_ascend1' and 'fasp\_smoother\_dbsr\_gs\_↔ascend' is that we don't have to multiply by the inverses of the diagonal blocks in each ROW since matrix A has been such scaled that all the diagonal blocks become identity matrices.

Definition at line 790 of file smoother\_bsr.c.

9.87.2.7 void fasp\_smoother\_dbsr\_gs\_order1 ( dBSRmat \* A, dvector \* b, dvector \* u, REAL \* diaginv, INT \* mark )

Gauss-Seidel relaxation in the user-defined order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)
<i>diaginv</i>	Inverses for all the diagonal blocks of A

<i>mark</i>	Pointer to the user-defined ordering
-------------	--------------------------------------

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Definition at line 862 of file smoother\_bsr.c.

9.87.2.8 void fasp\_smoother\_dbsr\_gs\_order2 ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, INT \* *mark*, REAL \* *work* )

Gauss-Seidel relaxation in the user-defined order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)
<i>mark</i>	Pointer to the user-defined ordering
<i>work</i>	Work temp array

**Author**

Zhiyang Zhou

**Date**

2010/11/08

**Note**

The only difference between the functions 'fasp\_smoother\_dbsr\_gs\_order2' and 'fasp\_smoother\_dbsr\_gs\_order1' lies in that we don't have to multiply by the inverses of the diagonal blocks in each ROW since matrix A has been such scaled that all the diagonal blocks become identity matrices.

Definition at line 940 of file smoother\_bsr.c.

9.87.2.9 void fasp\_smoother\_dbsr\_ilu ( dBSRmat \* *A*, dvector \* *b*, dvector \* *x*, void \* *data* )

ILU method as the smoother in solving  $Au=b$  with multigrid method.**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side

<i>x</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>data</i>	Pointer to user defined data

**Author**

Zhiyang Zhou

**Date**

2010/10/25

form residual  $zr = b - A x$ solve LU  $z=zr$  $x=x+z$ 

Definition at line 1573 of file smoother\_bsr.c.

9.87.2.10 void fasp\_smoother\_dbsr\_jacobi ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u* )

Jacobi relaxation.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Modified by Chunsheng Feng, Zheng Li on 08/02/2012

Definition at line 35 of file smoother\_bsr.c.

9.87.2.11 void fasp\_smoother\_dbsr\_jacobi1 ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv* )

Jacobi relaxation.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)

<i>diaginv</i>	Inverses for all the diagonal blocks of A
----------------	---

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Modified by Chunsheng Feng, Zheng Li on 08/03/2012

Definition at line 259 of file smoother\_bsr.c.

9.87.2.12 void fasp\_smoother\_dbsr\_jacobi\_setup ( dBSRmat \* A, dvector \* b, dvector \* u, REAL \* diaginv )

Setup for jacobi relaxation, fetch the diagonal sub-block matrixes and make them inverse first.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>diaginv</i>	Inverse of the diagonal entries

**Author**

Zhiyang Zhou

**Date**

10/25/2010

Modified by Chunsheng Feng, Zheng Li on 08/02/2012

Definition at line 150 of file smoother\_bsr.c.

9.87.2.13 void fasp\_smoother\_dbsr\_sor ( dBSRmat \* A, dvector \* b, dvector \* u, INT order, INT \* mark, REAL weight )

SOR relaxation.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending order DESCEND 21: in descending order If mark != NULL: in the user-defined order



<i>mark</i>	Pointer to NULL or to the user-defined ordering
<i>weight</i>	Over-relaxation weight

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Modified by Chunsheng Feng, Zheng Li on 08/03/2012

Definition at line 1019 of file smoother\_bsr.c.

**9.87.2.14** void fasp\_smoother\_dbsr\_sor1 ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, INT *order*, INT \* *mark*, REAL \* *diaginv*, REAL *weight* )

SOR relaxation.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending order DESCEND 21: in descending order If mark != NULL: in the user-defined order
<i>mark</i>	Pointer to NULL or to the user-defined ordering
<i>diaginv</i>	Inverses for all the diagonal blocks of A
<i>weight</i>	Over-relaxation weight

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Definition at line 1141 of file smoother\_bsr.c.

**9.87.2.15** void fasp\_smoother\_dbsr\_sor\_ascend ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, REAL *weight* )

SOR relaxation in the ascending order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side

<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)
<i>diaginv</i>	Inverses for all the diagonal blocks of A
<i>weight</i>	Over-relaxation weight

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Modified by Chunsheng Feng, Zheng Li on 2012/09/04

Definition at line 1182 of file smoother\_bsr.c.

9.87.2.16 void fasp\_smoother\_dbsr\_sor\_descend ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, REAL *weight* )

SOR relaxation in the descending order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial guess, OUT: approximation)
<i>diaginv</i>	Inverses for all the diagonal blocks of A
<i>weight</i>	Over-relaxation weight

**Author**

Zhiyang Zhou

**Date**

2010/10/25

Modified by Chunsheng Feng, Zheng Li on 2012/09/04

Definition at line 1311 of file smoother\_bsr.c.

9.87.2.17 void fasp\_smoother\_dbsr\_sor\_order ( dBSRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, INT \* *mark*, REAL *weight* )

SOR relaxation in the user-defined order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>diaginv</i>	Inverses for all the diagonal blocks of A
<i>mark</i>	Pointer to the user-defined ordering
<i>weight</i>	Over-relaxation weight

## Author

Zhiyang Zhou

## Date

2010/10/25

Modified by Chunsheng Feng, Zheng Li on 2012/09/04

Definition at line 1442 of file smoother\_bsr.c.

## 9.88 smoother\_csr.c File Reference

Smoother for `dCSRmat` matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void `fasp_smoother_dcsr_jacobi` (`dvector` \*u, const `INT` i\_1, const `INT` i\_n, const `INT` s, `dCSRmat` \*A, `dvector` \*b, `INT` L)  
*Jacobi method as a smoother.*
- void `fasp_smoother_dcsr_gs` (`dvector` \*u, const `INT` i\_1, const `INT` i\_n, const `INT` s, `dCSRmat` \*A, `dvector` \*b, `INT` L)  
*Gauss-Seidel method as a smoother.*
- void `fasp_smoother_dcsr_gs_cf` (`dvector` \*u, `dCSRmat` \*A, `dvector` \*b, `INT` L, `INT` \*mark, const `INT` order)  
*Gauss-Seidel smoother with C/F ordering for  $Au=b$ .*
- void `fasp_smoother_dcsr_sgs` (`dvector` \*u, `dCSRmat` \*A, `dvector` \*b, `INT` L)  
*Symmetric Gauss-Seidel method as a smoother.*
- void `fasp_smoother_dcsr_sor` (`dvector` \*u, const `INT` i\_1, const `INT` i\_n, const `INT` s, `dCSRmat` \*A, `dvector` \*b, `INT` L, const `REAL` w)  
*SOR method as a smoother.*
- void `fasp_smoother_dcsr_sor_cf` (`dvector` \*u, `dCSRmat` \*A, `dvector` \*b, `INT` L, const `REAL` w, `INT` \*mark, const `INT` order)  
*SOR smoother with C/F ordering for  $Au=b$ .*
- void `fasp_smoother_dcsr_ilu` (`dCSRmat` \*A, `dvector` \*b, `dvector` \*x, void \*data)  
*ILU method as a smoother.*
- void `fasp_smoother_dcsr_kaczmarz` (`dvector` \*u, const `INT` i\_1, const `INT` i\_n, const `INT` s, `dCSRmat` \*A, `dvector` \*b, `INT` L, const `REAL` w)  
*Kaczmarz method as a smoother.*
- void `fasp_smoother_dcsr_L1diag` (`dvector` \*u, const `INT` i\_1, const `INT` i\_n, const `INT` s, `dCSRmat` \*A, `dvector` \*b, `INT` L)  
*Diagonal scaling (using L1 norm) as a smoother.*
- void `fasp_smoother_dcsr_gs_rb3d` (`dvector` \*u, `dCSRmat` \*A, `dvector` \*b, `INT` L, `INT` order, `INT` \*mark, `INT` maximap, `INT` nx, `INT` ny, `INT` nz)  
*Colored Gauss-Seidel smoother for  $Au=b$ .*

### 9.88.1 Detailed Description

Smoothers for [dCSRmat](#) matrices.

Definition in file [smoother\\_csr.c](#).

### 9.88.2 Function Documentation

9.88.2.1 `void fasp_smoother_dcsr_gs ( dvector * u, const INT i_1, const INT i_n, const INT s, dCSRmat * A, dvector * b, INT L )`

Gauss-Seidel method as a smoother.

#### Parameters

<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>i_1</i>	Starting index
<i>i_n</i>	Ending index
<i>s</i>	Increasing step
<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>L</i>	Number of iterations

#### Author

Xuehai Huang, Chensong Zhang

#### Date

09/26/2009

Modified by Chunsheng Feng, Zheng Li on 09/01/2012

Definition at line 195 of file [smoother\\_csr.c](#).

9.88.2.2 `void fasp_smoother_dcsr_gs_cf ( dvector * u, dCSRmat * A, dvector * b, INT L, INT * mark, const INT order )`

Gauss-Seidel smoother with C/F ordering for  $Au=b$ .

#### Parameters

<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>L</i>	Number of iterations
<i>mark</i>	C/F marker array
<i>order</i>	C/F ordering: -1: F-first; 1: C-first

#### Author

Zhiyang Zhou

## Date

11/12/2010

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/24/2012

Definition at line 364 of file smoother\_csr.c.

9.88.2.3 void fasp\_smoother\_dcsr\_gs\_rb3d ( dvector \* *u*, dCSRmat \* *A*, dvector \* *b*, INT *L*, INT *order*, INT \* *mark*, INT *maximap*, INT *nx*, INT *ny*, INT *nz* )

Colored Gauss-Seidel smoother for  $Au=b$ .

## Parameters

<i>u</i>	Initial guess and the new approximation to the solution
<i>A</i>	Pointer to stiffness matrix
<i>b</i>	Pointer to right hand side
<i>L</i>	Number of iterations
<i>order</i>	Ordering: -1: Forward; 1: Backward
<i>mark</i>	Marker for C/F points
<i>maximap</i>	Size of IMAP
<i>nx</i>	Number vertex of X direction
<i>ny</i>	Number vertex of Y direction
<i>nz</i>	Number vertex of Z direction

## Author

Chunsheng Feng

## Date

02/08/2012

Definition at line 1426 of file smoother\_csr.c.

9.88.2.4 void fasp\_smoother\_dcsr\_ilu ( dCSRmat \* *A*, dvector \* *b*, dvector \* *x*, void \* *data* )

ILU method as a smoother.

## Parameters

<i>A</i>	Pointer to dBSRmat: the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>data</i>	Pointer to user defined data

## Author

Shiquan Zhang, Xiaozhe Hu

## Date

2010/11/12

form residual  $zr = b - A x$ 

Definition at line 1067 of file smoother\_csr.c.

9.88.2.5 void fasp\_smoother\_dcsr\_jacobi ( dvector \* *u*, const INT *i\_1*, const INT *i\_n*, const INT *s*, dCSRmat \* *A*, dvector \* *b*, INT *L* )

Jacobi method as a smoother.

#### Parameters

<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>i_1</i>	Starting index
<i>i_n</i>	Ending index
<i>s</i>	Increasing step
<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>L</i>	Number of iterations

#### Author

Xuehai Huang, Chensong Zhang

#### Date

09/26/2009

Modified by Chunsheng Feng, Zheng Li on 08/29/2012

Definition at line 59 of file smoother\_csr.c.

9.88.2.6 void fasp\_smoother\_dcsr\_kaczmarz ( dvector \* *u*, const INT *i\_1*, const INT *i\_n*, const INT *s*, dCSRmat \* *A*, dvector \* *b*, INT *L*, const REAL *w* )

Kaczmarz method as a smoother.

#### Parameters

<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>i_1</i>	Starting index
<i>i_n</i>	Ending index
<i>s</i>	Increasing step
<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>L</i>	Number of iterations
<i>w</i>	Over-relaxation weight

#### Author

Xiaozhe Hu

#### Date

2010/11/12

Modified by Chunsheng Feng, Zheng Li on 2012/09/01

Definition at line 1145 of file smoother\_csr.c.

9.88.2.7 void fasp\_smoother\_dcsr\_L1diag ( dvector \* *u*, const INT *i\_1*, const INT *i\_n*, const INT *s*, dCSRmat \* *A*, dvector \* *b*, INT *L* )

Diagonal scaling (using L1 norm) as a smoother.

## Parameters

$u$	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
$i_1$	Starting index
$i_n$	Ending index
$s$	Increasing step
$A$	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
$b$	Pointer to dvector: the right hand side
$L$	Number of iterations

## Author

Xiaozhe Hu, James Brannick

## Date

01/26/2011

Modified by Chunsheng Feng, Zheng Li on 09/01/2012

Definition at line 1286 of file smoother\_csr.c.

**9.88.2.8** void fasp\_smoother\_dcsr\_sgs ( dvector \*  $u$ , dCSRmat \*  $A$ , dvector \*  $b$ , INT  $L$  )

Symmetric Gauss-Seidel method as a smoother.

## Parameters

$u$	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
$A$	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
$b$	Pointer to dvector: the right hand side
$L$	Number of iterations

## Author

Xiaozhe Hu

## Date

10/26/2010

Modified by Chunsheng Feng, Zheng Li on 09/01/2012

Definition at line 629 of file smoother\_csr.c.

**9.88.2.9** void fasp\_smoother\_dcsr\_sor ( dvector \*  $u$ , const INT  $i_1$ , const INT  $i_n$ , const INT  $s$ , dCSRmat \*  $A$ , dvector \*  $b$ , INT  $L$ , const REAL  $w$  )

SOR method as a smoother.



## Parameters

<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>i_1</i>	Starting index
<i>i_n</i>	Ending index
<i>s</i>	Increasing step
<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>L</i>	Number of iterations
<i>w</i>	Over-relaxation weight

## Author

Xiaozhe Hu

## Date

10/26/2010

Modified by Chunsheng Feng, Zheng Li on 09/01/2012

Definition at line 745 of file smoother\_csr.c.

9.88.2.10 void fasp\_smoother\_dcsr\_sor\_cf ( dvector \* *u*, dCSRmat \* *A*, dvector \* *b*, INT *L*, const REAL *w*, INT \* *mark*, const INT *order* )

SOR smoother with C/F ordering for  $Au=b$ .

## Parameters

<i>u</i>	Pointer to dvector: the unknowns (IN: initial, OUT: approximation)
<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>L</i>	Number of iterations
<i>w</i>	Over-relaxation weight
<i>mark</i>	C/F marker array
<i>order</i>	C/F ordering: -1: F-first; 1: C-first

## Author

Zhiyang Zhou

## Date

2010/11/12

Modified by Chunsheng Feng, Zheng Li on 08/29/2012

Definition at line 873 of file smoother\_csr.c.

