

## Fast Auxiliary Space Preconditioning

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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-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 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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## 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 628 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)*
- [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*
- [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 presmoothers*
- **SHORT** `postsmooth_iter`  
*number of postsmoothers*
- **REAL** `relaxation`  
*relaxation parameter for SOR smoother*
- **SHORT** `polynomial_degree`  
*degree of the polynomial smoother*
- **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** `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*
- **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\\_ifil](#)  
*level of fill-in for ILUs and ILUK*
- [REAL ILU\\_droptol](#)  
*drop tolerance for ILU<sub>t</sub>*
- [REAL ILU\\_relax](#)  
*relaxation 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 504 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 \\* I](#)  
*integer array of row indices, the size is nnz*
- [INT \\* J](#)  
*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.

Definition at line 207 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 263 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 147 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 107 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 302 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 340 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 \\* pdiri](#)
- [INT \\* ediri](#)
- [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 1005 of file fasp.h.

## 8.17.2 Field Documentation

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

Vertices of edges

Definition at line 1008 of file fasp.h.

### 8.17.2.2 `INT edges`

Number of edges

Definition at line 1019 of file fasp.h.

### 8.17.2.3 `INT* ediri`

Boundary flags (0 <=> interior edge)

Definition at line 1012 of file fasp.h.

### 8.17.2.4 `INT* efather`

Father edge or triangle

Definition at line 1015 of file fasp.h.

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

Coordinates of vertices

Definition at line 1007 of file fasp.h.

### 8.17.2.6 `INT* pdiri`

Boundary flags (0 <=> interior point)

Definition at line 1011 of file fasp.h.

### 8.17.2.7 `INT* pfather`

Father point or edge

Definition at line 1014 of file fasp.h.

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

Edges of triangles

Definition at line 1010 of file fasp.h.

**8.17.2.9 INT(\* t)[3]**

Vertices of triangles

Definition at line 1009 of file fasp.h.

**8.17.2.10 INT\* tfather**

Father triangle

Definition at line 1016 of file fasp.h.

**8.17.2.11 INT triangles**

Number of triangles

Definition at line 1020 of file fasp.h.

**8.17.2.12 INT vertices**

Number of grid points

Definition at line 1018 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 237 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 177 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 126 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 \\* ijl](#)  
*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 398 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\\_lfil](#)  
*level of fill-in for ILUk*
- [REAL ILU\\_droptol](#)  
*drop tolerance for ILUt*
- [REAL ILU\\_relax](#)  
*add the sum of dropped elements to diagnal 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 372 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_scaling`
- `SHORT AMG_amli_degree`
- `SHORT AMG_nl_amli_krylov_type`
- `INT AMG_schwarz_levels`
- `SHORT AMG_coarsening_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`
- `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 912 of file fasp.h.

### 8.23.2 Field Documentation

#### 8.23.2.1 INT AMG\_aggressive\_level

number of levels use aggressive coarsening

Definition at line 968 of file fasp.h.

#### 8.23.2.2 INT AMG\_aggressive\_path

number of paths used to determine strongly coupled C-set

Definition at line 969 of file fasp.h.

#### 8.23.2.3 SHORT AMG\_amli\_degree

degree of the polynomial used by AMLI cycle

Definition at line 958 of file fasp.h.

#### 8.23.2.4 INT AMG\_coarse\_dof

minimal coarsest level dof

Definition at line 953 of file fasp.h.

#### 8.23.2.5 SHORT AMG\_coarse\_scaling

switch of scaling of the coarse grid correction

Definition at line 957 of file fasp.h.

#### 8.23.2.6 SHORT AMG\_coarsening\_type

coarsening type

Definition at line 963 of file fasp.h.

#### 8.23.2.7 SHORT AMG\_cycle\_type

type of cycle

Definition at line 946 of file fasp.h.

**8.23.2.8 SHORT AMG\_ILU\_levels**

how many levels use ILU smoother

Definition at line 956 of file fasp.h.

**8.23.2.9 SHORT AMG\_interpolation\_type**

interpolation type

Definition at line 964 of file fasp.h.

**8.23.2.10 SHORT AMG\_levels**

maximal number of levels

Definition at line 945 of file fasp.h.

**8.23.2.11 INT AMG\_max\_aggregation**

max size of each aggregate

Definition at line 973 of file fasp.h.

**8.23.2.12 REAL AMG\_max\_row\_sum**

maximal row sum

Definition at line 967 of file fasp.h.

**8.23.2.13 INT AMG\_maxit**

number of iterations for AMG used as preconditioner

Definition at line 955 of file fasp.h.

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

type of krylov method used by nonlinear AMLI cycle

Definition at line 959 of file fasp.h.

**8.23.2.15 SHORT AMG\_polynomial\_degree**

degree of the polynomial smoother

Definition at line 950 of file fasp.h.

**8.23.2.16 SHORT AMG\_postsmooth\_iter**

number of postsmoothing

Definition at line 952 of file fasp.h.

**8.23.2.17 SHORT AMG\_presmooth\_iter**

number of presmoothing

Definition at line 951 of file fasp.h.

**8.23.2.18 REAL AMG\_relaxation**

over-relaxation parameter for SOR

Definition at line 949 of file fasp.h.

**8.23.2.19 INT AMG\_schwarz\_levels**

number of levels use schwarz smoother

Definition at line 960 of file fasp.h.

**8.23.2.20 SHORT AMG\_smooth\_filter**

use filter for smoothing the tentative prolongation or not

Definition at line 975 of file fasp.h.

**8.23.2.21 SHORT AMG\_smooth\_order**

order for smoothers

Definition at line 948 of file fasp.h.

**8.23.2.22 SHORT AMG\_smoother**

type of smoother

Definition at line 947 of file fasp.h.

**8.23.2.23 REAL AMG\_strong\_coupled**

strong coupled threshold for aggregate

Definition at line 972 of file fasp.h.

**8.23.2.24 REAL AMG\_strong\_threshold**

strong threshold for coarsening

Definition at line 965 of file fasp.h.

**8.23.2.25 REAL AMG\_tentative\_smooth**

relaxation factor for smoothing the tentative prolongation

Definition at line 974 of file fasp.h.

**8.23.2.26 REAL AMG\_tol**

tolerance for AMG if used as preconditioner

Definition at line 954 of file fasp.h.

**8.23.2.27 REAL AMG\_truncation\_threshold**

truncation factor for interpolation

Definition at line 966 of file fasp.h.

**8.23.2.28 SHORT AMG\_type**

Type of AMG

Definition at line 944 of file fasp.h.

**8.23.2.29 REAL ILU\_droptol**

drop tolerance

Definition at line 934 of file fasp.h.

**8.23.2.30 INT ILU\_lfil**

level of fill-in

Definition at line 933 of file fasp.h.

**8.23.2.31 REAL ILU\_permtol**

permutation tolerance

Definition at line 936 of file fasp.h.

**8.23.2.32 REAL ILU\_relax**

scaling factor: add the sum of dropped entries to diagonal

Definition at line 935 of file fasp.h.

**8.23.2.33 SHORT ILU\_type**

ILU type for decomposition

Definition at line 932 of file fasp.h.

**8.23.2.34 char inifile[256]**

ini file name

Definition at line 919 of file fasp.h.

**8.23.2.35 INT itsolver\_maxit**

maximal number of iterations for iterative solvers

Definition at line 928 of file fasp.h.

**8.23.2.36 REAL itsolver\_tol**

tolerance for iterative linear solver

Definition at line 927 of file fasp.h.

**8.23.2.37 SHORT output\_type**

type of output stream

Definition at line 916 of file fasp.h.

**8.23.2.38 SHORT precondition\_type**

type of preconditioner for iterative solvers

Definition at line 925 of file fasp.h.

**8.23.2.39 SHORT print\_level**

print level

Definition at line 915 of file fasp.h.

**8.23.2.40 INT problem\_num**

problem number to solve

Definition at line 921 of file fasp.h.

**8.23.2.41 INT restart**

restart number used in GMRES

Definition at line 929 of file fasp.h.

**8.23.2.42 INT Schwarz\_maxlvl**

maximal levels

Definition at line 940 of file fasp.h.

**8.23.2.43 INT Schwarz\_mmsize**

maximal block size

Definition at line 939 of file fasp.h.

#### 8.23.2.44 INT Schwarz\_type

type of schwarz method

Definition at line 941 of file fasp.h.

#### 8.23.2.45 SHORT solver\_type

type of iterative solvers

Definition at line 924 of file fasp.h.

#### 8.23.2.46 SHORT stop\_type

type of stopping criteria for iterative solvers

Definition at line 926 of file fasp.h.

#### 8.23.2.47 char workdir[256]

working directory for data files

Definition at line 920 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 983 of file fasp.h.



### 8.24.2 Field Documentation

#### 8.24.2.1 SHORT itsolver\_type

solver type: see message.h

Definition at line 985 of file fasp.h.

#### 8.24.2.2 INT maxit

max number of iterations

Definition at line 988 of file fasp.h.

#### 8.24.2.3 SHORT precondition\_type

preconditioner type: see message.h

Definition at line 986 of file fasp.h.

#### 8.24.2.4 SHORT print\_level

print level: 0–10

Definition at line 991 of file fasp.h.

#### 8.24.2.5 INT restart

number of steps for restarting: for GMRES etc

Definition at line 990 of file fasp.h.

#### 8.24.2.6 SHORT stop\_type

stopping criteria type

Definition at line 987 of file fasp.h.