## 9.89 smoother\_csr\_cr.c File Reference

Smoother for [dCSRmat](#) matrices using compatible relaxation.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_smoother\\_dcsr\\_gscr](#) (INT pt, INT n, REAL \*u, INT \*ia, INT \*ja, REAL \*a, REAL \*b, INT L, INT \*CF)  
*Gauss Seidel method restricted to a block.*

### 9.89.1 Detailed Description

Smoothers for [dCSRmat](#) matrices using compatible relaxation.

#### Note

Restricted-smoothers for compatible relaxation, C/F smoothing, etc.

Definition in file [smoother\\_csr\\_cr.c](#).

### 9.89.2 Function Documentation

9.89.2.1 void [fasp\\_smoother\\_dcsr\\_gscr](#) ( INT pt, INT n, REAL \* u, INT \* ia, INT \* ja, REAL \* a, REAL \* b, INT L, INT \* CF )

Gauss Seidel method restricted to a block.

#### Parameters

<i>pt</i>	Relax type, e.g., cpt, fpt, etc..
<i>n</i>	Number of variables
<i>u</i>	Iterated solution
<i>ia</i>	Row pointer
<i>ja</i>	Column index
<i>a</i>	Pointers to sparse matrix values in CSR format
<i>b</i>	Pointer to right hand side – remove later also as MG relaxation on error eqn
<i>L</i>	Number of iterations
<i>CF</i>	Marker for C, F points

#### Author

James Brannick

#### Date

09/07/2010

#### Note

Gauss Seidel CR smoother (Smoother\_Type = 99)

Definition at line 38 of file [smoother\\_csr\\_cr.c](#).

## 9.90 smoother\_csr\_poly.c File Reference

Smoothers for [dCSRmat](#) matrices using poly. approx. to  $A^{-1}$ .

```
#include <math.h>
#include <time.h>
#include <float.h>
#include <limits.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_smoother\\_dcsr\\_poly](#) ([dCSRmat](#) \**Amat*, [dvector](#) \**brhs*, [dvector](#) \**usol*, [INT](#) *n*, [INT](#) *ndeg*, [INT](#) *L*)  
*poly approx to  $A^{-1}$  as MG smoother*
- void [fasp\\_smoother\\_dcsr\\_poly\\_old](#) ([dCSRmat](#) \**Amat*, [dvector](#) \**brhs*, [dvector](#) \**usol*, [INT](#) *n*, [INT](#) *ndeg*, [INT](#) *L*)  
*poly approx to  $A^{-1}$  as MG smoother: JK&LTZ2010*

### 9.90.1 Detailed Description

Smoothers for [dCSRmat](#) matrices using poly. approx. to  $A^{-1}$ .

Definition in file [smoother\\_csr\\_poly.c](#).

### 9.90.2 Function Documentation

9.90.2.1 void [fasp\\_smoother\\_dcsr\\_poly](#) ( [dCSRmat](#) \* *Amat*, [dvector](#) \* *brhs*, [dvector](#) \* *usol*, [INT](#) *n*, [INT](#) *ndeg*, [INT](#) *L* )

poly approx to  $A^{-1}$  as MG smoother

#### Parameters

<i>Amat</i>	Pointer to stiffness matrix, consider square matrix.
<i>brhs</i>	Pointer to right hand side
<i>usol</i>	Pointer to solution
<i>n</i>	Problem size
<i>ndeg</i>	Degree of poly
<i>L</i>	Number of iterations

#### Author

Fei Cao, Xiaozhe Hu

#### Date

05/24/2012

Definition at line 46 of file [smoother\\_csr\\_poly.c](#).

9.90.2.2 void [fasp\\_smoother\\_dcsr\\_poly\\_old](#) ( [dCSRmat](#) \* *Amat*, [dvector](#) \* *brhs*, [dvector](#) \* *usol*, [INT](#) *n*, [INT](#) *ndeg*, [INT](#) *L* )

poly approx to  $A^{-1}$  as MG smoother: JK&LTZ2010

## Parameters

<i>Amat</i>	Pointer to stiffness matrix
<i>brhs</i>	Pointer to right hand side
<i>usol</i>	Pointer to solution
<i>n</i>	Problem size
<i>ndeg</i>	Degree of poly
<i>L</i>	Number of iterations

## Author

James Brannick and Ludmil T Zikatanov

## Date

06/28/2010

Modified by Chunsheng Feng, Zheng Li on 10/18/2012

Definition at line 145 of file smoother\_csr\_poly.c.

## 9.91 smoother\_str.c File Reference

Smoothers for [dSTRmat](#) matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_smoother\\_dstr\\_jacobi](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u)  
*Jacobi method as the smoother.*
- void [fasp\\_smoother\\_dstr\\_jacobi1](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [REAL](#) \*diaginv)  
*Jacobi method as the smoother with diag\_inv given.*
- void [fasp\\_smoother\\_dstr\\_gs](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [INT](#) order, [INT](#) \*mark)  
*Gauss-Seidel method as the smoother.*
- void [fasp\\_smoother\\_dstr\\_gs1](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [INT](#) order, [INT](#) \*mark, [REAL](#) \*diaginv)  
*Gauss-Seidel method as the smoother with diag\_inv given.*
- void [fasp\\_smoother\\_dstr\\_gs\\_ascend](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [REAL](#) \*diaginv)  
*Gauss-Seidel method as the smoother in the ascending manner.*
- void [fasp\\_smoother\\_dstr\\_gs\\_descend](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [REAL](#) \*diaginv)  
*Gauss-Seidel method as the smoother in the descending manner.*
- void [fasp\\_smoother\\_dstr\\_gs\\_order](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [REAL](#) \*diaginv, [INT](#) \*mark)  
*Gauss method as the smoother in the user-defined order.*
- void [fasp\\_smoother\\_dstr\\_gs\\_cf](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [REAL](#) \*diaginv, [INT](#) \*mark, [INT](#) order)  
*Gauss method as the smoother in the C-F manner.*
- void [fasp\\_smoother\\_dstr\\_sor](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*u, [INT](#) order, [INT](#) \*mark, [REAL](#) weight)  
*SOR method as the smoother.*

- void `fasp_smoother_dstr_sor1` (`dSTRmat *A`, `dvector *b`, `dvector *u`, `INT order`, `INT *mark`, `REAL *diaginv`, `REAL weight`)  
*SOR method as the smoother.*
- void `fasp_smoother_dstr_sor_ascend` (`dSTRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `REAL weight`)  
*SOR method as the smoother in the ascending manner.*
- void `fasp_smoother_dstr_sor_descend` (`dSTRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `REAL weight`)  
*SOR method as the smoother in the descending manner.*
- void `fasp_smoother_dstr_sor_order` (`dSTRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `INT *mark`, `REAL weight`)  
*SOR method as the smoother in the user-defined order.*
- void `fasp_smoother_dstr_sor_cf` (`dSTRmat *A`, `dvector *b`, `dvector *u`, `REAL *diaginv`, `INT *mark`, `INT order`, `REAL weight`)  
*SOR method as the smoother in the C-F manner.*
- void `fasp_generate_diaginv_block` (`dSTRmat *A`, `ivector *neigh`, `dvector *diaginv`, `ivector *pivot`)  
*Generate inverse of diagonal block for block smoothers.*
- void `fasp_smoother_dstr_schwarz` (`dSTRmat *A`, `dvector *b`, `dvector *u`, `dvector *diaginv`, `ivector *pivot`, `ivector *neigh`, `ivector *order`)  
*Schwarz method as the smoother.*

### 9.91.1 Detailed Description

Smoothers for `dSTRmat` matrices.

Definition in file `smoother_str.c`.

### 9.91.2 Function Documentation

#### 9.91.2.1 void fasp\_generate\_diaginv\_block ( dSTRmat \* A, ivector \* neigh, dvector \* diaginv, ivector \* pivot )

Generate inverse of diagonal block for block smoothers.

Parameters

<i>A</i>	Pointer to <code>dCSRmat</code> : the coefficient matrix
<i>neigh</i>	Pointer to <code>ivector</code> : neighborhoods
<i>diaginv</i>	Pointer to <code>dvector</code> : the inverse of the diagonals
<i>pivot</i>	Pointer to <code>ivector</code> : the pivot of diagonal blocks

Author

Xiaozhe Hu

Date

10/01/2011

Definition at line 1517 of file `smoother_str.c`.

#### 9.91.2.2 void fasp\_smoother\_dstr\_gs ( dSTRmat \* A, dvector \* b, dvector \* u, INT order, INT \* mark )

Gauss-Seidel method as the smoother.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending manner D↔ ESCEND 21: in descending manner If mark != NULL USERDEFINED 0 : in the user-defined manner CPFIRST 1 : C-points first and then F-points FPFIRST -1 : F-points first and then C-points
<i>mark</i>	Pointer to the user-defined ordering(when order=0) or CF_marker array(when order!=0)

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 202 of file smoother\_str.c.

9.91.2.3 void fasp\_smoother\_dstr\_gs1 ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, INT *order*, INT \* *mark*, REAL \* *diaginv* )

Gauss-Seidel method as the smoother with diag\_inv given.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending manner D↔ ESCEND 21: in descending manner If mark != NULL USERDEFINED 0 : in the user-defined manner CPFIRST 1 : C-points first and then F-points FPFIRST -1 : F-points first and then C-points
<i>mark</i>	Pointer to the user-defined ordering(when order=0) or CF_marker array(when order!=0)
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 261 of file smoother\_str.c.

9.91.2.4 void fasp\_smoother\_dstr\_gs\_ascend ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv* )

Gauss-Seidel method as the smoother in the ascending manner.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 306 of file smoother\_str.c.

**9.91.2.5** void fasp\_smoother\_dstr\_gs\_cf ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, INT \* *mark*, INT *order* )

Gauss method as the smoother in the C-F manner.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1
<i>mark</i>	Pointer to the user-defined order array
<i>order</i>	Flag to indicate the order for smoothing CPFIRST 1 : C-points first and then F-points FPFIRST -1 : F-points first and then C-points

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 660 of file smoother\_str.c.

**9.91.2.6** void fasp\_smoother\_dstr\_gs\_descend ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv* )

Gauss-Seidel method as the smoother in the descending manner.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1

**Author**

Shiquan Zhang, Zhiyang Zhou

**Date**

10/10/2010

Definition at line 421 of file smoother\_str.c.

9.91.2.7 void fasp\_smoother\_dstr\_gs\_order ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, INT \* *mark* )

Gauss method as the smoother in the user-defined order.

**Parameters**

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1
<i>mark</i>	Pointer to the user-defined order array

**Author**

Shiquan Zhang, Zhiyang Zhou

**Date**

10/10/2010

Definition at line 538 of file smoother\_str.c.

9.91.2.8 void fasp\_smoother\_dstr\_jacobi ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u* )

Jacobi method as the smoother.

**Parameters**

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns

**Author**

Shiquan Zhang, Zhiyang Zhou



## Date

10/10/2010

Definition at line 31 of file smoother\_str.c.

9.91.2.9 void fasp\_smoother\_dstr\_jacobi1 ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv* )

Jacobi method as the smoother with diag\_inv given.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 79 of file smoother\_str.c.

9.91.2.10 void fasp\_smoother\_dstr\_schwarz ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, dvector \* *diaginv*, ivector \* *pivot*, ivector \* *neigh*, ivector \* *order* )

Schwarz method as the smoother.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	Pointer to dvector: the inverse of the diagonals
<i>pivot</i>	Pointer to ivector: the pivot of diagonal blocks
<i>neigh</i>	Pointer to ivector: neighborhoods
<i>order</i>	Pointer to ivector: the smoothing order

## Author

Xiaozhe Hu

## Date

10/01/2011

Definition at line 1639 of file smoother\_str.c.

9.91.2.11 void fasp\_smoother\_dstr\_sor ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, INT *order*, INT \* *mark*, REAL *weight* )

SOR method as the smoother.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending manner D↔ ESCEND 21: in descending manner If mark != NULL USERDEFINED 0 : in the user-defined manner CPFIRST 1 : C-points first and then F-points FPFIRST -1 : F-points first and then C-points
<i>mark</i>	Pointer to the user-defined ordering(when order=0) or CF_marker array(when order!=0)
<i>weight</i>	Over-relaxation weight

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 851 of file smoother\_str.c.

**9.91.2.12** void fasp\_smoother\_dstr\_sor1 ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, INT *order*, INT \* *mark*, REAL \* *diaginv*, REAL *weight* )

SOR method as the smoother.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>order</i>	Flag to indicate the order for smoothing If mark = NULL ASCEND 12: in ascending manner D↔ ESCEND 21: in descending manner If mark != NULL USERDEFINED 0 : in the user-defined manner CPFIRST 1 : C-points first and then F-points FPFIRST -1 : F-points first and then C-points
<i>mark</i>	Pointer to the user-defined ordering(when order=0) or CF_marker array(when order!=0)
<i>diaginv</i>	Inverse of the diagonal entries
<i>weight</i>	Over-relaxation weight

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 912 of file smoother\_str.c.

**9.91.2.13** void fasp\_smoother\_dstr\_sor\_ascend ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, REAL *weight* )

SOR method as the smoother in the ascending manner.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1
<i>weight</i>	Over-relaxation weight

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 958 of file smoother\_str.c.

**9.91.2.14** void fasp\_smoother\_dstr\_sor\_cf ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, INT \* *mark*, INT *order*, REAL *weight* )

SOR method as the smoother in the C-F manner.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when (A->nc)>1, and NULL when (A->nc)=1
<i>mark</i>	Pointer to the user-defined order array
<i>order</i>	Flag to indicate the order for smoothing CPFIRST 1 : C-points first and then F-points FPFIRST -1 : F-points first and then C-points
<i>weight</i>	Over-relaxation weight

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 1330 of file smoother\_str.c.

**9.91.2.15** void fasp\_smoother\_dstr\_sor\_descend ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, REAL \* *diaginv*, REAL *weight* )

SOR method as the smoother in the descending manner.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when $(A->nc)>1$ , and NULL when $(A->nc)=1$
<i>weight</i>	Over-relaxation weight

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 1078 of file smoother\_str.c.

```
9.91.2.16 void fasp_smoother_dstr_sor_order ( dSTRmat * A, dvector * b, dvector * u, REAL * diaginv, INT * mark,
REAL weight )
```

SOR method as the smoother in the user-defined order.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>diaginv</i>	All the inverse matrices for all the diagonal block of A when $(A->nc)>1$ , and NULL when $(A->nc)=1$
<i>mark</i>	Pointer to the user-defined order array
<i>weight</i>	Over-relaxation weight

## Author

Shiquan Zhang, Zhiyang Zhou

## Date

10/10/2010

Definition at line 1199 of file smoother\_str.c.

## 9.92 sparse\_block.c File Reference

Sparse matrix block operations.

```
#include <time.h>
#include "fasp.h"
#include "fasp_block.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_bdcsr\\_free](#) ([block\\_dCSRmat](#) \*A)  
*Free block CSR sparse matrix data memeory space.*
- **SHORT** [fasp\\_dcsr\\_getblk](#) ([dCSRmat](#) \*A, [INT](#) \*Is, [INT](#) \*Js, [INT](#) m, [INT](#) n, [dCSRmat](#) \*B)  
*Get a sub CSR matrix of A with specified rows and columns.*
- **SHORT** [fasp\\_dbsr\\_getblk](#) ([dBSRmat](#) \*A, [INT](#) \*Is, [INT](#) \*Js, [INT](#) m, [INT](#) n, [dBSRmat](#) \*B)  
*Get a sub BSR matrix of A with specified rows and columns.*
- [dCSRmat](#) [fasp\\_dbsr\\_getblk\\_dcsr](#) ([dBSRmat](#) \*A)  
*get dCSRmat block from a dBSRmat matrix*
- [dCSRmat](#) [fasp\\_dbsr\\_Linfinity\\_dcsr](#) ([dBSRmat](#) \*A)  
*get dCSRmat from a dBSRmat matrix using L infinity norm of each small block*

### 9.92.1 Detailed Description

Sparse matrix block operations.

Definition in file [sparse\\_block.c](#).

### 9.92.2 Function Documentation

#### 9.92.2.1 void fasp\_bdcsr\_free ( block\_dCSRmat \* A )

Free block CSR sparse matrix data memeory space.

Parameters

<a href="#">A</a>	Pointer to the <a href="#">block_dCSRmat</a> matrix
-------------------	---

Author

Xiaozhe Hu

Date

04/18/2014

Definition at line 31 of file [sparse\\_block.c](#).

#### 9.92.2.2 SHORT fasp\_dbsr\_getblk ( dBSRmat \* A, INT \* Is, INT \* Js, INT m, INT n, dBSRmat \* B )

Get a sub BSR matrix of A with specified rows and columns.

Parameters

<a href="#">A</a>	Pointer to <a href="#">dBSRmat</a> BSR matrix
<a href="#">B</a>	Pointer to <a href="#">dBSRmat</a> BSR matrix

<i>Is</i>	Pointer to selected rows
<i>Js</i>	Pointer to selected columns
<i>m</i>	Number of selected rows
<i>n</i>	Number of selected columns

**Returns**

FASP\_SUCCESS if succeeded, otherwise return error information.

**Author**

Shiquan Zhang, Xiaozhe Hu

**Date**

12/25/2010

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 162 of file sparse\_block.c.

**9.92.2.3 dCSRmat fasp\_dbsr\_getblk\_dcsr ( dBSRmat \* A )**

get [dCSRmat](#) block from a [dBSRmat](#) matrix

**Parameters**

<i>*A</i>	Pointer to the BSR format matrix
-----------	----------------------------------

**Returns**

[dCSRmat](#) matrix if succeed, NULL if fail

**Author**

Xiaozhe Hu

**Date**

03/16/2012

Definition at line 258 of file sparse\_block.c.

**9.92.2.4 dCSRmat fasp\_dbsr\_Linfinity\_dcsr ( dBSRmat \* A )**

get [dCSRmat](#) from a [dBSRmat](#) matrix using L infinity norm of each small block

**Parameters**

<i>*A</i>	Pointer to the BSR format matrix
-----------	----------------------------------

**Returns**

[dCSRmat](#) matrix if succeed, NULL if fail

**Author**

Xiaozhe Hu

**Date**

05/25/2014

Definition at line 312 of file sparse\_block.c.

### 9.92.2.5 **SHORT** fasp\_dcsr\_getblk ( [dCSRmat](#) \* *A*, INT \* *Is*, INT \* *Js*, INT *m*, INT *n*, [dCSRmat](#) \* *B* )

Get a sub CSR matrix of A with specified rows and columns.

**Parameters**

<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix
<i>B</i>	Pointer to <a href="#">dCSRmat</a> matrix
<i>Is</i>	Pointer to selected rows
<i>Js</i>	Pointer to selected columns
<i>m</i>	Number of selected rows
<i>n</i>	Number of selected columns

**Returns**

FASP\_SUCCESS if succeeded, otherwise return error information.

**Author**

Shiquan Zhang, Xiaozhe Hu

**Date**

12/25/2010

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 69 of file sparse\_block.c.

## 9.93 sparse\_bsr.c File Reference

Sparse matrix operations for [dBSRmat](#) matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- `dBSRmat fasp_dbsr_create (INT ROW, INT COL, INT NNZ, INT nb, INT storage_manner)`  
Create BSR sparse matrix data memory space.
- `void fasp_dbsr_alloc (INT ROW, INT COL, INT NNZ, INT nb, INT storage_manner, dBSRmat *A)`  
Allocate memory space for BSR format sparse matrix.
- `void fasp_dbsr_free (dBSRmat *A)`  
Free memory space for BSR format sparse matrix.
- `void fasp_dbsr_null (dBSRmat *A)`  
Initialize sparse matrix on structured grid.
- `void fasp_dbsr_cp (dBSRmat *A, dBSRmat *B)`  
copy a *dCSRmat* to a new one  $B=A$
- `INT fasp_dbsr_trans (dBSRmat *A, dBSRmat *AT)`  
Find  $A^T$  from given *dBSRmat* matrix  $A$ .
- `SHORT fasp_dbsr_diagpref (dBSRmat *A)`  
Reorder the column and data arrays of a square BSR matrix, so that the first entry in each row is the diagonal one.
- `dvector fasp_dbsr_getdiainv (dBSRmat *A)`  
Get  $D^{-1}$  of matrix  $A$ .
- `dBSRmat fasp_dbsr_diainv (dBSRmat *A)`  
Compute  $B := D^{-1} * A$ , where ' $D$ ' is the block diagonal part of  $A$ .
- `dBSRmat fasp_dbsr_diainv2 (dBSRmat *A, REAL *diainv)`  
Compute  $B := D^{-1} * A$ , where ' $D$ ' is the block diagonal part of  $A$ .
- `dBSRmat fasp_dbsr_diainv3 (dBSRmat *A, REAL *diainv)`  
Compute  $B := D^{-1} * A$ , where ' $D$ ' is the block diagonal part of  $A$ .
- `dBSRmat fasp_dbsr_diainv4 (dBSRmat *A, REAL *diainv)`  
Compute  $B := D^{-1} * A$ , where ' $D$ ' is the block diagonal part of  $A$ .
- `void fasp_dbsr_getdiag (INT n, dBSRmat *A, REAL *diag)`  
Abstract the diagonal blocks of a BSR matrix.
- `dBSRmat fasp_dbsr_diagLU (dBSRmat *A, REAL *DL, REAL *DU)`  
Compute  $B := DL * A * DU$ . We decompose each diagonal block of  $A$  into LDU form and  $DL = \text{diag}(L^{-1})$  and  $DU = \text{diag}(U^{-1})$ .
- `dBSRmat fasp_dbsr_diagLU2 (dBSRmat *A, REAL *DL, REAL *DU)`

### 9.93.1 Detailed Description

Sparse matrix operations for *dBSRmat* matrices.

Definition in file `sparse_bsr.c`.

### 9.93.2 Function Documentation

#### 9.93.2.1 `void fasp_dbsr_alloc ( INT ROW, INT COL, INT NNZ, INT nb, INT storage_manner, dBSRmat * A )`

Allocate memory space for BSR format sparse matrix.



## Parameters

<i>ROW</i>	Number of rows of block
<i>COL</i>	Number of columns of block
<i>NNZ</i>	Number of nonzero blocks
<i>nb</i>	Dimension of exch block
<i>storage_manner</i>	Storage manner for each sub-block
<i>A</i>	Pointer to new <a href="#">dBSRmat</a> matrix

## Author

Xiaozhe Hu

## Date

10/26/2010

Definition at line 86 of file sparse\_bsr.c.

9.93.2.2 void fasp\_dbsr\_cp ( [dBSRmat](#) \* *A*, [dBSRmat](#) \* *B* )copy a [dCSRmat](#) to a new one B=A

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>B</i>	Pointer to the <a href="#">dBSRmat</a> matrix

## Author

Xiaozhe Hu

## Date

08/07/2011

Definition at line 180 of file sparse\_bsr.c.

9.93.2.3 [dBSRmat](#) fasp\_dbsr\_create ( INT *ROW*, INT *COL*, INT *NNZ*, INT *nb*, INT *storage\_manner* )

Create BSR sparse matrix data memory space.

## Parameters

<i>ROW</i>	Number of rows of block
<i>COL</i>	Number of columns of block
<i>NNZ</i>	Number of nonzero blocks
<i>nb</i>	Dimension of exch block
<i>storage_manner</i>	Storage manner for each sub-block

## Returns

A The new [dBSRmat](#) matrix

**Author**

Xiaozhe Hu

**Date**

10/26/2010

Definition at line 35 of file sparse\_bsr.c.

**9.93.2.4 dBSRmat fasp\_dbsr\_diaginv ( dBSRmat \* A )**Compute  $B := D^{-1} * A$ , where 'D' is the block diagonal part of A.**Parameters**

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
----------	---

**Author**

Zhiyang Zhou

**Date**

2010/10/26

**Note**

Works for general nb (Xiaozhe)

Modified by Chunsheng Feng, Zheng Li on 08/25/2012

Definition at line 505 of file sparse\_bsr.c.

**9.93.2.5 dBSRmat fasp\_dbsr\_diaginv2 ( dBSRmat \* A, REAL \* diaginv )**Compute  $B := D^{-1} * A$ , where 'D' is the block diagonal part of A.**Parameters**

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>diaginv</i>	Pointer to the inverses of all the diagonal blocks

**Author**

Zhiyang Zhou

**Date**

2010/11/07

**Note**

Works for general nb (Xiaozhe)

Modified by Chunsheng Feng, Zheng Li on 08/25/2012

Definition at line 667 of file sparse\_bsr.c.

9.93.2.6 `dBSRmat fasp_dbsr_diaginv3 ( dBSRmat * A, REAL * diaginv )`

Compute  $B := D^{-1} * A$ , where 'D' is the block diagonal part of A.

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>diaginv</i>	Pointer to the inverses of all the diagonal blocks

## Returns

BSR matrix after diagonal scaling

## Author

Xiaozhe Hu

## Date

12/25/2010

## Note

Works for general nb (Xiaozhe)

Modified by Xiaozhe Hu on 05/26/2012

Definition at line 769 of file sparse\_bsr.c.

### 9.93.2.7 dBSRmat fasp\_dbsr\_diaginv4 ( dBSRmat \* *A*, REAL \* *diaginv* )

Compute  $B := D^{-1}A$ , where 'D' is the block diagonal part of A.

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>diaginv</i>	Pointer to the inverses of all the diagonal blocks

## Returns

BSR matrix after diagonal scaling

## Note

Works for general nb (Xiaozhe)

A is preordered that the first block of each row is the diagonal block!

## Author

Xiaozhe Hu

## Date

03/12/2011

Modified by Chunsheng Feng, Zheng Li on 08/26/2012

Definition at line 1127 of file sparse\_bsr.c.

### 9.93.2.8 dBSRmat fasp\_dbsr\_diagLU ( dBSRmat \* *A*, REAL \* *DL*, REAL \* *DU* )

Compute  $B := DL * A * DU$ . We decompose each diagonal block of A into LDU form and  $DL = \text{diag}(L^{-1})$  and  $DU = \text{diag}(U^{-1})$ .

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>DL</i>	Pointer to the $\text{diag}(L^{-1})$
<i>DU</i>	Pointer to the $\text{diag}(U^{-1})$

## Returns

BSR matrix after scaling

## Author

Xiaozhe Hu

## Date

04/02/2014

## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>DL</i>	Pointer to the $\text{diag}(L^{-1})$
<i>DU</i>	Pointer to the $\text{diag}(U^{-1})$

## Returns

BSR matrix after scaling

## Author

Zheng Li, Xiaozhe Hu

## Date

06/17/2014

Definition at line 1457 of file sparse\_bsr.c.

### 9.93.2.9 SHORT fasp\_dbsr\_diagpref ( dBSRmat \* A )

Reorder the column and data arrays of a square BSR matrix, so that the first entry in each row is the diagonal one.

## Parameters

<i>A</i>	Pointer to the BSR matrix
----------	---------------------------

## Author

Xiaozhe Hu

## Date

03/10/2011

**Author**

Chunsheng Feng, Zheng Li

**Date**

09/02/2012

**Note**

Reordering is done in place.

Definition at line 292 of file sparse\_bsr.c.

**9.93.2.10 void fasp\_dbsr\_free ( dBSRmat \* A )**

Free memeory space for BSR format sparse matrix.

**Parameters**

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
----------	---

**Author**

Xiaozhe Hu

**Date**

10/26/2010

Definition at line 132 of file sparse\_bsr.c.

**9.93.2.11 fasp\_dbsr\_getdiag ( INT *n*, dBSRmat \* *A*, REAL \* *diag* )**

Abstract the diagonal blocks of a BSR matrix.

**Parameters**

<i>n</i>	Number of blocks to get
<i>A</i>	Pointer to the ' <a href="#">dBSRmat</a> ' type matrix
<i>diag</i>	Pointer to array which stores the diagonal blocks in row by row manner

**Author**

Zhiyang Zhou

**Date**

2010/10/26

**Note**

Works for general nb (Xiaozhe)

Modified by Chunsheng Feng, Zheng Li on 08/25/2012

Definition at line 1420 of file sparse\_bsr.c.

9.93.2.12 `dvector fasp_dbsr_getdiaginv ( dBSRmat * A )`

Get  $D^{-1}$  of matrix A.

## Parameters

$A$	Pointer to the <a href="#">dBSRmat</a> matrix
-----	---

## Author

Xiaozhe Hu

## Date

02/19/2013

## Note

Works for general nb (Xiaozhe)

Definition at line 401 of file sparse\_bsr.c.

**9.93.2.13** void fasp\_dbsr\_null ( [dBSRmat](#) \*  $A$  )

Initialize sparse matrix on structured grid.

## Parameters

$A$	Pointer to the <a href="#">dBSRmat</a> matrix
-----	---

## Author

Xiaozhe Hu

## Date

10/26/2010

Definition at line 157 of file sparse\_bsr.c.

**9.93.2.14** INT fasp\_dbsr\_trans ( [dBSRmat](#) \*  $A$ , [dBSRmat](#) \*  $AT$  )

Find  $A^T$  from given [dBSRmat](#) matrix  $A$ .

## Parameters

$A$	Pointer to the <a href="#">dBSRmat</a> matrix
$AT$	Pointer to the transpose of <a href="#">dBSRmat</a> matrix $A$

## Author

Chunsheng FENG

## Date

2011/06/08

Modified by Xiaozhe Hu (08/06/2011)

Definition at line 207 of file sparse\_bsr.c.