#### 8.24.2.7 REAL tol

convergence tolerance

Definition at line 989 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 354 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 1032 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 1049 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 896 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 877 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 diagonal preconditioning.

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

### Data Fields

- [dCSRmat](#) \* [A](#)
- [dvector](#) \* [r](#)
- [dCSRmat](#) \*\* [Ablock](#)
- [ivector](#) \*\* [row\\_idx](#)
- [ivector](#) \*\* [col\\_idx](#)
- [AMG\\_param](#) \* [amgparam](#)
- [dCSRmat](#) \*\* [Aarray](#)

### 8.30.1 Detailed Description

Data passed to the preconditioner for block diagonal preconditioning.

#### Note

This is needed for the diagonal block preconditioner.

Definition at line 460 of file fasp\_block.h.

### 8.30.2 Field Documentation

#### 8.30.2.1 dCSRmat\* A

problem data, the sparse matrix

Definition at line 462 of file fasp\_block.h.

#### 8.30.2.2 dCSRmat\*\* Aarray

data generated in the setup phase

Definition at line 470 of file fasp\_block.h.

#### 8.30.2.3 dCSRmat\*\* Ablock

problem data, the blocks

Definition at line 465 of file fasp\_block.h.

#### 8.30.2.4 AMG\_param\* amgparam

parameters for AMG

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

#### 8.30.2.5 ivector\*\* col\_idx

problem data, col indices

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

#### 8.30.2.6 dvector\* r

problem data, the right-hand side vector

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

#### 8.30.2.7 ivector\*\* row\_idx

problem data, row indices

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

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

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

## 8.31 precondition\_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  $(-I - A_{wr} * Arr^{-1} * A_{rw})^{-1}$ ,  $Arr$  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 361 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 441 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 442 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 444 of file fasp\_block.h.

#### 8.31.2.4 [ivector](#)\* [order](#)

order for smoothing

Definition at line 446 of file fasp\_block.h.

**8.31.2.5 ivector\* perf\_idx**

variable index for perf

Definition at line 434 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 443 of file fasp\_block.h.

**8.31.2.7 ivector\* pivotS**

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

Definition at line 445 of file fasp\_block.h.

**8.31.2.8 dCSRmat\* PP**

pressure block after diagonal scaling

Definition at line 438 of file fasp\_block.h.

**8.31.2.9 dvector r**

temporary dvector used to store and restore the residual

Definition at line 449 of file fasp\_block.h.

**8.31.2.10 dSTRmat\* RR**

Diagonal scaled reservoir block

Definition at line 436 of file fasp\_block.h.

**8.31.2.11 SHORT scaled**

whether the matrix is scaled

Definition at line 433 of file fasp\_block.h.

**8.31.2.12 dSTRmat\* SS**

saturation block after diagonal scaling

Definition at line 439 of file fasp\_block.h.

**8.31.2.13 REAL\* w**

temporary work space for other usage

Definition at line 450 of file fasp\_block.h.



## 8.31.2.14 dCSRmat\* WW

Argumented well block

Definition at line 437 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](#)  
*coarsening type*
- [SHORT polynomial\\_degree](#)  
*degree of the polynomial smoother*
- [SHORT coarsening\\_type](#)  
*switch of scaling of the coarse grid correction*
- [SHORT coarse\\_scaling](#)  
*relaxation parameter for SOR smoother*
- [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.*
- [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 689 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\\_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.*
- [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 282 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 768 of file [fasp.h](#).

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

- [fasp.h](#)

## 8.35 precondition\_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 264 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 861 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 aml\\_i\\_degree](#)  
*degree of the polynomial used by AMLI cycle*
- [REAL \\* aml\\_i\\_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 480 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 485 of file fasp\_block.h.

#### 8.37.2.2 **dvector\*** diaginv

inverse of the diagonal blocks of reservoir block

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

#### 8.37.2.3 **dvector\*** diaginv\_noscale

inverse of diagonal blocks for diagonal scaling

Definition at line 492 of file fasp\_block.h.

#### 8.37.2.4 **dvector\*** diaginv\_S

inverse of the diagonal blocks of saturation block

Definition at line 501 of file fasp\_block.h.

#### 8.37.2.5 **INT** maxit

max number of iterations

Definition at line 572 of file fasp\_block.h.

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

AMG data for presure-presure block

Definition at line 506 of file fasp\_block.h.



#### 8.37.2.7 **ivector\*** neigh

neighbor information of the reservoir block

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

#### 8.37.2.8 **ivector\*** order

ordering of the reservoir block

Definition at line 497 of file fasp\_block.h.

#### 8.37.2.9 **ivector\*** perf\_idx

index of blocks which have perforation

Definition at line 561 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 562 of file fasp\_block.h.

#### 8.37.2.11 **ivector\*** pivot

pivot for the GS smoothers for the reservoir matrix

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

#### 8.37.2.12 **ivector\*** pivot\_S

pivoting for the GS smoothers for saturation block

Definition at line 502 of file fasp\_block.h.

#### 8.37.2.13 **dCSRmat\*** PP

pressure block

Definition at line 505 of file fasp\_block.h.

#### 8.37.2.14 **dvector** r

temporary dvector used to store and restore the residual

Definition at line 577 of file fasp\_block.h.

#### 8.37.2.15 **INT** restart

number of iterations for restart

Definition at line 573 of file fasp\_block.h.

#### 8.37.2.16 dBSRmat\* RR

reservoir block

Definition at line 493 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 491 of file fasp\_block.h.

#### 8.37.2.18 dBSRmat\* SS

saturation block

Definition at line 500 of file fasp\_block.h.

#### 8.37.2.19 REAL tol

tolerance

Definition at line 574 of file fasp\_block.h.

#### 8.37.2.20 REAL\* w

temporary work space for other usage

Definition at line 578 of file fasp\_block.h.

#### 8.37.2.21 dCSRmat\* WW

Argumented well block

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

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

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

## 8.38 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*

### 8.38.1 Detailed Description

Data for Schwarz methods.

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

Definition at line 457 of file fasp.h.

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

- [fasp.h](#)

## 8.39 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*

### 8.39.1 Detailed Description

Parameters for Schwarz method.

Added on 05/14/2012

Definition at line 433 of file fasp.h.

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

- [fasp.h](#)

## Chapter 9

# File Documentation

### 9.1 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 algebaric multigrid methods.*

#### 9.1.1 Detailed Description

AMG method as an iterative solver (main file)

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

#### 9.1.2 Function Documentation

9.1.2.1 void [fasp\\_solver\\_amg](#) ( dCSRmat \* A, dvector \* b, dvector \* x, AMG\_param \* param )

Solve  $Ax = b$  by algebaric 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 05/05/2013: Remove error handling from AMG setup

Definition at line 37 of file amg.c.

## 9.2 amg\_setup\_aggregation\_bsr.inl File Reference

Utilities for multigrid cycles in BSR format.

### 9.2.1 Detailed Description

Utilities for multigrid cycles in BSR format.

Definition in file [amg\\_setup\\_aggregation\\_bsr.inl](#).

## 9.3 amg\_setup\_aggregation\_csr.inl File Reference

Utilities for multigrid cycles for CSR matrices.

### 9.3.1 Detailed Description

Utilities for multigrid cycles for CSR matrices.

Definition in file [amg\\_setup\\_aggregation\\_csr.inl](#).

## 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

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

- [INT fasp\\_amg\\_setup\\_rs](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Setup phase of Ruge and Stuben's classic AMG.*
- [INT fasp\\_amg\\_setup\\_rs\\_omp](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Setup of AMG based on R-S coarsening.*

### 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 INT 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

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.

Definition at line 47 of file [amg\\_setup\\_rs.c](#).

#### 9.5.2.2 INT fasp\_amg\_setup\_rs\_omp ( [AMG\\_data](#) \* *mgl*, [AMG\\_param](#) \* *param* )

Setup of AMG based on R-S coarsening.



## Parameters

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

## Returns

SUCCESS if succeeded, otherwise, error information.

## Author

Chunsheng Feng, Xiaoqiang Yue

## Date

03/11/2011

Definition at line 253 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 "amg_setup_aggregation_csr.inl"
```

## Functions

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

### 9.6.1 Detailed Description

Smoothed 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\\_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**

SUCCESS if succeed, error otherwise

**Author**

Xiaozhe Hu

**Date**

09/29/2009

**Note**

Only for testing smoothed P and unsmoothed A, not used usually.

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 50 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 "amg_setup_aggregation_csr.inl"
#include "amg_setup_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

SUCCESS if succeed, error otherwise

#### Author

Xiaozhe Hu

#### Date

12/28/2011

Definition at line 39 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

SUCCESS if succeed, error otherwise

#### Author

Xiaozhe Hu

#### Date

03/16/2012

Definition at line 70 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 747 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 293 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 568 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

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

$x$	Pointer to the original vector
$y$	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_axpyb` (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

<code>n</code>	Number of variables
<code>a</code>	Factor a
<code>x</code>	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\\_aApy](#) (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\\_aApy](#) (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\_aApy ( 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 231 of file blas\_bcsr.c.

9.12.2.2 void fasp\_blas\_bdbsr\_mnv ( [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 269 of file blas\_bcsr.c.

9.12.2.3 void fasp\_blas\_bdcsr\_aApy ( 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 130 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_functs.h"
```

### Functions

- 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\\_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 39 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 320 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 595 of file blas\_bsr.c.

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

Compute  $y := A x$ .

## Parameters

$A$	Pointer to the <a href="#">dBSRmat</a> matrix
$x$	Pointer to the array $x$
$y$	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 906 of file blas\_bsr.c.

9.13.2.5 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

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

## Author

Xiaozhe Hu

## Date

01/02/2014

## Note

Works for general nb (Xiaozhe)

Definition at line 2653 of file blas\_bsr.c.

9.13.2.6 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 5029 of file blas\_bsr.c.

9.13.2.7 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 4845 of file blas\_bsr.c.

9.13.2.8 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 5287 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 482 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 596 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

SUCCESS if succeeds, RUN\_FAIL 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 203 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

Xiaozhe Hu

## Date

11/07/2009

## Note

This fct will be replaced! –Chensong

Definition at line 762 of file blas\_csr.c.

9.14.2.6 void fasp\_blas\_dcsr\_mxv ( [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 y
----------	--------------------

**Author**

Chensong Zhang

**Date**

07/01/2009

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

Definition at line 227 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 $A$
<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 425 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 1600 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 dCSRmat matrix R
<i>A</i>	Pointer to the dCSRmat matrix A
<i>P</i>	Pointer to the dCSRmat matrix P
<i>RAP</i>	Pointer to dCSRmat 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 869 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 dCSRmat matrix
<i>A</i>	pointer to the dCSRmat 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 1699 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 1150 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 1417 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 707 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_dcsrl_mnv ( dCSRmat * A, REAL * x, REAL * y )`

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

#### Parameters

<i>A</i>	Pointer to <a href="#">dCSRmat</a> matrix A
<i>x</i>	Pointer to REAL array of vector x
<i>y</i>	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\\_mnv\\_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\\_mnv\\_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\\_mnv\\_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\\_mnv\\_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\\_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.*
- 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\*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\*2 dense matrix, Ass is its saturaton part 1\*1.
- void `fasp_blas_smat_ymAx_ns3` (`REAL *A`, `REAL *x`, `REAL *y`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a 3\*3 dense matrix, Ass is its saturaton part 2\*2.
- void `fasp_blas_smat_ymAx_ns5` (`REAL *A`, `REAL *x`, `REAL *y`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a 5\*5 dense matrix, Ass is its saturaton part 4\*4.
- void `fasp_blas_smat_ymAx_ns7` (`REAL *A`, `REAL *x`, `REAL *y`)  
Compute  $ys := ys - Ass * xs$ , where 'A' is a 7\*7 dense matrix, Ass is its saturaton part 6\*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  $n*n$  dense matrix, Ass is its saturaton part  $(n-1)*(n-1)$ .

### 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 627 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

$y$	Pointer to the destination array
-----	----------------------------------

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 650 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**

$a$	REAL factor a
$x$	Pointer to the original array
$y$	Pointer to the destination array

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 679 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**

$a$	REAL factor a
$x$	Pointer to the original array
$y$	Pointer to the destination array

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 726 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 442 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 469 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 502 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 553 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 1250 of file blas\_smat.c.

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

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

04/21/2010

Definition at line 390 of file blas\_smat.c.

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

## Author

Xiaozhe Hu

**Date**

18/11/2011

Definition at line 175 of file blas\_smat.c.

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

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 204 of file blas\_smat.c.

**9.16.2.13 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.

**Parameters**

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

**Author**

Xiaozhe Hu, Shiquan Zhang

**Date**

05/01/2010

Definition at line 241 of file blas\_smat.c.

**9.16.2.14 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.

## Parameters

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

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

05/01/2010

Definition at line 300 of file blas\_smat.c.

9.16.2.15 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 <i>n</i> * <i>n</i> matrix
<i>b</i>	Pointer to the REAL array with length <i>n</i>
<i>c</i>	Pointer to the REAL array with length <i>n</i>
<i>n</i>	Dimension of the matrix

## Author

Xiaozhe Hu, Shiquan Zhang

## Date

04/21/2010

Definition at line 125 of file blas\_smat.c.

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

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

## Parameters

<i>a</i>	Pointer to the REAL array which stands a 2*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 25 of file blas\_smat.c.

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

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

## Parameters

<i>a</i>	Pointer to the REAL array which stands a 3*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 47 of file blas\_smat.c.

**9.16.2.18 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*.

## 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 70 of file blas\_smat.c.

**9.16.2.19 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*.

## 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 96 of file blas\_smat.c.

9.16.2.20 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.

## 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 $n$
$n$	the dimension of the dense matrix

## Author

Zhiyang Zhou, Xiaozhe Hu

## Date

2010/10/25

Definition at line 1149 of file blas\_smat.c.

9.16.2.21 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 $2 \times 2$ 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 1019 of file blas\_smat.c.

9.16.2.22 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 $3 \times 3$ dense matrix
$x$	Pointer to the REAL array with length 3

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

**Author**

Xiaozhe Hu, Zhiyang Zhou

**Date**

01/06/2011

**Note**

Works for 3-component

Definition at line 1047 of file blas\_smat.c.

9.16.2.23 `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 1077 of file blas\_smat.c.

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

Compute  $y := y - Ax$ , where 'A' is a  $7 \times 7$  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 1111 of file blas\_smat.c.

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

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

**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 explictly use saturation block!!

Definition at line 1424 of file blas\_smat.c.

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

Compute  $y_s := y_s - Ass * x_s$ , where ' $A$ ' is a  $2 \times 2$  dense matrix,  $Ass$  is its saturaton 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 1300 of file blas\_smat.c.

9.16.2.27 `void fasp_blas_smat_ymAx_ns3 ( REAL * A, REAL * x, REAL * y )`

Compute  $ys := ys - Ass * xs$ , where 'A' is a 3\*3 dense matrix, Ass is its saturaton part 2\*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 1324 of file blas\_smat.c.

9.16.2.28 `void fasp_blas_smat_ymAx_ns5 ( REAL * A, REAL * x, REAL * y )`

Compute  $ys := ys - Ass * xs$ , 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 1352 of file blas\_smat.c.

9.16.2.29 `void fasp_blas_smat_ymAx_ns7 ( REAL * A, REAL * x, REAL * y )`

Compute  $y_s := y_s - A_{ss}x_s$ , where 'A' is a 7\*7 dense matrix,  $A_{ss}$  is its saturation 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 1386 of file blas\_smat.c.

9.16.2.30 `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.

## 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 918 of file blas\_smat.c.

9.16.2.31 `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 799 of file blas\_smat.c.

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

Compute  $y := y + Ax$ , where 'A' is a  $3 \times 3$  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

Zhiyang Zhou, Xiaozhe Hu

## Date

2010/10/25

Definition at line 825 of file blas\_smat.c.

9.16.2.33 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 852 of file blas\_smat.c.

9.16.2.34 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

$A$	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

Zhiyang Zhou, Xiaozhe Hu

## Date

2010/10/25

Definition at line 883 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\_aApy ( 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 'dSTRmat' type matrix A
<i>B</i>	Pointer to a 'dSTRmat' 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)  
*L1 norm of dvector x.*
- [REAL fasp\\_blas\\_dvec\\_norm2](#) ([dvector](#) \*x)  
*L2 norm of dvector x.*
- [REAL fasp\\_blas\\_dvec\\_norminf](#) ([dvector](#) \*x)  
*Linf 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**

07/01/209

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**

07/01/209

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

$L_{\infty}$  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 wether 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

$A$	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

$A$	pointer to the <a href="#">dCSRmat</a> matrix
-----	---

## Returns

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

$A$	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

- [INT 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 INT 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

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

<code>A</code>	Pointer to <code>dCSRmat</code> : the coefficient matrix
<code>b</code>	Pointer to <code>dvector</code> : the right hand side
<code>x</code>	Pointer to <code>dvector</code> : the unknowns
<code>param</code>	Pointer to <code>AMG_param</code> : 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 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 72 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 88 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 dlmalloc 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 1077 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 78 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 77 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  $a == \text{NAN}$ ?

Definition at line 81 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 86 of file fasp.h.

9.27.2.14 `#define LE( a, b ) (((a)<=(b))?(TRUE):(FALSE))`

is  $a \leq b$ ?

Definition at line 80 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 79 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 70 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 64 of file fasp.h.

**9.27.2.22 #define MAX\_STAG 20**

Maximal number of stagnation times

Definition at line 63 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 71 of file fasp.h.

**9.27.2.24 #define N2C( ind ) ((ind)-ISTART)**

map from Natural index 1,2,... to C index 0,1,...

Definition at line 87 of file fasp.h.

**9.27.2.25 #define NEDMALLOC OFF**

use nedmalloc instead of standard malloc

Definition at line 34 of file fasp.h.

**9.27.2.26 #define OPENMP\_HOLDS 2000**

Switch to sequence version when size is small

Definition at line 65 of file fasp.h.

**9.27.2.27 #define REAL double**

float type

Definition at line 53 of file fasp.h.

**9.27.2.28 #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.

#### 9.27.2.29 `#define SHORT short`

FASP integer and floating point numbers.

short integer type

Definition at line 49 of file fasp.h.

#### 9.27.2.30 `#define SMALLREAL 1e-20`

A small real number

Definition at line 59 of file fasp.h.

#### 9.27.2.31 `#define STAG_RATIO 1e-4`

Stagantation tolerance = tol\*STAGRATIO

Definition at line 62 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 1072 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 1026 of file fasp.h.