## 9.94 sparse\_coo.c File Reference

Sparse matrix operations for [dCOOmat](#) matrices.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- [dCOOmat fasp\\_dcoo\\_create](#) ([INT](#) m, [INT](#) n, [INT](#) nnz)  
*Create IJ sparse matrix data memory space.*
- void [fasp\\_dcoo\\_alloc](#) (const [INT](#) m, const [INT](#) n, const [INT](#) nnz, [dCOOmat](#) \*A)  
*Allocate COO sparse matrix memory space.*
- void [fasp\\_dcoo\\_free](#) ([dCOOmat](#) \*A)  
*Free IJ sparse matrix data memeory space.*
- void [fasp\\_dcoo\\_shift](#) ([dCOOmat](#) \*A, [INT](#) offset)  
*Reindex a REAL matrix in IJ format to make the index starting from 0 or 1.*

### 9.94.1 Detailed Description

Sparse matrix operations for [dCOOmat](#) matrices.

Definition in file [sparse\\_coo.c](#).

### 9.94.2 Function Documentation

#### 9.94.2.1 void fasp\_dcoo\_alloc ( const [INT](#) m, const [INT](#) n, const [INT](#) nnz, [dCOOmat](#) \* A )

Allocate COO sparse matrix memory space.

#### Parameters

<i>m</i>	Number of rows
<i>n</i>	Number of columns
<i>nnz</i>	Number of nonzeros
<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix

#### Author

Xiaozhe Hu

#### Date

03/25/2013

Definition at line 62 of file [sparse\\_coo.c](#).

#### 9.94.2.2 dCOOmat fasp\_dcoo\_create ( INT *m*, INT *n*, INT *nnz* )

Create IJ sparse matrix data memory space.

## Parameters

<i>m</i>	Number of rows
<i>n</i>	Number of columns
<i>nnz</i>	Number of nonzeros

## Returns

A The new [dCOOmat](#) matrix

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 34 of file sparse\_coo.c.

#### 9.94.2.3 void fasp\_dcoo\_free ( [dCOOmat](#) \* *A* )

Free IJ sparse matrix data memeory space.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCOOmat</a> matrix
----------	---

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 95 of file sparse\_coo.c.

#### 9.94.2.4 void fasp\_dcoo\_shift ( [dCOOmat](#) \* *A*, *INT offset* )

Reindex a REAL matrix in IJ format to make the index starting from 0 or 1.

## Parameters

<i>A</i>	Pointer to IJ matrix
<i>offset</i>	Size of offset (1 or -1)

## Author

Chensong Zhang

## Date

2010/04/06

Modified by Chunsheng Feng, Zheng Li on 08/25/2012

Definition at line 117 of file sparse\_coo.c.

## 9.95 sparse\_csr.c File Reference

Sparse matrix operations for `dCSRmat` matrices.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- `dCSRmat fasp_dcsr_create` (const `INT` m, const `INT` n, const `INT` nnz)  
*Create CSR sparse matrix data memory space.*
- `iCSRmat fasp_icsr_create` (const `INT` m, const `INT` n, const `INT` nnz)  
*Create CSR sparse matrix data memory space.*
- void `fasp_dcsr_alloc` (const `INT` m, const `INT` n, const `INT` nnz, `dCSRmat` \*A)  
*Allocate CSR sparse matrix memory space.*
- void `fasp_dcsr_free` (`dCSRmat` \*A)  
*Free CSR sparse matrix data memeory space.*
- void `fasp_icsr_free` (`iCSRmat` \*A)  
*Free CSR sparse matrix data memeory space.*
- void `fasp_dcsr_null` (`dCSRmat` \*A)  
*Initialize CSR sparse matrix.*
- void `fasp_icsr_null` (`iCSRmat` \*A)  
*Initialize CSR sparse matrix.*
- `dCSRmat fasp_dcsr_perm` (`dCSRmat` \*A, `INT` \*P)  
*Apply permutation of A, i.e. Aperm=PAP' by the orders given in P.*
- void `fasp_dcsr_sort` (`dCSRmat` \*A)  
*Sort each row of A in ascending order w.r.t. column indices.*
- void `fasp_dcsr_getdiag` (`INT` n, `dCSRmat` \*A, `dvector` \*diag)  
*Get first n diagonal entries of a CSR matrix A.*
- void `fasp_dcsr_getcol` (const `INT` n, `dCSRmat` \*A, `REAL` \*col)  
*Get the n-th column of a CSR matrix A.*
- void `fasp_dcsr_diagpref` (`dCSRmat` \*A)  
*Re-order the column and data arrays of a CSR matrix, so that the first entry in each row is the diagonal.*
- `SHORT fasp_dcsr_regdiag` (`dCSRmat` \*A, `REAL` value)  
*Regularize diagonal entries of a CSR sparse matrix.*
- void `fasp_icsr_cp` (`iCSRmat` \*A, `iCSRmat` \*B)  
*Copy a iCSRmat to a new one B=A.*
- void `fasp_dcsr_cp` (`dCSRmat` \*A, `dCSRmat` \*B)  
*copy a dCSRmat to a new one B=A*
- void `fasp_icsr_trans` (`iCSRmat` \*A, `iCSRmat` \*AT)  
*Find transpose of iCSRmat matrix A.*
- `INT fasp_dcsr_trans` (`dCSRmat` \*A, `dCSRmat` \*AT)  
*Find tranpose of dCSRmat matrix A.*
- void `fasp_dcsr_transpose` (`INT` \*row[2], `INT` \*col[2], `REAL` \*val[2], `INT` \*nn, `INT` \*tniz)
- void `fasp_dcsr_compress` (`dCSRmat` \*A, `dCSRmat` \*B, `REAL` dtol)

Compress a CSR matrix  $A$  and store in CSR matrix  $B$  by dropping small entries  $\text{abs}(a_{ij}) \leq \text{dtol}$ .

- **SHORT** `fasp_dcsr_compress_inplace` (`dCSRmat` \* $A$ , `REAL`  $\text{dtol}$ )

Compress a CSR matrix  $A$  IN PLACE by dropping small entries  $\text{abs}(a_{ij}) \leq \text{dtol}$ .

- void `fasp_dcsr_shift` (`dCSRmat` \* $A$ , `INT`  $\text{offset}$ )

Reindex a `REAL` matrix in CSR format to make the index starting from 0 or 1.

- void `fasp_dcsr_symdiagscale` (`dCSRmat` \* $A$ , `dvector` \* $\text{diag}$ )

Symmetric diagonal scaling  $D^{-1/2} A D^{-1/2}$ .

- `dCSRmat` `fasp_dcsr_sympat` (`dCSRmat` \* $A$ )

Symmetrize the parttern of a `dCSRmat` matrix.

- void `fasp_dcsr_multicoloring` (`dCSRmat` \* $A$ , `INT` \* $\text{flags}$ , `INT` \* $\text{groups}$ )

Use the greedy multicoloring to get color groups of the adjacency graph of  $A$ .

### 9.95.1 Detailed Description

Sparse matrix operations for `dCSRmat` matrices.

Definition in file `sparse_csr.c`.

### 9.95.2 Function Documentation

#### 9.95.2.1 void fasp\_dcsr\_alloc ( const INT $m$ , const INT $n$ , const INT $nnz$ , `dCSRmat` \* $A$ )

Allocate CSR sparse matrix memory space.

Parameters

$m$	Number of rows
$n$	Number of columns
$nnz$	Number of nonzeros
$A$	Pointer to the <code>dCSRmat</code> matrix

Author

Chensong Zhang

Date

2010/04/06

Definition at line 125 of file `sparse_csr.c`.

#### 9.95.2.2 void fasp\_dcsr\_compress ( `dCSRmat` \* $A$ , `dCSRmat` \* $B$ , `REAL` $\text{dtol}$ )

Compress a CSR matrix  $A$  and store in CSR matrix  $B$  by dropping small entries  $\text{abs}(a_{ij}) \leq \text{dtol}$ .

Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> CSR matrix
<i>B</i>	Pointer to <a href="#">dCSRmat</a> CSR matrix
<i>dtol</i>	Drop tolerance

**Author**

Shiquan Zhang

**Date**

03/10/2010

Modified by Chunsheng Feng, Zheng Li on 08/25/2012

Definition at line 961 of file sparse\_csr.c.

**9.95.2.3 SHORT fasp\_dcsr\_compress\_inplace ( dCSRmat \* A, REAL dtol )**Compress a CSR matrix A IN PLACE by dropping small entries  $\text{abs}(a_{ij}) \leq \text{dtol}$ .**Parameters**

<i>A</i>	Pointer to <a href="#">dCSRmat</a> CSR matrix
<i>dtol</i>	Drop tolerance

**Author**

Xiaozhe Hu

**Date**

12/25/2010

Modified by Chensong on 02/21/2013

**Note**

This routine can be modified for filtering.

Definition at line 1041 of file sparse\_csr.c.

**9.95.2.4 void fasp\_dcsr\_cp ( dCSRmat \* A, dCSRmat \* B )**copy a [dCSRmat](#) to a new one B=A**Parameters**

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
<i>B</i>	Pointer to the <a href="#">dCSRmat</a> matrix

**Author**

Chensong Zhang

## Date

04/06/2010

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 722 of file sparse\_csr.c.

**9.95.2.5 dCSRmat fasp\_dcsr\_create ( const INT  $m$ , const INT  $n$ , const INT  $nnz$  )**

Create CSR sparse matrix data memory space.

## Parameters

$m$	Number of rows
$n$	Number of columns
$nnz$	Number of nonzeros

## Returns

A the new [dCSRmat](#) matrix

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 34 of file sparse\_csr.c.

**9.95.2.6 void fasp\_dcsr\_diagpref ( dCSRmat \*  $A$  )**

Re-order the column and data arrays of a CSR matrix, so that the first entry in each row is the diagonal.

## Parameters

$A$	Pointer to the matrix to be re-ordered
-----	--

## Author

Zhiyang Zhou

## Date

09/09/2010

## Author

Chunsheng Feng, Zheng Li

## Date

09/02/2012

## Note

Reordering is done in place.

Modified by Chensong Zhang on Dec/21/2012

Definition at line 551 of file sparse\_csr.c.

**9.95.2.7 void fasp\_dcsr\_free ( dCSRmat \* A )**

Free CSR sparse matrix data memeory space.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
----------	---

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 166 of file sparse\_csr.c.

**9.95.2.8 void fasp\_dcsr\_getcol ( const INT *n*, dCSRmat \* *A*, REAL \* *col* )**Get the *n*-th column of a CSR matrix *A*.

## Parameters

<i>n</i>	Index of a column of <i>A</i> ( $0 \leq n \leq A.col-1$ )
<i>A</i>	Pointer to <a href="#">dCSRmat</a> CSR matrix
<i>col</i>	Pointer to the column

## Author

Xiaozhe Hu

## Date

11/07/2009

Modified by Chunsheng Feng, Zheng Li on 07/08/2012

Definition at line 472 of file sparse\_csr.c.

**9.95.2.9 void fasp\_dcsr\_getdiag ( INT *n*, dCSRmat \* *A*, dvector \* *diag* )**Get first *n* diagonal entries of a CSR matrix *A*.



## Parameters

<i>n</i>	Number of diag entries to get (if $n=0$ , then get all diagonal entries)
<i>A</i>	Pointer to <a href="#">dCSRmat</a> CSR matrix
<i>diag</i>	Pointer to the diagonal as a dvector

## Author

Chensong Zhang

## Date

05/20/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 408 of file sparse\_csr.c.

9.95.2.10 void fasp\_dcsr\_multicoloring ( [dCSRmat](#) \* *A*, INT \* *flags*, INT \* *groups* )Use the greedy multicoloring to get color groups of the adjacency graph of *A*.

## Parameters

<i>A</i>	Input <a href="#">dCSRmat</a>
<i>flags</i>	flags for the independent group
<i>groups</i>	Return group numbers

## Author

Chunsheng Feng

## Date

09/15/2012

Definition at line 1273 of file sparse\_csr.c.

9.95.2.11 void fasp\_dcsr\_null ( [dCSRmat](#) \* *A* )

Initialize CSR sparse matrix.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
----------	---

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 204 of file sparse\_csr.c.

9.95.2.12 `dCSRmat fasp_dcsr_perm ( dCSRmat * A, INT * P )`

Apply permutation of A, i.e.  $A_{perm} = PAP'$  by the orders given in P.

## Parameters

<i>A</i>	Pointer to the original <a href="#">dCSRmat</a> matrix
<i>P</i>	Pointer to orders

## Returns

The new ordered [dCSRmat](#) matrix if succeed, NULL if fail

## Author

Shiquan Zhang

## Date

03/10/2010

## Note

$P[i] = k$  means k-th row and column become i-th row and column!

Modified by Chunsheng Feng, Zheng Li on 07/12/2012

Definition at line 245 of file sparse\_csr.c.

#### 9.95.2.13 **SHORT** fasp\_dcsr\_regdiag ( [dCSRmat](#) \* *A*, **REAL** *value* )

Regularize diagonal entries of a CSR sparse matrix.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
<i>value</i>	Set a value on diag( <i>A</i> ) which is too close to zero to "value"

## Returns

FASP\_SUCCESS if no diagonal entry is close to zero, else ERROR

## Author

Shiquan Zhang

## Date

11/07/2009

Definition at line 658 of file sparse\_csr.c.

#### 9.95.2.14 **void** fasp\_dcsr\_shift ( [dCSRmat](#) \* *A*, **INT** *offset* )

Reindex a REAL matrix in CSR format to make the index starting from 0 or 1.

## Parameters

<i>A</i>	Pointer to CSR matrix
<i>offset</i>	Size of offset (1 or -1)

## Author

Chensong Zhang

## Date

04/06/2010

Modified by chunsheng Feng, Zheng Li on 07/11/2012

Definition at line 1089 of file sparse\_csr.c.

9.95.2.15 void fasp\_dcsr\_sort ( dCSRmat \* *A* )Sort each row of *A* in ascending order w.r.t. column indices.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
----------	---

## Author

Shiquan Zhang

## Date

06/10/2010

Definition at line 356 of file sparse\_csr.c.

9.95.2.16 void fasp\_dcsr\_symdiagscale ( dCSRmat \* *A*, dvector \* *diag* )Symmetric diagonal scaling  $D^{-1/2}AD^{-1/2}$ .

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
<i>diag</i>	Pointer to the diagonal entries

## Author

Xiaozhe Hu

## Date

01/31/2011

Modified by Chunsheng Feng, Zheng Li on 07/11/2012

Definition at line 1152 of file sparse\_csr.c.

#### 9.95.2.17 dCSRmat fasp\_dcsr\_symmat ( dCSRmat \* A )

Symmetrize the parttarn of a [dCSRmat](#) matrix.

## Parameters

<code>*A</code>	pointer to the <a href="#">dCSRmat</a> matrix
-----------------	---

## Returns

symmetrized the [dCSRmat](#) matrix

## Author

Xiaozhe Hu

## Date

03/21/2011

Definition at line 1239 of file `sparse_csr.c`.

9.95.2.18 `void fasp_dcsr_trans ( dCSRmat * A, dCSRmat * AT )`

Find tranpose of [dCSRmat](#) matrix A.