#### 9.27.3.15 `typedef grid2d* pgrid2d`

Grid in 2d

Definition at line 1024 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\\_ivector](#)  
*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 diagonal preconditioning.*

- struct [precond\\_FASP\\_blkoi\\_data](#)

*Data passed to the preconditioner for preconditioning reservoir simulation problems.*

## 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\\_ivecator](#) [block\\_ivecator](#)
- 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_ivecator block_ivecator`

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 precondition_block_reservoir_data precondition_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

<code>Ab</code>	Pointer to <code>block_dCSRmat</code> 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

<code>B</code>	Pointer to <code>dBSRmat</code> matrix
----------------	--

Returns

Pointer to `dCOOmat` matrix

## Author

Zhiyang Zhou

## Date

2010/10/26

Definition at line 914 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 dCOOmat matrix
<i>B</i>	Pointer to dCSRmat matrix

## Returns

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

Definition at line 719 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**

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\_dcsrl\_dcsr ( dCSRmat \* A )**

Convert a [dCSRmat](#) into a [dCSRLmat](#).

## Parameters

$A$	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 810 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

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  $y \mid \beta e_1 - H*y$ .**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 $\mid \beta e_1 - H*y \mid$
<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** prtlvl)  
*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** prtlvl)  
*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** prtlvl)  
*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** prtlvl)  
*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 466 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 <a href="#">dBSRmat</a> matrix
<i>filename</i>	File name
<i>size</i>	size*size 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 106 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>	<code>size*size</code> 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 175 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 **sybmfactor** (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 **sybmfactor\_** (const [INT](#) \*n, [INT](#) \*colind, [INT](#) \*rwptr, 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 oringinal 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 sturcture 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 memeory space.*
- void [fasp\\_amg\\_data\\_free](#) ([AMG\\_data](#) \*mgl, [AMG\\_param](#) \*param)  
*Free [AMG\\_data](#) data memeory space.*
- void [fasp\\_amg\\_data\\_bsr\\_free](#) ([AMG\\_data\\_bsr](#) \*mgl)  
*Free [AMG\\_data\\_bsr](#) data memeory space.*
- void [fasp\\_ilu\\_data\\_free](#) ([ILU\\_data](#) \*ILUdata)  
*Create [ILU\\_data](#) sturcture.*
- 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

<a href="#">max_levels</a>	Max number of levels allowed
----------------------------	------------------------------

#### Returns

Pointer to the [AMG\\_data](#) data structure

#### Author

Xiaozhe Hu

## Date

08/07/2011

Definition at line 83 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 213 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 166 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 111 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 258 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 279 of file init.c.

9.39.2.8 void fasp\_precond\_data\_null ( [precond\\_data](#) \* *pcdata* )

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 ( [precond](#) \* *pcdata* )

Initialize precondition data.

## Parameters

<i>pcdata</i>	Pointer to precondition
---------------	-------------------------

## Author

Chensong Zhang

## Date

2010/03/23

Definition at line 295 of file init.c.

9.39.2.10 void fasp\_schwarz\_data\_free ( [Schwarz\\_data](#) \* *schwarz* )

Free [Schwarz\\_data](#) data memory space.

## Parameters

<i>*schwarz</i>	pointer to the <a href="#">AMG_data</a> data
-----------------	--

## Author

Xiaozhe Hu

## Date

2010/04/06

Definition at line 137 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](#) (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 ( 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 95 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

*vec	pointer to the dvector
*filename	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 <code>dCSRmat</code> : 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

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 158 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"
```

## Functions

- void `fasp_dcsrvec1_read` (char \*filename, `dCSRmat` \*A, `dvector` \*b)  
*Read A and b from a SINGLE disk file.*
- void `fasp_dcsrvec2_read` (char \*filemat, char \*filerhs, `dCSRmat` \*A, `dvector` \*b)  
*Read A and b from two disk files.*
- void `fasp_dcsr_read` (char \*filename, `dCSRmat` \*A)  
*Read A from matrix disk file in IJ format.*
- void `fasp_dcoo_read` (char \*filename, `dCSRmat` \*A)  
*Read A from matrix disk file in IJ format – indices starting from 0.*
- void `fasp_dcoo1_read` (char \*filename, `dCOOmat` \*A)  
*Read A from matrix disk file in IJ format – indices starting from 0.*
- void `fasp_dmtx_read` (char \*filename, `dCSRmat` \*A)  
*Read A from matrix disk file in MatrixMarket general format.*
- void `fasp_dmtxsym_read` (char \*filename, `dCSRmat` \*A)  
*Read A from matrix disk file in MatrixMarket sym format.*
- void `fasp_dstr_read` (char \*filename, `dSTRmat` \*A)  
*Read A from a disk file in dSTRmat format.*
- void `fasp_dbsr_read` (char \*filename, `dB SRmat` \*A)  
*Read A from a disk file in dB SRmat format.*
- void `fasp_dvecind_read` (char \*filename, `dvector` \*b)  
*Read b from matrix disk file.*
- void `fasp_dvec_read` (char \*filename, `dvector` \*b)  
*Read b from a disk file in array format.*
- void `fasp_ivecind_read` (char \*filename, `ivector` \*b)  
*Read b from matrix disk file.*
- void `fasp_ivec_read` (char \*filename, `ivector` \*b)  
*Read b from a disk file in array format.*
- void `fasp_dcsrvec1_write` (char \*filename, `dCSRmat` \*A, `dvector` \*b)  
*Write A and b to a SINGLE disk file.*
- void `fasp_dcsrvec2_write` (char \*filemat, char \*filerhs, `dCSRmat` \*A, `dvector` \*b)  
*Write A and b to two disk files.*
- void `fasp_dcoo_write` (char \*filename, `dCSRmat` \*A)  
*Write a matrix to disk file in IJ format (coordinate format)*
- void `fasp_dstr_write` (char \*filename, `dSTRmat` \*A)  
*Write a dSTRmat to a disk file.*
- void `fasp_dbsr_write` (char \*filename, `dB SRmat` \*A)  
*Write a dB SRmat to a disk file.*
- void `fasp_dvec_write` (char \*filename, `dvector` \*vec)  
*Write a dvector to disk file.*
- void `fasp_dvecind_write` (char \*filename, `dvector` \*vec)  
*Write a dvector to disk file in coordinate format.*
- void `fasp_ivec_write` (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` (char \*filename, void \*A)
- *Read matrix from different kinds of formats from both ASCII and binary files.*
- void `fasp_matrix_read_bin` (char \*filename, void \*A)
- *Read matrix in binary format.*
- void `fasp_matrix_write` (char \*filename, void \*A, INT flag)
- *write matrix from different kinds of formats from both ASCII and binary files*
- void `fasp_vector_read` (char \*filerhs, void \*b)
- *Read RHS vector from different kinds of formats from both ASCII and binary files.*
- void `fasp_vector_write` (char \*filerhs, void \*b, INT flag)
- *write RHS vector from different kinds of formats in both ASCII and binary files*

## 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

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

## Author

Ziteng Wang

## Date

12/24/2012

Modified by Chunsheng Feng

## Date

11/16/2013

Definition at line 1384 of file io.c.

9.47.2.2 void fasp\_dbsr\_read ( char \* *filename*, [dBSRmat](#) \* *A* )Read *A* from a disk file in [dBSRmat](#) format.

## Parameters

<i>filename</i>	File name for matrix <i>A</i>
<i>A</i>	Pointer to the <a href="#">dBSRmat</a> <i>A</i>

## 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 635 of file io.c.

9.47.2.3 void fasp\_dbsr\_write ( 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 1143 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 A

## Author

Chunsheng Feng

## Date

11/14/2013

Definition at line 1419 of file io.c.

9.47.2.5 void fasp\_dcoo1\_read ( 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 366 of file io.c.

## 9.47.2.6 void fasp\_dcoo\_print ( dCOOmat \* A )

Print out a dCOOmat matrix in coordinate format.

## Parameters

A	Pointer to the dCOOmat matrix A
---	---------------------------------

## Author

Ziteng Wang

## Date

12/24/2012

Definition at line 1362 of file io.c.

## 9.47.2.7 void fasp\_dcoo\_read ( char \* filename, dCSRmat \* A )

Read A from matrix disk file in IJ format – indices starting from 0.

## Parameters

filename	File name for matrix
A	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 315 of file io.c.

## 9.47.2.8 void fasp\_dcoo\_write ( 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 1043 of file io.c.

**9.47.2.9 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 A
----------	---

## Author

Xuehai Huang

## Date

03/29/2009

Definition at line 1340 of file io.c.

**9.47.2.10 void fasp\_dcsr\_read ( 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 254 of file io.c.

9.47.2.11 `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 1465 of file io.c.

9.47.2.12 `void fasp_dcsrvec1_read ( 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 84 of file io.c.

9.47.2.13 void fasp\_dcsrvec1\_write ( 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 895 of file io.c.

9.47.2.14 void fasp\_dcsrvec2\_read ( char \* *filemat*, 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 175 of file io.c.

9.47.2.15 void fasp\_dcsrvec2\_write ( char \* *filemat*, 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 972 of file io.c.

9.47.2.16 void fasp\_dmtx\_read ( char \* filename, dCSRmat \* A )

Read A from matrix disk file in MatrixMarket general format.

Parameters

<i>filename</i>	File name for matrix
A	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 416 of file io.c.

9.47.2.17 void fasp\_dmtxsym\_read ( 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 478 of file io.c.

**9.47.2.18 void fasp\_dstr\_print ( dSTRmat \* A )**

Print out a [dSTRmat](#) matrix in coordinate format.

**Parameters**

<i>A</i>	Pointer to the <a href="#">dSTRmat</a> matrix A
----------	---

**Author**

Ziteng Wang

**Date**

12/24/2012

Definition at line 1504 of file io.c.

**9.47.2.19 void fasp\_dstr\_read ( 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 <a href="#">dSTRmat</a>

**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
- $\text{diag}(j)$ ,  $j=0:n-1$
- offset, length: offset and length of off-diag1
- $\text{offdiag}(j)$ ,  $j=0:\text{length}-1$

**Author**

Xuehai Huang

**Date**

03/29/2009

Definition at line 555 of file io.c.

9.47.2.20 `void fasp_dstr_write ( 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 1083 of file io.c.

9.47.2.21 `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 1301 of file io.c.

**9.47.2.22 void fasp\_dvec\_read ( char \* *filename*, dvector \* *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**

Chensong Zhang

**Date**

03/29/2009

Definition at line 754 of file io.c.

**9.47.2.23 void fasp\_dvec\_write ( 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 1198 of file io.c.

**9.47.2.24 void fasp\_dvecind\_read ( char \* *filename*, dvector \* *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

Because the index is given, order is not important!

## Author

Chensong Zhang

## Date

03/29/2009

Definition at line 704 of file io.c.

9.47.2.25 void fasp\_dvecind\_write ( 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 1234 of file io.c.

9.47.2.26 void fasp\_ivec\_print ( INT *n*, ivec \* *u* )

Print first n entries of a vector of INT type.

## Parameters

<i>n</i>	An interger (if n=0, then print all entries)
<i>u</i>	Pointer to an ivector

## Author

Chensong Zhang

## Date

03/29/2009

Definition at line 1321 of file io.c.

**9.47.2.27** void fasp\_ivec\_read ( 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 844 of file io.c.

**9.47.2.28** void fasp\_ivec\_write ( 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 1269 of file io.c.

**9.47.2.29** void fasp\_ivecind\_read ( char \* *filename*, ivector \* *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

**Author**

Chensong Zhang

**Date**

03/29/2009

Definition at line 804 of file io.c.

**9.47.2.30** fasp\_matrix\_read ( 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 1538 of file io.c.

**9.47.2.31 void fasp\_matrix\_read\_bin ( 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 1643 of file io.c.

9.47.2.32 `fasp_matrix_write ( 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 1717 of file io.c.

#### 9.47.2.33 fasp\_vector\_read ( 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 1810 of file io.c.

**9.47.2.34 fasp\_vector\_write ( 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 1907 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.*

### 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\\_bdcsr\\_itsolver](#) ( [block\\_dCSRmat](#) \* 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="#">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>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

11/25/2010

Definition at line 35 of file [itsolver\\_bcsr.c](#).

#### 9.48.2.2 INT fasp\_solver\_bdcsr\_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 105 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, [precond](#) \*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.*

## 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 175 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 382 of file itsolver\_bsr.c.

**9.49.2.5 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 219 of file itsolver\_bsr.c.

**9.49.2.6 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 315 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.*

### 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

<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>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 139 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 330 of file itsolver\_csr.c.

**9.50.2.4 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 189 of file itsolver\_csr.c.

**9.50.2.5 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 438 of file itsolver\_csr.c.

**9.50.2.6** 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 525 of file itsolver\_csr.c.

**9.50.2.7** 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 253 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*, precondition \* *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, precondition * 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 109 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 290 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 149 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 dSTRmat 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 207 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 close to zero!\n")  
*Warning for solution close to zero.*
- #define ITS\_RESTART printf("### WARNING: Iteration restarted due to stagnation!\n")  
*Warning for iteration restarted.*
- #define ITS\_STAGGED printf("### WARNING: Iteration stopped due to staggnation!\n")  
*Warning for staged iteration.*
- #define ITS\_ZEROTOL printf("### WARNING: The tolerance might be too small!\n")  
*Warning for tolerance practically close to zero.*
- #define ITS\_DIVZERO printf("### WARNING: Divided by zero!\n")  
*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!\n")`  
*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_functs.h"
```