## Parameters

<code>A</code>	Pointer to the <a href="#">dCSRmat</a> matrix
<code>AT</code>	Pointer to the transpose of <a href="#">dCSRmat</a> matrix A (output)

## Author

Chensong Zhang

## Date

04/06/2010

Modified by Chunsheng Feng, Zheng Li on 06/20/2012

Definition at line 828 of file `sparse_csr.c`.

9.95.2.19 `void fasp_icsr_cp ( iCSRmat * A, iCSRmat * B )`

Copy a [iCSRmat](#) to a new one B=A.

## Parameters

<code>A</code>	Pointer to the <a href="#">iCSRmat</a> matrix
<code>B</code>	Pointer to the <a href="#">iCSRmat</a> matrix

## Author

Chensong Zhang

## Date

05/16/2013

Definition at line 697 of file `sparse_csr.c`.

9.95.2.20 `iCSRmat fasp_icsr_create ( const INT m, const INT n, const INT nnz )`

Create CSR sparse matrix data memory space.

## Parameters

$m$	Number of rows
$n$	Number of columns
$nnz$	Number of nonzeros

## Returns

A the new [iCSRmat](#) matrix

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 80 of file sparse\_csr.c.

#### 9.95.2.21 void fasp\_iclr\_free ( iCSRmat \* A )

Free CSR sparse matrix data memeory space.

## Parameters

$A$	Pointer to the <a href="#">iCSRmat</a> matrix
-----	---

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 185 of file sparse\_csr.c.

#### 9.95.2.22 void fasp\_iclr\_null ( iCSRmat \* A )

Initialize CSR sparse matrix.

## Parameters

$A$	Pointer to the <a href="#">iCSRmat</a> matrix
-----	---

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 221 of file sparse\_csr.c.



9.95.2.23 void fasp\_icsr\_trans ( iCSRmat \* A, iCSRmat \* AT )

Find transpose of iCSRmat matrix A.

**Parameters**

<i>A</i>	Pointer to the <a href="#">iCSRmat</a> matrix A
<i>AT</i>	Pointer to the <a href="#">iCSRmat</a> matrix A'

**Returns**

The transpose of [iCSRmat](#) matrix A

**Author**

Chensong Zhang

**Date**

04/06/2010

Modified by Chunsheng Feng, Zheng Li on 06/20/2012

Definition at line 749 of file `sparse_csr.c`.

## 9.96 `sparse_csr.c` File Reference

Sparse matrix operations for [dCSRLmat](#) matrices.

```
#include "fasp.h"
#include "fasp_functs.h"
```

**Functions**

- [dCSRLmat](#) \* [fasp\\_dcsr\\_create](#) ([INT](#) num\_rows, [INT](#) num\_cols, [INT](#) num\_nonzeros)  
*Create a [dCSRLmat](#) object.*
- void [fasp\\_dcsr\\_free](#) ([dCSRLmat](#) \*A)  
*Destroy a [dCSRLmat](#) object.*

### 9.96.1 Detailed Description

Sparse matrix operations for [dCSRLmat](#) matrices.

**Note**

For details of CSRL format, refer to Optimizing sparse matrix vector product computations using unroll and jam by John Mellor-Crummey and John Garvin, Tech Report Rice Univ, Aug 2002.

Definition in file [sparse\\_csr.c](#).

### 9.96.2 Function Documentation

9.96.2.1 [dCSRLmat](#) \* [fasp\\_dcsr\\_create](#) ( [INT](#) num\_rows, [INT](#) num\_cols, [INT](#) num\_nonzeros )

Create a [dCSRLmat](#) object.

## Parameters

<i>num_rows</i>	Number of rows
<i>num_cols</i>	Number of cols
<i>num_nonzeros</i>	Number of nonzero entries

## Author

Zhiyang Zhou

## Date

01/07/2001

Definition at line 30 of file sparse\_csrl.c.

## 9.96.2.2 void fasp\_dcsrl\_free ( dCSRmat \* A )

Destroy a dCSRmat object.

## Parameters

<i>A</i>	Pointer to the dCSRmat type matrix
----------	------------------------------------

## Author

Zhiyang Zhou

## Date

01/07/2011

Definition at line 58 of file sparse\_csrl.c.

## 9.97 sparse\_str.c File Reference

Sparse matrix operations for dSTRmat matrices.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_dstr\\_null](#) (dSTRmat \*A)  
*Initialize sparse matrix on structured grid.*
- [dSTRmat fasp\\_dstr\\_create](#) (INT nx, INT ny, INT nz, INT nc, INT nband, INT \*offsets)  
*Create STR sparse matrix data memory space.*
- void [fasp\\_dstr\\_alloc](#) (INT nx, INT ny, INT nz, INT nxy, INT ngrid, INT nband, INT nc, INT \*offsets, dSTRmat \*A)  
*Allocate STR sparse matrix memory space.*

- void [fasp\\_dstr\\_free](#) ([dSTRmat](#) \*A)  
*Free STR sparse matrix data memeory space.*
- void [fasp\\_dstr\\_cp](#) ([dSTRmat](#) \*A, [dSTRmat](#) \*A1)  
*Copy a [dSTRmat](#) to a new one A1=A.*

### 9.97.1 Detailed Description

Sparse matrix operations for [dSTRmat](#) matrices.

Definition in file [sparse\\_str.c](#).

### 9.97.2 Function Documentation

9.97.2.1 void [fasp\\_dstr\\_alloc](#) ( INT *nx*, INT *ny*, INT *nz*, INT *nxy*, INT *ngrid*, INT *nband*, INT *nc*, INT \* *offsets*, [dSTRmat](#) \* *A* )

Allocate STR sparse matrix memory space.

Parameters

<i>nx</i>	Number of grids in x direction
<i>ny</i>	Number of grids in y direction
<i>nz</i>	Number of grids in z direction
<i>nxy</i>	Number of grids in x-y plane
<i>ngrid</i>	Number of grids
<i>nband</i>	Number of off-diagonal bands
<i>nc</i>	Number of components
<i>offsets</i>	Shift from diagonal
<i>A</i>	Pointer to the <a href="#">dSTRmat</a> matrix

Author

Shiquan Zhang, Xiaozhe Hu

Date

05/17/2010

Definition at line 107 of file [sparse\\_str.c](#).

9.97.2.2 void [fasp\\_dstr\\_cp](#) ( [dSTRmat](#) \* *A*, [dSTRmat](#) \* *A1* )

Copy a [dSTRmat](#) to a new one A1=A.

Parameters

<i>A</i>	Pointer to the <a href="#">dSTRmat</a> matrix
<i>A1</i>	Pointer to the <a href="#">dSTRmat</a> matrix

Author

Zhiyang Zhou

## Date

04/21/2010

Definition at line 179 of file sparse\_str.c.

**9.97.2.3 dSTRmat fasp\_dstr\_create ( INT *nx*, INT *ny*, INT *nz*, INT *nc*, INT *nband*, INT \* *offsets* )**

Create STR sparse matrix data memory space.

## Parameters

<i>nx</i>	Number of grids in x direction
<i>ny</i>	Number of grids in y direction
<i>nz</i>	Number of grids in z direction
<i>nc</i>	Number of components
<i>nband</i>	Number of off-diagonal bands
<i>offsets</i>	Shift from diagonal

## Returns

The [dSTRmat](#) matrix

## Author

Shiquan Zhang, Xiaozhe Hu

## Date

05/17/2010

Definition at line 56 of file sparse\_str.c.

**9.97.2.4 void fasp\_dstr\_free ( dSTRmat \* *A* )**

Free STR sparse matrix data memeory space.

## Parameters

<i>A</i>	Pointer to the <a href="#">dSTRmat</a> matrix
----------	---

## Author

Shiquan Zhang, Xiaozhe Hu

## Date

05/17/2010

Definition at line 150 of file sparse\_str.c.

**9.97.2.5 void fasp\_dstr\_null ( dSTRmat \* *A* )**

Initialize sparse matrix on structured grid.

## Parameters

A	Pointer to the <a href="#">dSTRmat</a> matrix
---	---

## Author

Shiquan Zhang, Xiaozhe Hu

## Date

05/17/2010

Definition at line 25 of file `sparse_str.c`.

## 9.98 sparse\_util.c File Reference

Routines for sparse matrix operations.

```
#include <math.h>
#include <time.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- void [fasp\\_sparse\\_abybms\\_](#) (INT \*ia, INT \*ja, INT \*ib, INT \*jb, INT \*nap, INT \*map, INT \*mbp, INT \*ic, INT \*jc)  
*Multiplication of two sparse matrices: calculating the nonzero structure of the result if jc is not null. If jc is null only finds num of nonzeros.*
- void [fasp\\_sparse\\_abyb\\_](#) (INT \*ia, INT \*ja, REAL \*a, INT \*ib, INT \*jb, REAL \*b, INT \*nap, INT \*map, INT \*mbp, INT \*ic, INT \*jc, REAL \*c)  
*Multiplication of two sparse matrices: calculating the numerical values in the result.*
- void [fasp\\_sparse\\_iit\\_](#) (INT \*ia, INT \*ja, INT \*na, INT \*ma, INT \*iat, INT \*jat)  
*Transpose a boolean matrix (only given by ia, ja)*
- void [fasp\\_sparse\\_aat\\_](#) (INT \*ia, INT \*ja, REAL \*a, INT \*na, INT \*ma, INT \*iat, INT \*jat, REAL \*at)  
*transpose a boolean matrix (only given by ia, ja)*
- void [fasp\\_sparse\\_aplbms\\_](#) (INT \*ia, INT \*ja, INT \*ib, INT \*jb, INT \*nab, INT \*mab, INT \*ic, INT \*jc)  
*Addition of two sparse matrices: calculating the nonzero structure of the result if jc is not null. If jc is null only finds num of nonzeros.*
- void [fasp\\_sparse\\_aplusb\\_](#) (INT \*ia, INT \*ja, REAL \*a, INT \*ib, INT \*jb, REAL \*b, INT \*nab, INT \*mab, INT \*ic, INT \*jc, REAL \*c)  
*Addition of two sparse matrices: calculating the numerical values in the result.*
- void [fasp\\_sparse\\_rapms\\_](#) (INT \*ir, INT \*jr, INT \*ia, INT \*ja, INT \*ip, INT \*jp, INT \*nin, INT \*ncin, INT \*iac, INT \*jac, INT \*maxrout)  
*Calculates the nonzero structure of  $R \cdot A \cdot P$ , if jac is not null. If jac is null only finds num of nonzeros.*
- void [fasp\\_sparse\\_wtams\\_](#) (INT \*jw, INT \*ia, INT \*ja, INT \*nwp, INT \*map, INT \*jv, INT \*nvp, INT \*icp)  
*Finds the nonzeros in the result of  $v^{\wedge} t = w^{\wedge} t A$ , where w is a sparse vector and A is sparse matrix. jv is an integer array containing the indices of the nonzero elements in the result.*
- void [fasp\\_sparse\\_wta\\_](#) (INT \*jw, REAL \*w, INT \*ia, INT \*ja, REAL \*a, INT \*nwp, INT \*map, INT \*jv, REAL \*v, INT \*nvp)

Calculate  $v^t = w^t A$ , where  $w$  is a sparse vector and  $A$  is sparse matrix.  $v$  is an array of dimension = number of columns in  $A$ .

- void [fasp\\_sparse\\_ytxbig\\_](#) (INT \*jy, REAL \*y, INT \*nyp, REAL \*x, REAL \*s)

Calculates  $s = y^t x$ .  $y$ -sparse,  $x$  - no.

- void [fasp\\_sparse\\_ytx\\_](#) (INT \*jy, REAL \*y, INT \*jx, REAL \*x, INT \*nyp, INT \*npx, INT \*icp, REAL \*s)

Calculates  $s = y^t x$ .  $y$  is sparse,  $x$  is sparse.

- void [fasp\\_sparse\\_rapcmp\\_](#) (INT \*ir, INT \*jr, REAL \*r, INT \*ia, INT \*ja, REAL \*a, INT \*ipt, INT \*jpt, REAL \*pt, INT \*nin, INT \*ncin, INT \*iac, INT \*jac, REAL \*ac, INT \*idummy)

Calculates  $R*A*P$  after the nonzero structure of the result is known.  $iac,jac,ac$  have to be allocated before call to this function.

- ivector [fasp\\_sparse\\_MIS](#) (dCSRmat \*A)

get the maximal independet set of a CSR matrix

### 9.98.1 Detailed Description

Routines for sparse matrix operations.

#### Note

Most algorithms work as follows: (a) Boolean operations (to determine the nonzero structure); (b) Numerical part, where the result is calculated.

: Parameter notation :I: is input; :O: is output; :IO: is both

C-version: by Ludmil Zikatanov 2010-04-08 tested 2010-04-08

: Modified Xiaozhe Hu 2010-10-18

Definition in file [sparse\\_util.c](#).

### 9.98.2 Function Documentation

9.98.2.1 void [fasp\\_sparse\\_aat\\_](#) ( INT \* ia, INT \* ja, REAL \* a, INT \* na, INT \* ma, INT \* iat, INT \* jat, REAL \* at )

transpose a boolean matrix (only given by ia, ja)

#### Parameters

<i>ia</i>	array of row pointers (as usual in CSR)
<i>ja</i>	array of column indices
<i>a</i>	array of entries of teh input
<i>na</i>	number of rows of A
<i>ma</i>	number of cols of A
<i>iat</i>	array of row pointers in the result
<i>jat</i>	array of column indices
<i>at</i>	array of entries of the result

Definition at line 272 of file [sparse\\_util.c](#).

9.98.2.2 void [fasp\\_sparse\\_abyb\\_](#) ( INT \* ia, INT \* ja, REAL \* a, INT \* ib, INT \* jb, REAL \* b, INT \* nap, INT \* map, INT \* mbp, INT \* ic, INT \* jc, REAL \* c )

Multiplication of two sparse matrices: calculating the numerical values in the result.

## Parameters

<i>ia</i>	array of row pointers 1st multiplicand
<i>ja</i>	array of column indices 1st multiplicand
<i>a</i>	entries of the 1st multiplicand
<i>ib</i>	array of row pointers 2nd multiplicand
<i>jb</i>	array of column indices 2nd multiplicand
<i>b</i>	entries of the 2nd multiplicand
<i>ic</i>	array of row pointers in $c=a*b$
<i>jc</i>	array of column indices in $c=a*b$
<i>c</i>	entries of the result: $c= a*b$
<i>nap</i>	number of rows in the 1st multiplicand
<i>map</i>	number of columns in the 1st multiplicand
<i>mbp</i>	number of columns in the 2nd multiplicand

Modified by Chensong Zhang on 09/11/2012

Definition at line 124 of file sparse\_util.c.

**9.98.2.3** void fasp\_sparse\_abybms\_ ( INT \* *ia*, INT \* *ja*, INT \* *ib*, INT \* *jb*, INT \* *nap*, INT \* *map*, INT \* *mbp*, INT \* *ic*, INT \* *jc* )

Multiplication of two sparse matrices: calculating the nonzero structure of the result if *jc* is not null. If *jc* is null only finds num of nonzeros.

## Parameters

<i>ia</i>	array of row pointers 1st multiplicand
<i>ia</i>	array of row pointers 1st multiplicand
<i>ja</i>	array of column indices 1st multiplicand
<i>ib</i>	array of row pointers 2nd multiplicand
<i>jb</i>	array of column indices 2nd multiplicand
<i>nap</i>	number of rows of A
<i>map</i>	number of cols of A
<i>mbp</i>	number of cols of b
<i>ic</i>	array of row pointers in the result (this is also computed here again, so that we can have a stand alone call of this routine, if for some reason the number of nonzeros in the result is known)
<i>jc</i>	array of column indices in the result $c=a*b$

Modified by Chensong Zhang on 09/11/2012

Definition at line 51 of file sparse\_util.c.

**9.98.2.4** void void fasp\_sparse\_aplbms\_ ( INT \* *ia*, INT \* *ja*, INT \* *ib*, INT \* *jb*, INT \* *nab*, INT \* *mab*, INT \* *ic*, INT \* *jc* )

Addition of two sparse matrices: calculating the nonzero structure of the result if *jc* is not null. if *jc* is null only finds num of nonzeros.

## Parameters

<i>ia</i>	array of row pointers 1st summand
<i>ia</i>	array of row pointers 1st summand



<i>ja</i>	array of column indices 1st summand
<i>ib</i>	array of row pointers 2nd summand
<i>jb</i>	array of column indices 2nd summand
<i>nab</i>	number of rows
<i>mab</i>	number of cols
<i>ic</i>	array of row pointers in the result (this is also computed here again, so that we can have a stand alone call of this routine, if for some reason the number of nonzeros in the result is known)
<i>jc</i>	array of column indices in the result $c=a+b$

Definition at line 359 of file sparse\_util.c.

**9.98.2.5** void fasp\_sparse\_aplusb\_ ( INT \* *ia*, INT \* *ja*, REAL \* *a*, INT \* *ib*, INT \* *jb*, REAL \* *b*, INT \* *nab*, INT \* *mab*, INT \* *ic*, INT \* *jc*, REAL \* *c* )

Addition of two sparse matrices: calculating the numerical values in the result.

Parameters

<i>ia</i>	array of row pointers 1st summand
<i>ja</i>	array of column indices 1st summand
<i>a</i>	entries of the 1st summand
<i>ib</i>	array of row pointers 2nd summand
<i>jb</i>	array of column indices 2nd summand
<i>b</i>	entries of the 2nd summand
<i>nab</i>	number of rows
<i>mab</i>	number of cols
<i>ic</i>	array of row pointers in $c=a+b$
<i>jc</i>	array of column indices in $c=a+b$
<i>c</i>	entries of the result: $c=a+b$

Definition at line 431 of file sparse\_util.c.

**9.98.2.6** void fasp\_sparse\_iit\_ ( INT \* *ia*, INT \* *ja*, INT \* *na*, INT \* *ma*, INT \* *iat*, INT \* *jat* )

Transpose a boolean matrix (only given by *ia*, *ja*)

Parameters

<i>ia</i>	array of row pointers (as usual in CSR)
<i>ja</i>	array of column indices
<i>na</i>	number of rows
<i>ma</i>	number of cols
<i>iat</i>	array of row pointers in the result
<i>jat</i>	array of column indices

Note

For the concrete algorithm, see:

Definition at line 197 of file sparse\_util.c.

**9.98.2.7** ivector fasp\_sparse\_MIS ( dCSRmat \* *A* )

get the maximal independet set of a CSR matrix

## Parameters

<i>A</i>	pointer to the matrix
----------	-----------------------

## Note

: only use the sparsity of A, index starts from 1 (fortran)!!

information of A

work space

return

Definition at line 913 of file sparse\_util.c.

**9.98.2.8** void fasp\_sparse\_rapcmp\_ ( INT \* *ir*, INT \* *jr*, REAL \* *r*, INT \* *ia*, INT \* *ja*, REAL \* *a*, INT \* *ipt*, INT \* *jpt*, REAL \* *pt*, INT \* *nin*, INT \* *ncin*, INT \* *iac*, INT \* *jac*, REAL \* *ac*, INT \* *idummy* )

Calculates  $R \cdot A \cdot P$  after the nonzero structure of the result is known. *iac,jac,ac* have to be allocated before call to this function.

## Note

:I: is input :O: is output :IO: is both

## Parameters

<i>ir</i>	:I: array of row pointers for R
<i>jr</i>	:I: array of column indices for R
<i>r</i>	:I: entries of R
<i>ia</i>	:I: array of row pointers for A
<i>ja</i>	:I: array of column indices for A
<i>a</i>	:I: entries of A
<i>ipt</i>	:I: array of row pointers for P
<i>jpt</i>	:I: array of column indices for P
<i>pt</i>	:I: entries of P
<i>nin</i>	:I: number of rows in R
<i>ncin</i>	:I: number of rows in
<i>iac</i>	:O: array of row pointers for P
<i>jac</i>	:O: array of column indices for P
<i>ac</i>	:O: entries of P
<i>idummy</i>	not changed

## Note

compute  $R \cdot A \cdot P$  for known nonzero structure of the result the result is stored in *iac,jac,ac*!

Definition at line 791 of file sparse\_util.c.

**9.98.2.9** void fasp\_sparse\_rapms\_ ( INT \* *ir*, INT \* *jr*, INT \* *ia*, INT \* *ja*, INT \* *ip*, INT \* *jp*, INT \* *nin*, INT \* *ncin*, INT \* *iac*, INT \* *jac*, INT \* *maxrout* )

Calculates the nonzero structure of  $R \cdot A \cdot P$ , if *jac* is not null. If *jac* is null only finds num of nonzeros.

## Note

:I: is input :O: is output :IO: is both

## Parameters

<i>ir</i>	:I: array of row pointers for R
<i>jr</i>	:I: array of column indices for R
<i>ia</i>	:I: array of row pointers for A
<i>ja</i>	:I: array of column indices for A
<i>ip</i>	:I: array of row pointers for P
<i>jp</i>	:I: array of column indices for P
<i>nin</i>	:I: number of rows in R
<i>ncin</i>	:I: number of columns in R
<i>iac</i>	:O: array of row pointers for Ac
<i>jac</i>	:O: array of column indices for Ac
<i>maxrout</i>	:O: the maximum nonzeros per row for R

## Note

Computes the sparsity pattern of  $R \cdot A \cdot P$ . maxrout is output and is the maximum nonzeros per row for r. On output we also have iac (if jac is null) and jac (if jac entry is not null). R is (nc,n) A is (n,n) and P is (n,nc)!

Modified by Chensong Zhang on 09/11/2012

Definition at line 514 of file sparse\_util.c.

**9.98.2.10** void fasp\_sparse\_wta\_ ( INT \* *jw*, REAL \* *w*, INT \* *ia*, INT \* *ja*, REAL \* *a*, INT \* *nwp*, INT \* *map*, INT \* *jv*, REAL \* *v*, INT \* *nvp* )

Calculate  $v^t = w^t A$ , where *w* is a sparse vector and *A* is sparse matrix. *v* is an array of dimension = number of columns in *A*.

## Note

:I: is input :O: is output :IO: is both

## Parameters

<i>jw</i>	:I: indices such that <i>w</i> [ <i>jw</i> ] is nonzero
<i>w</i>	:I: the values of <i>w</i>
<i>ia</i>	:I: array of row pointers for A
<i>ja</i>	:I: array of column indices for A
<i>a</i>	:I: entries of A
<i>nwp</i>	:I: number of nonzeros in <i>w</i> (the length of <i>w</i> )
<i>map</i>	:I: number of columns in A
<i>jv</i>	:O: indices such that <i>v</i> [ <i>jv</i> ] is nonzero
<i>v</i>	:O: the result $v^t = w^t A$
<i>nvp</i>	:I: number of nonzeros in <i>v</i>

Definition at line 651 of file sparse\_util.c.

**9.98.2.11** void fasp\_sparse\_wtams\_ ( INT \* *jw*, INT \* *ia*, INT \* *ja*, INT \* *nwp*, INT \* *map*, INT \* *jv*, INT \* *nvp*, INT \* *icp* )

Finds the nonzeros in the result of  $v^t = w^t A$ , where *w* is a sparse vector and *A* is sparse matrix. *jv* is an integer array containing the indices of the nonzero elements in the result.

:I: is input :O: is output :IO: is both

## Parameters

<i>jw</i>	:l: indices such that $w[jw]$ is nonzero
<i>ia</i>	:l: array of row pointers for A
<i>ja</i>	:l: array of column indices for A
<i>nwp</i>	:l: number of nonzeros in w (the length of w)
<i>map</i>	:l: number of columns in A
<i>jv</i>	:O: indices such that $v[jv]$ is nonzero
<i>nvp</i>	:l: number of nonzeros in v
<i>icp</i>	:IO: is a working array of length (*map) which on output satisfies $icp[jv[k]-1]=k$ ; Values of $icp[]$ at positions * other than $(jv[k]-1)$ remain unchanged.

Modified by Chensong Zhang on 09/11/2012

Definition at line 598 of file sparse\_util.c.

9.98.2.12 void fasp\_sparse\_ytx\_ ( INT \* *jy*, REAL \* *y*, INT \* *jx*, REAL \* *x*, INT \* *nyp*, INT \* *nxp*, INT \* *icp*, REAL \* *s* )

Calculates  $s = y^t x$ . y is sparse, x is sparse.

note :l: is input :O: is output :IO: is both

## Parameters

<i>jy</i>	:l: indices such that $y[jy]$ is nonzero
<i>y</i>	:l: is a sparse vector.
<i>nyp</i>	:l: number of nonzeros in y
<i>jx</i>	:l: indices such that $x[jx]$ is nonzero
<i>x</i>	:l: is a sparse vector.
<i>nxp</i>	:l: number of nonzeros in x
<i>icp</i>	???
<i>s</i>	:O: $s = y^t x$ .

Definition at line 736 of file sparse\_util.c.

9.98.2.13 void fasp\_sparse\_ytxbig\_ ( INT \* *jy*, REAL \* *y*, INT \* *nyp*, REAL \* *x*, REAL \* *s* )

Calculates  $s = y^t x$ . y-sparse, x - no.

## Note

:l: is input :O: is output :IO: is both

## Parameters

<i>jy</i>	:l: indices such that $y[jy]$ is nonzero
<i>y</i>	:l: is a sparse vector.
<i>nyp</i>	:l: number of nonzeros in y
<i>x</i>	:l: also a vector assumed to have entry for any $j=jy[i]-1$ ; for $i=1:nyp$ . This means that x here does not have to be sparse.

$s$	:O: $s = y^t x$ .
-----	-------------------

Definition at line 702 of file sparse\_util.c.

## 9.99 spbcgs.c File Reference

Krylov subspace methods – Preconditioned BiCGstab with safe net.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_dcsr\\_spbcgs](#) (dCSRmat \*A, dvector \*b, dvector \*u, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT stop\_type, const SHORT print\_level)  
*Preconditioned BiCGstab method for solving  $Au=b$  with safe net.*
- [INT fasp\\_solver\\_dbsr\\_spbcgs](#) (dBSRmat \*A, dvector \*b, dvector \*u, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT stop\_type, const SHORT print\_level)  
*Preconditioned BiCGstab method for solving  $Au=b$  with safe net.*
- [INT fasp\\_solver\\_bdcsr\\_spbcgs](#) (block\_dCSRmat \*A, dvector \*b, dvector \*u, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT stop\_type, const SHORT print\_level)  
*Preconditioned BiCGstab method for solving  $Au=b$  with safe net.*
- [INT fasp\\_solver\\_dstr\\_spbcgs](#) (dSTRmat \*A, dvector \*b, dvector \*u, precondition \*pc, const REAL tol, const INT MaxIt, const SHORT stop\_type, const SHORT print\_level)  
*Preconditioned BiCGstab method for solving  $Au=b$  with safe net.*

### 9.99.1 Detailed Description

Krylov subspace methods – Preconditioned BiCGstab with safe net.

Abstract algorithm

PBICGStab method to solve  $A*x=b$  is to generate  $\{x_k\}$  to approximate  $x$

Note: We generate a series of  $\{p_k\}$  such that  $V_k=\text{span}\{p_1,\dots,p_k\}$ .

Step 0. Given  $A$ ,  $b$ ,  $x_0$ ,  $M$

Step 1. Compute residual  $r_0 = b - A*x_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}*r_0$ ,  $p_0=z_0$ ;

Step 3. Main loop ...

FOR  $k = 0:\text{MaxIt}$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha*p_k$ ;
- check whether  $x$  is NAN;

- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha(A \cdot p_k)$ ;
- if  $r_{k+1} < r_{\text{best}}$ : save  $x_{k+1}$  as  $x_{\text{best}}$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of k-th iteration; END FOR

Convergence check:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check:

- IF  $\text{norm}(\alpha \cdot p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A \cdot x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A \cdot x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

Safe net check:

- IF  $r_{k+1} > r_{\text{best}}$ 
  1.  $x_{k+1} = x_{\text{best}}$
- END IF

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
See [spbcgs.c](#) for a safer version

Definition in file [spbcgs.c](#).

## 9.99.2 Function Documentation

9.99.2.1 **INT fasp\_solver\_bdcsr\_spbcgs ( block\_dCSRmat \* A, dvector \* b, dvector \* u, precondition \* pc, const REAL tol, const INT MaxIt, const SHORT stop\_type, const SHORT print\_level )**

Preconditioned BiCGstab method for solving  $Au=b$  with safe net.

## Parameters

<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

03/31/2013

Definition at line 868 of file spbcgs.c.

**9.99.2.2** `INT fasp_solver_dbsr_spbcgs ( dBSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned BiCGstab method for solving  $Au=b$  with safe net.

## Parameters

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

03/31/2013

Definition at line 480 of file spbcgs.c.



9.99.2.3 INT fasp\_solver\_dcsr\_spbcgs ( dCSRmat \* *A*, dvector \* *b*, dvector \* *u*, precondition \* *pc*, const REAL *tol*, const INT *MaxIt*, const SHORT *stop\_type*, const SHORT *print\_level* )

Preconditioned BiCGstab method for solving  $Au=b$  with safe net.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

03/31/2013

Definition at line 92 of file spbcgs.c.

9.99.2.4 INT fasp\_solver\_dstr\_spbcgs ( dSTRmat \* *A*, dvector \* *b*, dvector \* *u*, precondition \* *pc*, const REAL *tol*, const INT *MaxIt*, const SHORT *stop\_type*, const SHORT *print\_level* )

Preconditioned BiCGstab method for solving  $Au=b$  with safe net.

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

03/31/2013

Definition at line 1256 of file spbcgs.c.

## 9.100 spcg.c File Reference

Krylov subspace methods – Preconditioned conjugate gradient with safe net.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- `INT fasp_solver_dcsr_spcg (dCSRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*Preconditioned conjugate gradient method for solving  $Au=b$  with safe net.*
- `INT fasp_solver_bdcsr_spcg (block_dCSRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*Preconditioned conjugate gradient method for solving  $Au=b$  with safe net.*
- `INT fasp_solver_dstr_spcg (dSTRmat *A, dvector *b, dvector *u, precondition *pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level)`  
*Preconditioned conjugate gradient method for solving  $Au=b$  with safe net.*

### 9.100.1 Detailed Description

Krylov subspace methods – Preconditioned conjugate gradient with safe net.

Abstract algorithm

PCG method to solve  $Ax=b$  is to generate  $\{x_k\}$  to approximate  $x$

Step 0. Given  $A$ ,  $b$ ,  $x_0$ ,  $M$

Step 1. Compute residual  $r_0 = b - Ax_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}r_0$ ,  $p_0 = z_0$ ;

Step 3. Main loop ...

FOR  $k = 0:MaxIt$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha p_k$ ;
- check whether  $x$  is NAN;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha(Ap_k)$ ;
- if  $r_{k+1} < r_{\{best\}}$ : save  $x_{k+1}$  as  $x_{\{best\}}$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of  $k$ -th iteration; END FOR

Convergence check:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check:

- IF  $\text{norm}(\alpha * p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A * x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A * x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

Safe net check:

- IF  $r_{k+1} > r_{\text{best}}$ 
  1.  $x_{k+1} = x_{\text{best}}$
- END IF

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
See [pcg.c](#) for a version without safe net

Definition in file [spcg.c](#).

## 9.100.2 Function Documentation

9.100.2.1 **INT fasp\_solver\_bdcsr\_spcg ( block\_dCSRmat \* *A*, dvector \* *b*, dvector \* *u*, precondition \* *pc*, const REAL *tol*, const INT *MaxIt*, const SHORT *stop\_type*, const SHORT *print\_level* )**

Preconditioned conjugate gradient method for solving  $Au=b$  with safe net.

#### Parameters

<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)

<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Chensong Zhang

**Date**

03/28/2013

Definition at line 414 of file spcg.c.

**9.100.2.2** `INT fasp_solver_dcsr_spcg ( dCSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned conjugate gradient method for solving  $Au=b$  with safe net.

**Parameters**

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Chensong Zhang

**Date**

03/28/2013

Definition at line 89 of file spcg.c.

**9.100.2.3** `INT fasp_solver_dstr_spcg ( dSTRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

Preconditioned conjugate gradient method for solving  $Au=b$  with safe net.

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>MaxIt</i>	Maximal number of iterations
<i>tol</i>	Tolerance for stopping
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>print_level</i>	How much information to print out
<i>stop_type</i>	Stopping criteria type

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

03/28/2013

Definition at line 738 of file spcg.c.

## 9.101 spgmres.c File Reference

Krylov subspace methods – Preconditioned GMRes with safe net.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

## Functions

- [INT fasp\\_solver\\_dcsr\\_spgmres](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$  with safe-guard.*
- [INT fasp\\_solver\\_bdcsr\\_spgmres](#) ([block\\_dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$  with safe-guard.*
- [INT fasp\\_solver\\_dbsr\\_spgmres](#) ([dBSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$  with safe-guard.*
- [INT fasp\\_solver\\_dstr\\_spgmres](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving  $Au=b$  with safe-guard.*

### 9.101.1 Detailed Description

Krylov subspace methods – Preconditioned GMRes with safe net.

#### Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
 See also [pgmres.c](#) for a variable restarting version.  
 See [pgmres.c](#) for a version without safe net

Definition in file [spgmres.c](#).

### 9.101.2 Function Documentation

**9.101.2.1** `INT fasp_solver_bdcsr_spgmres ( block_dCSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, SHORT restart, const SHORT stop_type, const SHORT print_level )`

Preconditioned GMRES method for solving  $Au=b$  with safe-guard.

#### Parameters

<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Chensong Zhang

#### Date

04/05/2013

Definition at line 387 of file [spgmres.c](#).

**9.101.2.2** `INT fasp_solver_dbsr_spgmres ( dBSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, SHORT restart, const SHORT stop_type, const SHORT print_level )`

Preconditioned GMRES method for solving  $Au=b$  with safe-guard.

## Parameters

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

04/05/2013

Definition at line 728 of file spgmres.c.

9.101.2.3 **INT** fasp\_solver\_dcsr\_spgmres ( **dCSRmat** \* *A*, **dvector** \* *b*, **dvector** \* *x*, **precond** \* *pc*, **const REAL** *tol*, **const INT** *MaxIt*, **SHORT** *restart*, **const SHORT** *stop\_type*, **const SHORT** *print\_level* )

Preconditioned GMRES method for solving  $Au=b$  with safe-guard.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

04/05/2013 Modified by Chunsheng Feng on 07/22/2013: Add adapt memory allocate

Definition at line 46 of file spgmres.c.



9.101.2.4 **INT** fasp\_solver\_dstr\_spgmres ( **dSTRmat** \* *A*, **dvector** \* *b*, **dvector** \* *x*, **precond** \* *pc*, **const REAL** *tol*, **const INT** *MaxIt*, **SHORT** *restart*, **const SHORT** *stop\_type*, **const SHORT** *print\_level* )

Preconditioned GMRES method for solving  $Au=b$  with safe-guard.

#### Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Chensong Zhang

#### Date

04/05/2013

Definition at line 1069 of file spgmres.c.

## 9.102 spminres.c File Reference

Krylov subspace methods – Preconditioned minimal residual with safe net.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

#### Functions

- **INT** fasp\_solver\_dcsr\_spminres (**dCSRmat** \**A*, **dvector** \**b*, **dvector** \**u*, **precond** \**pc*, **const REAL** *tol*, **const INT** *MaxIt*, **const SHORT** *stop\_type*, **const SHORT** *print\_level*)  
A preconditioned minimal residual (Minres) method for solving  $Au=b$  with safe net.
- **INT** fasp\_solver\_bdcsr\_spminres (**block\_dCSRmat** \**A*, **dvector** \**b*, **dvector** \**u*, **precond** \**pc*, **const REAL** *tol*, **const INT** *MaxIt*, **const SHORT** *stop\_type*, **const SHORT** *print\_level*)  
A preconditioned minimal residual (Minres) method for solving  $Au=b$  with safe net.
- **INT** fasp\_solver\_dstr\_spminres (**dSTRmat** \**A*, **dvector** \**b*, **dvector** \**u*, **precond** \**pc*, **const REAL** *tol*, **const INT** *MaxIt*, **const SHORT** *stop\_type*, **const SHORT** *print\_level*)  
A preconditioned minimal residual (Minres) method for solving  $Au=b$  with safe net.

### 9.102.1 Detailed Description

Krylov subspace methods – Preconditioned minimal residual with safe net.

Abstract algorithm

Krylov method to solve  $A*x=b$  is to generate  $\{x_k\}$  to approximate  $x$ , where  $x_k$  is the optimal solution in Krylov space

$V_k = \text{span}\{r_0, A*r_0, A^2*r_0, \dots, A^{k-1}*r_0\}$ ,

under some inner product.

For the implementation, we generate a series of  $\{p_k\}$  such that  $V_k = \text{span}\{p_1, \dots, p_k\}$ . Details:

Step 0. Given  $A$ ,  $b$ ,  $x_0$ ,  $M$

Step 1. Compute residual  $r_0 = b - A*x_0$  and convergence check;

Step 2. Initialization  $z_0 = M^{-1}*r_0$ ,  $p_0 = z_0$ ;

Step 3. Main loop ...

FOR  $k = 0:\text{MaxIt}$

- get step size  $\alpha = f(r_k, z_k, p_k)$ ;
- update solution:  $x_{k+1} = x_k + \alpha*p_k$ ;
- check whether  $x$  is NAN;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha*(A*p_k)$ ;
- if  $r_{k+1} < r_{\text{best}}$ : save  $x_{k+1}$  as  $x_{\text{best}}$ ;
- perform residual check;
- obtain  $p_{k+1}$  using  $\{p_0, p_1, \dots, p_k\}$ ;
- prepare for next iteration;
- print the result of  $k$ -th iteration; END FOR

Convergence check:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

Stagnation check:

- IF  $\text{norm}(\alpha*p_k)/\text{norm}(x_{k+1}) < \text{tol\_stag}$ 
  1. compute  $r = b - A*x_{k+1}$ ;
  2. convergence check;
  3. IF ( not converged & restart\_number < Max\_Stag\_Check ) restart;
- END IF

Residual check:

- IF  $\text{norm}(r_{k+1})/\text{norm}(b) < \text{tol}$ 
  1. compute the real residual  $r = b - A*x_{k+1}$ ;
  2. convergence check;

- 3. IF ( not converged & restart\_number < Max\_Res\_Check ) restart;
- END IF

Safe net check:

- IF  $r_{k+1} > r_{\text{best}}$ 
  - 1.  $x_{k+1} = x_{\text{best}}$
- END IF

Note

Refer to Y. Saad 2003 Iterative methods for sparse linear systems (2nd Edition), SIAM  
See [pminres.c](#) for a version without safe net

Definition in file [spminres.c](#).

## 9.102.2 Function Documentation

**9.102.2.1** `INT fasp_solver_bdcsr_spminres ( block_dCSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

A preconditioned minimal residual (Minres) method for solving  $Au=b$  with safe net.

Parameters

<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

Returns

Number of iterations if converged, error message otherwise

Author

Chensong Zhang

Date

04/09/2013

Definition at line 543 of file spminres.c.

**9.102.2.2** `INT fasp_solver_dcsr_spminres ( dCSRmat * A, dvector * b, dvector * u, precondition * pc, const REAL tol, const INT MaxIt, const SHORT stop_type, const SHORT print_level )`

A preconditioned minimal residual (Minres) method for solving  $Au=b$  with safe net.

## Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

04/09/2013

Definition at line 96 of file spminres.c.

9.102.2.3 **INT** fasp\_solver\_dstr\_spminres ( **dSTRmat** \* *A*, **dvector** \* *b*, **dvector** \* *u*, **precond** \* *pc*, **const REAL** *tol*, **const INT** *MaxIt*, **const SHORT** *stop\_type*, **const SHORT** *print\_level* )

A preconditioned minimal residual (Minres) method for solving  $Au=b$  with safe net.

## Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>u</i>	Pointer to dvector: the unknowns
<i>MaxIt</i>	Maximal number of iterations
<i>tol</i>	Tolerance for stopping
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>print_level</i>	How much information to print out
<i>stop_type</i>	Stopping criteria type

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

04/09/2013

Definition at line 990 of file spminres.c.

## 9.103 spvgmres.c File Reference

Krylov subspace methods – Preconditioned variable-restart GMRes with safe net.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
#include "itsolver_util.inl"
```