### Functions

- [SHORT fasp\\_smat\\_lu\\_decomp](#) ([REAL](#) \*A, [INT](#) pivot[], [INT](#) n)  
*LU decomposition of A usind 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 usind Doolittle's method.

##### Parameters

<i>A</i>	Pointer to the full matrix
<i>pivot</i>	Pivoting positions
<i>n</i>	Size of matrix A

##### Returns

SUCCESS if succeed, RUN\_FAIL 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
<i>b</i>	Right hand side array
<i>pivot</i>	Pivoting positions
<i>x</i>	Pointer to the solution array
<i>n</i>	Size of matrix A

## Returns

SUCCESS if succeed, RUN\_FAIL 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, 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*, char \* *message*, INT *ERR* )

Check wether 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

SUCCESS or error code

## Author

Chensong Zhang

## Date

11/16/2009

Definition at line 191 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

SUCCESS if success, else ERROR message (negative value)

## Author

Xiaozhe Hu

## Date

11/27/09

Definition at line 241 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 144 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 checked
----------------	-----------------------

**Returns**

SUCCESS if success, else ERROR (negative value)

**Author**

Xiaozhe Hu, Chensong Zhang

**Date**

11/27/09

Definition at line 215 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 110 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 169 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_funcs.h"
```

## Functions

- 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.*
- void [print\\_amgcomplexity](#) ([AMG\\_data](#) \*mgl, const [SHORT](#) ptrlvl)  
*Print complexities of AMG method.*
- void [print\\_amgcomplexity\\_bsr](#) ([AMG\\_data\\_bsr](#) \*mgl, const [SHORT](#) ptrlvl)  
*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](#) ptrlvl, 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 \* *fctname* )

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 195 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>ptrlvl</i>	How much information to print

## Author

Chensong Zhang

## Date

05/10/2013

Definition at line 120 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 161 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 178 of file message.c.

**9.58 messages.h File Reference**

Definition of all kinds of messages, including error messages, solver types, etc.

**Macros**

- #define [ERROR\\_OPEN\\_FILE](#) -10  
*Definition of return status and error messages.*
- #define [ERROR\\_WRONG\\_FILE](#) -11
- #define [ERROR\\_INPUT\\_PAR](#) -13
- #define [ERROR\\_REGRESS](#) -14
- #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 `RUN_FAIL` -99
- #define `SUCCESS` 0
- #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_CG` 1

*Definition of solver types for iterative methods.*

- #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
- Definition of solver types for direct methods (requires external libs)*
- #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 ILU<sub>t</sub> 2
- #define ILU<sub>tp</sub> 3
- #define CLASSIC\_AMG 1
- Definition of AMG types.*
- #define SA\_AMG 2
- #define UA\_AMG 3
- #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 UNPT -1`
- Type of vertices (dofs) for C/F splitting.*
- `#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 160 of file messages.h.

#### 9.58.2.2 `#define ASCEND 12`

Ascending order

Definition at line 217 of file messages.h.

#### 9.58.2.3 `#define CF_ORDER 1`

C/F order smoothing

Definition at line 209 of file messages.h.

**9.58.2.4 #define CGPT 1**

coarse grid points

Definition at line 202 of file messages.h.

**9.58.2.5 #define CLASSIC\_AMG 1**

Definition of AMG types.

classic AMG

Definition at line 151 of file messages.h.

**9.58.2.6 #define COARSE\_AC 4**

Aggressive coarsening

Definition at line 188 of file messages.h.

**9.58.2.7 #define COARSE\_CR 3**

Compatible relaxation

Definition at line 187 of file messages.h.

**9.58.2.8 #define COARSE\_RS 1**

Definition of coarsening types.

Classical coarsening

Definition at line 186 of file messages.h.

**9.58.2.9 #define CPFIRST 1**

C-points first order

Definition at line 215 of file messages.h.

**9.58.2.10 #define DESCEND 21**

Dsscending order

Definition at line 218 of file messages.h.

**9.58.2.11 #define ERROR\_ALLOC\_MEM -20**

fail to allocate memory

Definition at line 33 of file messages.h.

**9.58.2.12 #define ERROR\_AMG\_COARSE\_TYPE -32**

unknown coarsening type

Definition at line 40 of file messages.h.

**9.58.2.13 #define ERROR\_AMG\_COARSEING -33**

coarsening step failed to complete

Definition at line 41 of file messages.h.

**9.58.2.14 #define ERROR\_AMG\_INTERP\_TYPE -30**

unknown interpolation type

Definition at line 38 of file messages.h.

**9.58.2.15 #define ERROR\_AMG\_SMOOTH\_TYPE -31**

unknown smoother type

Definition at line 39 of file messages.h.

**9.58.2.16 #define ERROR\_DATA\_STRUCTURE -21**

problem with data structures

Definition at line 34 of file messages.h.

**9.58.2.17 #define ERROR\_DATA\_ZERODIAG -22**

matrix has zero diagonal entries

Definition at line 35 of file messages.h.

**9.58.2.18 #define ERROR\_DUMMY\_VAR -23**

unexpected input data

Definition at line 36 of file messages.h.

**9.58.2.19 #define ERROR\_INPUT\_PAR -13**

wrong input argument

Definition at line 28 of file messages.h.

**9.58.2.20 #define ERROR\_LIC\_TYPE -80**

wrong license type

Definition at line 56 of file messages.h.

**9.58.2.21 #define ERROR\_MISC -19**

other error

Definition at line 31 of file messages.h.

**9.58.2.22 #define ERROR\_NUM\_BLOCKS -18**

wrong number of blocks

Definition at line 30 of file messages.h.

**9.58.2.23 #define ERROR\_OPEN\_FILE -10**

Definition of return status and error messages.

fail to open a file

Definition at line 26 of file messages.h.

**9.58.2.24 #define ERROR\_QUAD\_DIM -61**

unsupported quadrature dim

Definition at line 54 of file messages.h.

**9.58.2.25 #define ERROR\_QUAD\_TYPE -60**

unknown quadrature type

Definition at line 53 of file messages.h.

**9.58.2.26 #define ERROR\_REGRESS -14**

regression test fail

Definition at line 29 of file messages.h.

**9.58.2.27 #define ERROR\_SOLVER\_EXIT -49**

solver does not quit successfully

Definition at line 51 of file messages.h.

**9.58.2.28 #define ERROR\_SOLVER\_ILUSETUP -45**

ILU setup error

Definition at line 48 of file messages.h.

**9.58.2.29 #define ERROR\_SOLVER\_MAXIT -48**

maximal iteration number exceeded

Definition at line 50 of file messages.h.

**9.58.2.30 #define ERROR\_SOLVER\_MISC -46**

misc solver error during run time

Definition at line 49 of file messages.h.

**9.58.2.31 #define ERROR\_SOLVER\_PRECTYPE -41**

unknown precondition type

Definition at line 44 of file messages.h.

**9.58.2.32 #define ERROR\_SOLVER\_SOLSTAG -43**

solver's solution is too small

Definition at line 46 of file messages.h.

**9.58.2.33 #define ERROR\_SOLVER\_STAG -42**

solver stagnates

Definition at line 45 of file messages.h.

**9.58.2.34 #define ERROR\_SOLVER\_TOLSMALL -44**

solver's tolerance is too small

Definition at line 47 of file messages.h.

**9.58.2.35 #define ERROR\_SOLVER\_TYPE -40**

unknown solver type

Definition at line 43 of file messages.h.

**9.58.2.36 #define ERROR\_WRONG\_FILE -11**

input contains wrong format

Definition at line 27 of file messages.h.

**9.58.2.37 #define FALSE 0**

logic FALSE

Definition at line 65 of file messages.h.

**9.58.2.38 #define FGPT 0**

fine grid points

Definition at line 201 of file messages.h.

**9.58.2.39 #define FPFIRST -1**

F-points first order

Definition at line 216 of file messages.h.

**9.58.2.40 #define ILUk 1**

Type of ILU methods.

ILUk

Definition at line 144 of file messages.h.

**9.58.2.41 #define ILUt 2**

ILUt

Definition at line 145 of file messages.h.

**9.58.2.42 #define ILUtp 3**

ILUtp

Definition at line 146 of file messages.h.

**9.58.2.43 #define INTERP\_DIR 1**

Definition of interpolation types.

Direct interpolation

Definition at line 193 of file messages.h.

**9.58.2.44 #define INTERP\_ENG 3**

energy minimization interp in C

Definition at line 195 of file messages.h.

**9.58.2.45 #define INTERP\_STD 2**

Standard interpolation

Definition at line 194 of file messages.h.

**9.58.2.46 #define ISPT 2**

isolated points

Definition at line 203 of file messages.h.

**9.58.2.47 #define MAT\_bBSR 5**

block matrix of BSR for bordered systems

Definition at line 91 of file messages.h.

**9.58.2.48 #define MAT\_bCSR 4**

block matrix of CSR

Definition at line 90 of file messages.h.

**9.58.2.49 #define MAT\_BSR 2**

blockwise compressed sparse row

Definition at line 88 of file messages.h.

**9.58.2.50 #define MAT\_CSR 1**

compressed sparse row

Definition at line 87 of file messages.h.

**9.58.2.51 #define MAT\_CSRL 6**

modified CSR to reduce cache missing

Definition at line 92 of file messages.h.

**9.58.2.52 #define MAT\_FREE 0**

Definition of matrix format.

matrix-free format: only mxv action

Definition at line 86 of file messages.h.

**9.58.2.53 #define MAT\_STR 3**

structured sparse matrix

Definition at line 89 of file messages.h.

**9.58.2.54 #define MAT\_SymCSR 7**

symmetric CSR format

Definition at line 93 of file messages.h.

**9.58.2.55 #define NL\_AMLI\_CYCLE 4**

Nonlinear AMLI-cycle

Definition at line 161 of file messages.h.

**9.58.2.56 #define NO\_ORDER 0**

Definition of smoothing order.

Natural order smoothing

Definition at line 208 of file messages.h.

**9.58.2.57 #define OFF 0**

turn off certain parameter

Definition at line 71 of file messages.h.

**9.58.2.58 #define ON 1**

Definition of switch.

turn on certain parameter

Definition at line 70 of file messages.h.

**9.58.2.59 #define PREC\_AMG 2**

with AMG precondition

Definition at line 136 of file messages.h.