### Functions

- [INT fasp\\_solver\\_dcsr\\_spvgmres](#) ([dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*
- [INT fasp\\_solver\\_bdcsr\\_spvgmres](#) ([block\\_dCSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Preconditioned GMRES method for solving Au=b.*
- [INT fasp\\_solver\\_dbsr\\_spvgmres](#) ([dBSRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*
- [INT fasp\\_solver\\_dstr\\_spvgmres](#) ([dSTRmat](#) \*A, [dvector](#) \*b, [dvector](#) \*x, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)  
*Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.*

### 9.103.1 Detailed Description

Krylov subspace methods – Preconditioned variable-restart GMRes with safe net.

#### Note

Refer to A.H. Baker, E.R. Jessup, and Tz.V. Kolev A Simple Strategy for Varying the Restart Parameter in GMRES(m) Journal of Computational and Applied Mathematics, 230 (2009) pp. 751-761. UCRL-JRNL-235266.  
See [pvgmres.c](#) a version without safe net

Definition in file [spvgmres.c](#).

### 9.103.2 Function Documentation

**9.103.2.1** [INT fasp\\_solver\\_bdcsr\\_spvgmres](#) ( [block\\_dCSRmat](#) \* A, [dvector](#) \* b, [dvector](#) \* x, [precond](#) \* pc, const [REAL](#) tol, const [INT](#) MaxIt, [SHORT](#) restart, const [SHORT](#) stop\_type, const [SHORT](#) print\_level )

Preconditioned GMRES method for solving Au=b.

## Parameters

<i>A</i>	Pointer to <a href="#">block_dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

04/06/2013

Definition at line 427 of file spvgmres.c.

9.103.2.2 **INT** fasp\_solver\_dbsr\_spvgmres ( **dBSRmat** \* *A*, **dvector** \* *b*, **dvector** \* *x*, **precond** \* *pc*, **const REAL** *tol*, **const INT** *MaxIt*, **SHORT** *restart*, **const SHORT** *stop\_type*, **const SHORT** *print\_level* )

Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

## Parameters

<i>A</i>	Pointer to <a href="#">dBSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

## Returns

Number of iterations if converged, error message otherwise

## Author

Chensong Zhang

## Date

04/06/2013

Definition at line 807 of file spvgmres.c.

9.103.2.3 **INT** fasp\_solver\_dcsr\_spvgmres ( **dCSRmat** \* *A*, **dvector** \* *b*, **dvector** \* *x*, **precond** \* *pc*, **const REAL** *tol*, **const INT** *MaxIt*, **SHORT** *restart*, **const SHORT** *stop\_type*, **const SHORT** *print\_level* )

Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

#### Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type
<i>print_level</i>	How much information to print out

#### Returns

Number of iterations if converged, error message otherwise

#### Author

Chensong Zhang

#### Date

04/06/2013 Modified by Chunsheng Feng on 07/22/2013: Add adapt memory allocate

Definition at line 49 of file spvgmres.c.

9.103.2.4 **INT** fasp\_solver\_dstr\_spvgmres ( **dSTRmat** \* *A*, **dvector** \* *b*, **dvector** \* *x*, **precond** \* *pc*, **const REAL** *tol*, **const INT** *MaxIt*, **SHORT** *restart*, **const SHORT** *stop\_type*, **const SHORT** *print\_level* )

Solve "Ax=b" using PGMRES(right preconditioned) iterative method in which the restart parameter can be adaptively modified during the iteration.

#### Parameters

<i>A</i>	Pointer to <a href="#">dSTRmat</a> : the coefficient matrix
<i>b</i>	Pointer to dvector: the right hand side
<i>x</i>	Pointer to dvector: the unknowns
<i>pc</i>	Pointer to the structure of precondition (precond)
<i>tol</i>	Tolerance for stopping
<i>MaxIt</i>	Maximal number of iterations
<i>restart</i>	Restarting steps
<i>stop_type</i>	Stopping criteria type

<i>print_level</i>	How much information to print out
--------------------	-----------------------------------

**Returns**

Number of iterations if converged, error message otherwise

**Author**

Chensong Zhang

**Date**

04/06/2013

Definition at line 1187 of file spvgmres.c.