**9.58.2.60 #define PREC\_DIAG 1**

with diagonal precondition

Definition at line 135 of file messages.h.

**9.58.2.61 #define PREC\_FMG 3**

with full AMG precondition

Definition at line 137 of file messages.h.



**9.58.2.62 #define PREC\_ILU 4**

with ILU precondition

Definition at line 138 of file messages.h.

**9.58.2.63 #define PREC\_NULL 0**

Definition of preconditioner type for iterative methods.

with no precondition

Definition at line 134 of file messages.h.

**9.58.2.64 #define PREC\_SCHWARZ 5**

with Schwarz preconditioner

Definition at line 139 of file messages.h.

**9.58.2.65 #define PRINT\_ALL 10**

everything: all printouts allowed

Definition at line 81 of file messages.h.

**9.58.2.66 #define PRINT\_MIN 1**

quiet: minimal print, like convergence

Definition at line 77 of file messages.h.

**9.58.2.67 #define PRINT\_MORE 4**

more: print more useful information

Definition at line 79 of file messages.h.

**9.58.2.68 #define PRINT\_MOST 8**

most: maximal printouts, no disk files

Definition at line 80 of file messages.h.

**9.58.2.69 #define PRINT\_NONE 0**

Print level for all subroutines – not including DEBUG output.

silent: no printout at all

Definition at line 76 of file messages.h.

**9.58.2.70 #define PRINT\_SOME 2**

some: print cpu time, iteration number

Definition at line 78 of file messages.h.

**9.58.2.71 #define RUN\_FAIL -99**

general failure

Definition at line 58 of file messages.h.

**9.58.2.72 #define SA\_AMG 2**

smoothed aggregation AMG

Definition at line 152 of file messages.h.

**9.58.2.73 #define SMOOTHER\_BLKOil 11**

Definition of specialized smoother types.

Used in monolithic AMG for black-oil

Definition at line 180 of file messages.h.

**9.58.2.74 #define SMOOTHER\_CG 4**

CG as a smoother

Definition at line 169 of file messages.h.

**9.58.2.75 #define SMOOTHER\_GS 2**

Gauss-Seidel smoother

Definition at line 167 of file messages.h.

**9.58.2.76 #define SMOOTHER\_GSOR 7**

GS + SOR smoother

Definition at line 172 of file messages.h.

**9.58.2.77 #define SMOOTHER\_JACOBI 1**

Definition of standard smoother types.

Jacobi smoother

Definition at line 166 of file messages.h.

**9.58.2.78 #define SMOOTHER\_L1DIAG 10**

L1 norm diagonal scaling smoother

Definition at line 175 of file messages.h.

**9.58.2.79 #define SMOOTHER\_POLY 9**

Polynomial smoother

Definition at line 174 of file messages.h.

**9.58.2.80 #define SMOOTHER\_SGS 3**

symm Gauss-Seidel smoother

Definition at line 168 of file messages.h.

**9.58.2.81 #define SMOOTHER\_SGSOR 8**

SGS + SSOR smoother

Definition at line 173 of file messages.h.

**9.58.2.82 #define SMOOTHER\_SOR 5**

SOR smoother

Definition at line 170 of file messages.h.

**9.58.2.83 #define SMOOTHER\_SPETEN 19**

Used in monolithic AMG for black-oil

Definition at line 181 of file messages.h.

**9.58.2.84 #define SMOOTHER\_SSOR 6**

SSOR smoother

Definition at line 171 of file messages.h.

**9.58.2.85 #define SOLVER\_AMG 21**

AMG as an iterative solver

Definition at line 114 of file messages.h.

**9.58.2.86 #define SOLVER\_BiCGstab 2**

Biconjugate Gradient Stabilized

Definition at line 99 of file messages.h.

**9.58.2.87 #define SOLVER\_CG 1**

Definition of solver types for iterative methods.

Conjugate Gradient

Definition at line 98 of file messages.h.

**9.58.2.88 #define SOLVER\_FMG 22**

Full AMG as an solver

Definition at line 115 of file messages.h.

**9.58.2.89 #define SOLVER\_GCG 7**

Generalized Conjugate Gradient

Definition at line 104 of file messages.h.

**9.58.2.90 #define SOLVER\_GMRES 4**

Generalized Minimal Residual

Definition at line 101 of file messages.h.

**9.58.2.91 #define SOLVER\_MinRes 3**

Minimal Residual

Definition at line 100 of file messages.h.

**9.58.2.92 #define SOLVER\_MUMPS 33**

MUMPS Direct Solver

Definition at line 122 of file messages.h.

**9.58.2.93 #define SOLVER\_SBiCGstab 12**

BiCGstab with safe net

Definition at line 107 of file messages.h.

**9.58.2.94 #define SOLVER\_SCG 11**

Conjugate Gradient with safe net

Definition at line 106 of file messages.h.

**9.58.2.95 #define SOLVER\_SGCG 17**

GCG with safe net

Definition at line 112 of file messages.h.

**9.58.2.96 #define SOLVER\_SGMRES 14**

GMRes with safe net

Definition at line 109 of file messages.h.

**9.58.2.97 #define SOLVER\_SMinRes 13**

MinRes with safe net

Definition at line 108 of file messages.h.

**9.58.2.98 #define SOLVER\_SUPERLU 31**

Definition of solver types for direct methods (requires external libs)

SuperLU Direct Solver

Definition at line 120 of file messages.h.

**9.58.2.99 #define SOLVER\_SVFGMRES 16**

Variable-restart FGMRES with safe net

Definition at line 111 of file messages.h.

**9.58.2.100 #define SOLVER\_SVGMRES 15**

Variable-restart GMRES with safe net

Definition at line 110 of file messages.h.

**9.58.2.101 #define SOLVER\_UMFPACK 32**

UMFPack Direct Solver

Definition at line 121 of file messages.h.

**9.58.2.102 #define SOLVER\_VFGMRES 6**

Variable Restarting Flexible GMRES

Definition at line 103 of file messages.h.

9.58.2.103 `#define SOLVER_VGMRES 5`

Variable Restarting GMRES

Definition at line 102 of file messages.h.

9.58.2.104 `#define STOP_MOD_REL_RES 3`

modified relative residual  $\|r\|/\|x\|$

Definition at line 129 of file messages.h.

9.58.2.105 `#define STOP_REL_PRECRES 2`

relative B-residual  $\|r\|_B/\|b\|_B$

Definition at line 128 of file messages.h.

9.58.2.106 `#define STOP_REL_RES 1`

Definition of iterative solver stopping criteria types.

relative residual  $\|r\|/\|b\|$

Definition at line 127 of file messages.h.

9.58.2.107 `#define SUCCESS 0`

return from function successfully

Definition at line 59 of file messages.h.

9.58.2.108 `#define TRUE 1`

Definition of logic type.

logic TRUE

Definition at line 64 of file messages.h.

9.58.2.109 `#define UA_AMG 3`

unsmoothed aggregation AMG

Definition at line 153 of file messages.h.

9.58.2.110 `#define UNPT -1`

Type of vertices (dofs) for C/F splitting.

undetermined points

Definition at line 200 of file messages.h.

**9.58.2.111 #define USERDEFINED 0**

Type of ordering for smoothers.

USERDEFINED order

Definition at line 214 of file messages.h.

**9.58.2.112 #define V\_CYCLE 1**

Definition of cycle types.

V-cycle

Definition at line 158 of file messages.h.

**9.58.2.113 #define W\_CYCLE 2**

W-cycle

Definition at line 159 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 301 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 arrays.*
- `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 arrays are stored in numbers! Arrays 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 385 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 776 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 507 of file parameters.c.

9.63.2.4 void fasp\_param\_amg\_to\_prec ( precondition\_data \* *pcdata*, 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 649 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 714 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 468 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 869 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 577 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 \* pcd\_data )

Set AMG\_param with precondition\_data.

Parameters

amgparam	Parameters for AMG
pcdata	Preconditioning data structure

Author

Chensong Zhang

Date

2011/01/10

Definition at line 683 of file parameters.c.

9.63.2.12 void fasp\_param\_prec\_to\_amg\_bsr ( AMG\_param \* amgparam, precondition\_data\_bsr \* pcd\_data )

Set AMG\_param with precondition\_data.

Parameters

amgparam	Parameters for AMG
pcdata	Preconditioning data structure

Author

Xiaozhe Hu

Date

02/06/2012

Definition at line 747 of file parameters.c.

9.63.2.13 void fasp\_param\_schwarz\_init ( Schwarz\_param \* schparam )

Initialize Schwarz parameters.

Parameters

schparam	Parameters for Schwarz method
----------	-------------------------------

Author

Xiaozhe Hu

Date

05/22/2012

Definition at line 488 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 899 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 599 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 447 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 928 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 619 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  $k = 0:\text{MaxIt}$

- 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 [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*, **precond** \* *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 781 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 435 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 1127 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, precondition *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  $r_0 = b - A*x_0$  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 [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, precondition *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, precondition *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, precondition *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  $Ax=b$  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:  $r_{k+1} = r_k - \alpha(Ap_k)$ ;
- 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 [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 367 of file [pcg.c](#).

9.66.2.2 **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  $Au=b$ .

#### 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.

9.66.2.3 **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  $Au=b$ .

#### 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 648 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  $A*x=b$  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 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, [precond](#) \*pc, const [REAL](#) tol, const [INT](#) MaxIt, const [SHORT](#) stop\_type, const [SHORT](#) print\_level)

*Preconditioned generalized conjugate gradient (GCG) method for solving  $Au=b$ .*

### 9.68.1 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 generalizd 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, precondition \*pc, const REAL tol, const INT MaxIt, SHORT restart, const SHORT stop\_type, const SHORT print\_level)  
*Preconditioned GMRES method for solving  $Au=b$ .*
- **INT fasp\_solver\_bdcsr\_pgmres** (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  $Au=b$ .*
- **INT fasp\_solver\_dbsr\_pgmres** (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  $Au=b$ .*
- **INT fasp\_solver\_dstr\_pgmres** (dSTRmat \*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  $Au=b$ .*

### 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, precondition \* pc, const REAL tol, const INT MaxIt, SHORT restart, const SHORT stop\_type, const SHORT print\_level )

Preconditioned GMRES method for solving  $Au=b$ .

#### 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 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 345 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, 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 641 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, 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

Definition at line 49 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, 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 937 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, [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 GMRES(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, [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, 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\_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  $A*x=b$  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:  $\text{norm}(r)/\text{norm}(b) < \text{tol}$

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\_bdcsl\_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  $Ax=b$  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 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\_bsr.c File Reference

Preconditioners for [dBSRmat](#) matrices.

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

### 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.*

### 9.74.1 Detailed Description

Preconditioners for [dBSRmat](#) matrices.

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

### 9.74.2 Function Documentation

#### 9.74.2.1 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 561 of file precondition\_bsr.c.

9.74.2.2 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 35 of file precondition\_bsr.c.

9.74.2.3 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 109 of file precondition\_bsr.c.

**9.74.2.4 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 159 of file precondition\_bsr.c.

**9.74.2.5 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 209 of file precondition\_bsr.c.

**9.74.2.6 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 258 of file precondition\_bsr.c.

**9.74.2.7 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 304 of file `precond_bsr.c`.

**9.74.2.8** `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 604 of file `precond_bsr.c`.

## 9.75 `precond_csr.c` File Reference

Preconditioners for [dCSRmat](#) matrices.

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

## 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_free` (`SHORT` `precond_type`, `precond` \*`pc`)  
*free preconditioner*

### 9.75.1 Detailed Description

Preconditioners for `dCSRmat` matrices.

Definition in file `precond_csr.c`.

### 9.75.2 Function Documentation

#### 9.75.2.1 `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 417 of file `precond_csr.c`.

**9.75.2.2 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 486 of file precondition\_csr.c.

**9.75.2.3 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 165 of file precondition\_csr.c.

**9.75.2.4 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 453 of file precondition\_csr.c.

9.75.2.5 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 555 of file precondition\_csr.c.

9.75.2.6 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 191 of file precondition\_csr.c.

9.75.2.7 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 313 of file `precond_csr.c`.

9.75.2.8 `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, Shiquan Zhang

## Date

04/06/2010

Definition at line 260 of file `precond_csr.c`.

9.75.2.9 `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 519 of file `precond_csr.c`.



9.75.2.10 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 363 of file `precond_csr.c`.

9.75.2.11 `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 30 of file `precond_csr.c`.**9.76 `precond_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)*

### 9.76.1 Detailed Description

Preconditioners for [dSTRmat](#) matrices.

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

### 9.76.2 Function Documentation

#### 9.76.2.1 void fasp\_precond\_dstr\_blockgs ( [REAL](#) \* r, [REAL](#) \* z, void \* data )

CPR-type preconditioner (STR format)

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

10/17/2010

Definition at line 1707 of file [precond\\_str.c](#).

#### 9.76.2.2 void fasp\_precond\_dstr\_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

Shiquan Zhang

## Date

04/06/2010

Definition at line 27 of file precondition\_str.c.

9.76.2.3 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.

9.76.2.4 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.

9.76.2.5 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.

9.76.2.6 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.

9.76.2.7 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.

9.76.2.8 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`.

## 9.77 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, [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, [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.*

### 9.77.1 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 GMRES(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](#).



## 9.77.2 Function Documentation

9.77.2.1 **INT** fasp\_solver\_dbsr\_pvfgmres ( **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 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 373 of file pvfgmres.c.

**9.77.2.2** `INT fasp_solver_dcsr_pvfgmres ( dCSRmat * A, dvector * b, dvector * x, precondition * pc, const REAL tol, const INT MaxIt, 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.

## 9.78 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, [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 (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 GMRES(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](#).

### 9.78.2 Function Documentation

**9.78.2.1** [INT fasp\\_solver\\_pvfgmres](#) ( [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 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 pvgmres\_mf.c.

## 9.79 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, [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\\_pvgmres](#) ([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)  
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, [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_pvgmres (dSTRmat *A, dvector *b, dvector *x, precondition *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.

### 9.79.1 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](#).

### 9.79.2 Function Documentation

- 9.79.2.1 `INT fasp_solver_bdcsr_pvgmres ( 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 )`

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 386 of file pvgmres.c.

9.79.2.2 **INT** fasp\_solver\_dbsr\_pvgmres ( **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="#">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 723 of file pvgmres.c.

**9.79.2.3** `INT fasp_solver_dcsr_pvgmres ( dCSRmat * A, dvector * b, dvector * x, precondition * 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 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.

**9.79.2.4** `INT fasp_solver_dstr_pvgmres ( dSTRmat * A, dvector * b, dvector * x, precondition * 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 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 1060 of file pvgmres.c.

## 9.80 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.

### 9.80.1 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 GMRES(m) Journal of Computational and Applied Mathematics, 230 (2009) pp. 751-761. UCRL-JRNL-235266.

Definition in file [pvgmres\\_mf.c](#).

### 9.80.2 Function Documentation

**9.80.2.1 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.

## 9.81 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.*

### 9.81.1 Detailed Description

Quadrature rules.

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

### 9.81.2 Function Documentation

9.81.2.1 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.

9.81.2.2 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.

## 9.82 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  $R*A*P$ .

### 9.82.1 Detailed Description

R\*A\*P driver.

C-version by Ludmil Zikatanov 2010-04-08

tested 2010-04-08

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

### 9.82.2 Function Documentation

9.82.2.1 [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.

## 9.83 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)

### 9.83.1 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](#).

## 9.84 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.*

#### 9.84.1 Detailed Description

Setup phase for the Schwarz methods.

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

#### 9.84.2 Function Documentation

9.84.2.1 [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 showarz data
<i>mmsize</i>	Max block size
<i>maxlev</i>	Max number of levels