## 9.104 threads.c File Reference

Get and set number of threads and assigne work load for each thread.

```
#include <stdio.h>
#include <stdlib.h>
#include "fasp.h"
```

**Functions**

- void [FASP\\_GET\\_START\\_END](#) (INT *procid*, INT *nprocs*, INT *n*, INT \**start*, INT \**end*)  
*Assign Load to each thread.*

### 9.104.1 Detailed Description

Get and set number of threads and assigne work load for each thread.

Definition in file [threads.c](#).

### 9.104.2 Function Documentation

9.104.2.1 void [FASP\\_GET\\_START\\_END](#) ( INT *procid*, INT *nprocs*, INT *n*, INT \* *start*, INT \* *end* )

Assign Load to each thread.

**Parameters**

<i>procid</i>	Index of thread
<i>nprocs</i>	Number of threads



<i>n</i>	Total workload
<i>start</i>	Pointer to the begin of each thread in total workload
<i>end</i>	Pointer to the end of each thread in total workload

**Author**

Chunsheng Feng, Xiaoqiang Yue and Zheng Li

**Date**

June/25/2012

Definition at line 83 of file threads.c.

## 9.105 timing.c File Reference

Timing subroutines.

```
#include <time.h>
#include "fasp_functs.h"
#include "fasp.h"
```

**Functions**

- void [fasp\\_gettime](#) ([REAL](#) \*time)  
*Get system time.*

### 9.105.1 Detailed Description

Timing subroutines.

Definition in file [timing.c](#).

### 9.105.2 Function Documentation

#### 9.105.2.1 [fasp\\_gettime](#) ( [REAL](#) \* *time* )

Get system time.

**Author**

Chunsheng Feng, Zheng LI

**Date**

11/10/2012

Definition at line 28 of file timing.c.

## 9.106 vec.c File Reference

Simple operations for vectors.

```
#include <math.h>
#include "fasp.h"
#include "fasp_functs.h"
```

### Functions

- [INT fasp\\_dvec\\_isnan](#) ([dvector](#) \*u)  
*Check a dvector whether there is NAN.*
- [dvector fasp\\_dvec\\_create](#) (const [INT](#) m)  
*Create dvector data space of REAL type.*
- [ivector fasp\\_ivec\\_create](#) (const [INT](#) m)  
*Create vector data space of INT type.*
- void [fasp\\_dvec\\_alloc](#) (const [INT](#) m, [dvector](#) \*u)  
*Create dvector data space of REAL type.*
- void [fasp\\_ivec\\_alloc](#) (const [INT](#) m, [ivector](#) \*u)  
*Create vector data space of INT type.*
- void [fasp\\_dvec\\_free](#) ([dvector](#) \*u)  
*Free vector data space of REAL type.*
- void [fasp\\_ivec\\_free](#) ([ivector](#) \*u)  
*Free vector data space of INT type.*
- void [fasp\\_dvec\\_null](#) ([dvector](#) \*x)  
*Initialize dvector.*
- void [fasp\\_dvec\\_rand](#) (const [INT](#) n, [dvector](#) \*x)  
*Generate random REAL vector in the range from 0 to 1.*
- void [fasp\\_dvec\\_set](#) ([INT](#) n, [dvector](#) \*x, [REAL](#) val)  
*Initialize dvector  $x[i]=val$  for  $i=0:n-1$ .*
- void [fasp\\_ivec\\_set](#) (const [INT](#) m, [ivector](#) \*u)  
*Set ivector value to be m.*
- void [fasp\\_dvec\\_cp](#) ([dvector](#) \*x, [dvector](#) \*y)  
*Copy dvector x to dvector y.*
- [REAL fasp\\_dvec\\_maxdiff](#) ([dvector](#) \*x, [dvector](#) \*y)  
*Maximal difference of two dvector x and y.*
- void [fasp\\_dvec\\_symdiagscale](#) ([dvector](#) \*b, [dvector](#) \*diag)  
*Symmetric diagonal scaling  $D^{-1/2}b$ .*

### 9.106.1 Detailed Description

Simple operations for vectors.

#### Note

Every structures should be initialized before usage.

Definition in file [vec.c](#).

## 9.106.2 Function Documentation

### 9.106.2.1 void fasp\_dvec\_alloc ( const INT *m*, dvector \* *u* )

Create dvector data space of REAL type.

#### Parameters

<i>m</i>	Number of rows
<i>u</i>	Pointer to dvector (OUTPUT)

#### Author

Chensong Zhang

#### Date

2010/04/06

Definition at line 99 of file vec.c.

### 9.106.2.2 void fasp\_dvec\_cp ( dvector \* *x*, dvector \* *y* )

Copy dvector *x* to dvector *y*.

#### Parameters

<i>x</i>	Pointer to dvector
<i>y</i>	Pointer to dvector (MODIFIED)

#### Author

Chensong Zhang

#### Date

11/16/2009

Definition at line 345 of file vec.c.

### 9.106.2.3 dvector fasp\_dvec\_create ( const INT *m* )

Create dvector data space of REAL type.

#### Parameters

<i>m</i>	Number of rows
----------	----------------

#### Returns

*u* The new dvector

**Author**

Chensong Zhang

**Date**

2010/04/06

Definition at line 56 of file vec.c.

**9.106.2.4 void fasp\_dvec\_free ( dvector \*  $u$  )**

Free vector data space of REAL type.

**Parameters**

$u$	Pointer to dvector which needs to be deallocated
-----	--

**Author**

Chensong Zhang

**Date**

2010/04/03

Definition at line 139 of file vec.c.

**9.106.2.5 INT fasp\_dvec\_isnan ( dvector \*  $u$  )**

Check a dvector whether there is NAN.

**Parameters**

$u$	Pointer to dvector
-----	--------------------

**Returns**

Return TRUE if there is NAN

**Author**

Chensong Zhang

**Date**

2013/03/31

Definition at line 33 of file vec.c.

**9.106.2.6 REAL fasp\_dvec\_maxdiff ( dvector \*  $x$ , dvector \*  $y$  )**Maximal difference of two dvector  $x$  and  $y$ .

## Parameters

$x$	Pointer to dvector
$y$	Pointer to dvector

## Returns

Maximal norm of  $x-y$

## Author

Chensong Zhang

## Date

11/16/2009

Modified by chunsheng Feng, Zheng Li

## Date

06/30/2012

Definition at line 368 of file vec.c.

**9.106.2.7 void fasp\_dvec\_null ( dvector \*  $x$  )**

Initialize dvector.

## Parameters

$x$	Pointer to dvector which needs to be initialized
-----	--

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 177 of file vec.c.

**9.106.2.8 void fasp\_dvec\_rand ( const INT  $n$ , dvector \*  $x$  )**

Generate random REAL vector in the range from 0 to 1.

## Parameters

$n$	Size of the vector
$x$	Pointer to dvector

**Note**

Sample usage:

```
dvector xapp;
```

```
fasp_dvec_create(100,&xapp);
```

```
fasp_dvec_rand(100,&xapp);
```

```
fasp_dvec_print(100,&xapp);
```

**Author**

Chensong Zhang

**Date**

11/16/2009

Definition at line 203 of file vec.c.

#### 9.106.2.9 void fasp\_dvec\_set ( INT $n$ , dvector \* $x$ , REAL $val$ )

Initialize dvector  $x[i]=val$  for  $i=0:n-1$ .

**Parameters**

$n$	Number of variables
$x$	Pointer to dvector
$val$	Initial value for the vector

**Author**

Chensong Zhang

**Date**

11/16/2009

Modified by Chunsheng Feng, Xiaoqiang Yue on 05/23/2012

Definition at line 235 of file vec.c.

#### 9.106.2.10 void fasp\_dvec\_symdiagscale ( dvector \* $b$ , dvector \* $diag$ )

Symmetric diagonal scaling  $D^{-1/2}b$ .

## Parameters

<i>b</i>	Pointer to dvector
<i>diag</i>	Pointer to dvector: the diagonal entries

## Author

Xiaozhe Hu

## Date

01/31/2011

Definition at line 421 of file vec.c.

9.106.2.11 void fasp\_ivec\_alloc ( const INT *m*, ivector \* *u* )

Create vector data space of INT type.

## Parameters

<i>m</i>	Number of rows
<i>u</i>	Pointer to ivector (OUTPUT)

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 119 of file vec.c.

9.106.2.12 ivector fasp\_ivec\_create ( const INT *m* )

Create vector data space of INT type.

## Parameters

<i>m</i>	Number of rows
----------	----------------

## Returns

*u* The new ivector

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 78 of file vec.c.

9.106.2.13 `void fasp_ivec_free ( ivec * u )`

Free vector data space of INT type.



## Parameters

<i>u</i>	Pointer to ivector which needs to be deallocated
----------	--

## Author

Chensong Zhang

## Date

2010/04/03

## Note

This function is same as fasp\_dvec\_free except input type.

Definition at line 159 of file vec.c.

**9.106.2.14** void fasp\_ivec\_set ( const INT *m*, ivector \* *u* )

Set ivector value to be *m*.

## Parameters

<i>m</i>	Integer value of ivector
<i>u</i>	Pointer to ivector (MODIFIED)

## Author

Chensong Zhang

## Date

04/03/2010

Modified by Chunsheng Feng, Xiaoqiang Yue

## Date

05/23/2012

Definition at line 304 of file vec.c.

## 9.107 wrapper.c File Reference

Wrappers for accessing functions by advanced users.

```
#include "fasp.h"
#include "fasp_block.h"
#include "fasp_functs.h"
```

## Functions

- void [fasp\\_fwapper\\_amg\\_](#) (INT \*n, INT \*nnz, INT \*ia, INT \*ja, REAL \*a, REAL \*b, REAL \*u, REAL \*tol, INT \*maxit, INT \*ptrlvl)  
*Solve  $Ax=b$  by Ruge and Stuben's classic AMG.*
- void [fasp\\_fwapper\\_krylov\\_amg\\_](#) (INT \*n, INT \*nnz, INT \*ia, INT \*ja, REAL \*a, REAL \*b, REAL \*u, REAL \*tol, INT \*maxit, INT \*ptrlvl)  
*Solve  $Ax=b$  by Krylov method preconditioned by classic AMG.*
- INT [fasp\\_wrapper\\_dbsr\\_krylov\\_amg](#) (INT n, INT nnz, INT nb, INT \*ia, INT \*ja, REAL \*a, REAL \*b, REAL \*u, REAL tol, INT maxit, INT ptrlvl)  
*Solve  $Ax=b$  by Krylov method preconditioned by AMG (dcsr - > dbsr)*
- INT [fasp\\_wrapper\\_dcoo\\_dbsr\\_krylov\\_amg](#) (INT n, INT nnz, INT nb, INT \*ia, INT \*ja, REAL \*a, REAL \*b, REAL \*u, REAL tol, INT maxit, INT ptrlvl)  
*Solve  $Ax=b$  by Krylov method preconditioned by AMG (dcoo - > dbsr)*

### 9.107.1 Detailed Description

Wrappers for accessing functions by advanced users.

#### Note

Input variables should not need [fasp.h](#)!!!

Definition in file [wrapper.c](#).

### 9.107.2 Function Documentation

9.107.2.1 void void [fasp\\_fwapper\\_amg\\_](#) ( INT \* n, INT \* nnz, INT \* ia, INT \* ja, REAL \* a, REAL \* b, REAL \* u, REAL \* tol, INT \* maxit, INT \* ptrlvl )

Solve  $Ax=b$  by Ruge and Stuben's classic AMG.

#### Parameters

<i>n</i>	Number of cols of A
<i>nnz</i>	Number of nonzeros of A
<i>ia</i>	IA of A in CSR format
<i>ja</i>	JA of A in CSR format
<i>a</i>	VAL of A in CSR format
<i>b</i>	RHS vector
<i>u</i>	Solution vector
<i>tol</i>	Tolerance for iterative solvers
<i>maxit</i>	Max num of iterations
<i>ptrlvl</i>	Print level for iterative solvers

#### Author

Chensong Zhang

#### Date

09/16/2010

Definition at line 37 of file wrapper.c.

9.107.2.2 void fasp\_fwapper\_krylov\_amg\_ ( INT \* *n*, INT \* *nnz*, INT \* *ia*, INT \* *ja*, REAL \* *a*, REAL \* *b*, REAL \* *u*, REAL \* *tol*, INT \* *maxit*, INT \* *ptrlvl* )

Solve  $Ax=b$  by Krylov method preconditioned by classic AMG.

#### Parameters

<i>n</i>	Number of cols of A
<i>nnz</i>	Number of nonzeros of A
<i>ia</i>	IA of A in CSR format
<i>ja</i>	JA of A in CSR format
<i>a</i>	VAL of A in CSR format
<i>b</i>	RHS vector
<i>u</i>	Solution vector
<i>tol</i>	Tolerance for iterative solvers
<i>maxit</i>	Max num of iterations
<i>ptrlvl</i>	Print level for iterative solvers

#### Author

Chensong Zhang

#### Date

09/16/2010

Definition at line 87 of file wrapper.c.

9.107.2.3 INT fasp\_wrapper\_dbsr\_krylov\_amg ( INT *n*, INT *nnz*, INT *nb*, INT \* *ia*, INT \* *ja*, REAL \* *a*, REAL \* *b*, REAL \* *u*, REAL *tol*, INT *maxit*, INT *ptrlvl* )

Solve  $Ax=b$  by Krylov method preconditioned by AMG (dcsr - > dbsr)

#### Parameters

<i>n</i>	Number of cols of A
<i>nnz</i>	Number of nonzeros of A
<i>nb</i>	Size of each small block
<i>ia</i>	IA of A in CSR format
<i>ja</i>	JA of A in CSR format
<i>a</i>	VAL of A in CSR format
<i>b</i>	RHS vector
<i>u</i>	Solution vector
<i>tol</i>	Tolerance for iterative solvers
<i>maxit</i>	Max num of iterations
<i>ptrlvl</i>	Print level for iterative solvers

#### Author

Xiaoze Hu

#### Date

03/05/2013

Definition at line 144 of file wrapper.c.

9.107.2.4 `INT fasp_wrapper_dcoo_dbsr_krylov_amg ( INT n, INT nnz, INT nb, INT * ia, INT * ja, REAL * a, REAL * b,  
REAL * u, REAL tol, INT maxit, INT ptrlvl )`

Solve  $Ax=b$  by Krylov method preconditioned by AMG (dcoo - > dbsr)

#### Parameters

<i>n</i>	Number of cols of A
<i>nnz</i>	Number of nonzeros of A
<i>nb</i>	Size of each small block
<i>ia</i>	IA of A in COO format
<i>ja</i>	JA of A in COO format
<i>a</i>	VAL of A in COO format
<i>b</i>	RHS vector
<i>u</i>	Solution vector
<i>tol</i>	Tolerance for iterative solvers
<i>maxit</i>	Max num of iterations
<i>ptrlvl</i>	Print level for iterative solvers

#### Author

Xiaozhe Hu

#### Date

03/06/2013

Definition at line 228 of file wrapper.c.

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