<i>schwarz_type</i>	Type of the Schwarz method

##### Returns

SUCCESS if succeed

**Author**

Ludmil, Xiaozhe Hu

**Date**

03/22/2011

Modified by Chunsheng Feng, Zheng Li on 08/28/2012 find the blocks

LU decomposition of blocks

return

Definition at line 35 of file schwarz\_setup.c.

## 9.85 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 memory 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.*

### 9.85.1 Detailed Description

Simple operations for *small* full matrices in row-major format.

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

### 9.85.2 Function Documentation

#### 9.85.2.1 `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 n*n matrix
<i>n</i>	Dimension of the matrix

##### Author

Xiaozhe Hu, Shiquan Zhang

##### Date

04/21/2010

Definition at line 392 of file smat.c.

#### 9.85.2.2 `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.

#### 9.85.2.3 `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.

#### 9.85.2.4 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

Definition at line 102 of file smat.c.

#### 9.85.2.5 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 160 of file smat.c.

#### 9.85.2.6 void fasp\_blas\_smat\_inv\_nc7 ( REAL \* $a$ )

Compute the inverse matrix of a 7\*7 matrix a.



## Parameters

<i>a</i>	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 376 of file smat.c.

**9.85.2.7 void fasp\_iden\_free ( idenmat \* *A* )**

Free idenmat sparse matrix data memeory space.

## Parameters

<i>A</i>	Pointer to the idenmat matrix
----------	-------------------------------

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 481 of file smat.c.

**9.85.2.8 void fasp\_smat\_identity ( REAL \* *a*, INT *n*, INT *n2* )**

Set a  $n \times n$  full matrix to be a identity.

## Parameters

<i>a</i>	Pointer to the REAL vector which stands for a $n \times n$ full matrix
<i>n</i>	Size of full matrix
<i>n2</i>	Length of the REAL vector which stores the $n \times n$ full matrix

## Author

Xiaozhe Hu

## Date

2010/12/25

Definition at line 581 of file smat.c.

9.85.2.9 void fasp\_smat\_identity\_nc2 ( REAL \* a )

Set a 2\*2 full matrix to be a identity.

## Parameters

<i>a</i>	Pointer to the REAL vector which stands for a 2*2 full matrix
----------	---

## Author

Xiaozhe Hu

## Date

2011/11/18

Definition at line 501 of file smat.c.

**9.85.2.10 void fasp\_smat\_identity\_nc3 ( REAL \* *a* )**

Set a 3\*3 full matrix to be a identity.

## Parameters

<i>a</i>	Pointer to the REAL vector which stands for a 3*3 full matrix
----------	---

## Author

Xiaozhe Hu

## Date

2010/12/25

Definition at line 518 of file smat.c.

**9.85.2.11 void fasp\_smat\_identity\_nc5 ( REAL \* *a* )**

Set a 5\*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 535 of file smat.c.

**9.85.2.12 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 556 of file smat.c.

## 9.86 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.*

### 9.86.1 Detailed Description

Smoothers for `dBSRmat` matrices.

Definition in file `smoother_bsr.c`.

### 9.86.2 Function Documentation

#### 9.86.2.1 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 <code>dvector</code> : the unknowns (IN: initial, OUT: approximation)
<i>order</i>	Flag to indicate the order for smoothing If <code>mark = NULL</code> ASCEND 12: in ascending order DESCEND 21: in descending order If <code>mark != NULL</code> : 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`.

#### 9.86.2.2 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 A

## Author

Zhiyang Zhou

## Date

2010/10/25

Definition at line 535 of file smoother\_bsr.c.

9.86.2.3 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.

9.86.2.4 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.

**9.86.2.5 void fasp\_smoother\_dbsr\_gs\_descend ( dBSRmat \* A, dvector \* b, dvector \* u, REAL \* diaginvs )**

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.

**9.86.2.6 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.

9.86.2.7 void fasp\_smoother\_dbsr\_gs\_order1 ( dBSRmat \* A, dvector \* b, dvector \* u, REAL \* diagin, 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.

9.86.2.8 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.

**9.86.2.9** 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.

**9.86.2.10** 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.

9.86.2.11 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.

9.86.2.12 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.

9.86.2.13 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.

9.86.2.14 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.

9.86.2.15 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.

9.86.2.16 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.

9.86.2.17 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>diagin</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.

## 9.87 smoother\_csr.c File Reference

Smoothers 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  $Au=b$ .*

### 9.87.1 Detailed Description

Smoothers for `dCSRmat` matrices.

Definition in file `smoother_csr.c`.

### 9.87.2 Function Documentation

9.87.2.1 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 <code>dBSRmat</code> : 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`.

9.87.2.2 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.

9.87.2.3 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 1425 of file smoother\_csr.c.

9.87.2.4 void fasp\_smoother\_dcsr\_ilu ( dCSRmat \* *A*, dvector \* *b*, dvector \* *x*, void \* *data* )

ILU method as a smoother.



## Parameters

<i>A</i>	Pointer to <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

Shiquan Zhang, Xiaozhe Hu

## Date

2010/11/12

form residual  $zr = b - A x$

Definition at line 1067 of file smoother\_csr.c.

9.87.2.5 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.

9.87.2.6 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

$u$	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
$w$	Over-relaxation weight

## Author

Xiaozhe Hu

## Date

2010/11/12

Modified by Chunsheng Feng, Zheng Li on 2012/09/01

Definition at line 1144 of file smoother\_csr.c.

9.87.2.7 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 1285 of file smoother\_csr.c.

9.87.2.8 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.

9.87.2.9 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

$u$	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
$w$	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.

9.87.2.10 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.

## 9.88 smoother\_csr\_cr.c File Reference

Smoothers 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 restriced to a block.*

#### 9.88.1 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](#).

#### 9.88.2 Function Documentation

9.88.2.1 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 restriced 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.

## 9.89 smoother\_csr\_poly.c File Reference

Smoother 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_funcs.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*

### 9.89.1 Detailed Description

Smoother for [dCSRmat](#) matrices using poly. approx. to  $A^{-1}$ .

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

## 9.89.2 Function Documentation

9.89.2.1 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.

9.89.2.2 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 141 of file smoother\_csr\_poly.c.

## 9.90 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.*

### 9.90.1 Detailed Description

Smoothers for `dSTRmat` matrices.

Definition in file `smoother_str.c`.

### 9.90.2 Function Documentation

#### 9.90.2.1 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 <a href="#">dCSRmat</a> : the coefficient matrix
<i>neigh</i>	Pointer to ivector: neighborhoods
<i>diaginv</i>	Pointer to dvector: the inverse of the diagonals
<i>pivot</i>	Pointer to ivector: the pivot of diagonal blocks

## Author

Xiaozhe Hu

## Date

10/01/2011

Definition at line 1517 of file smoother\_str.c.

9.90.2.2 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.

9.90.2.3 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.

9.90.2.4 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.

9.90.2.5 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.

9.90.2.6 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.

9.90.2.7 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.

**9.90.2.8 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.

**9.90.2.9 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.

9.90.2.10 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.

9.90.2.11 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.

9.90.2.12 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.

9.90.2.13 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.

9.90.2.14 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.

9.90.2.15 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.

9.90.2.16 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.

## 9.91 sparse\_block.c File Reference

Sparse matrix block operations.

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

## Functions

- [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*

### 9.91.1 Detailed Description

Sparse matrix block operations.

Definition in file [sparse\\_block.c](#).

### 9.91.2 Function Documentation

#### 9.91.2.1 [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

<i>A</i>	Pointer to <a href="#">dBSRmat</a> BSR matrix
<i>B</i>	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

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 132 of file sparse\_block.c.

### 9.91.2.2 [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 226 of file sparse\_block.c.

### 9.91.2.3 `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

$A$	Pointer to <a href="#">dCSRmat</a> matrix
$B$	Pointer to <a href="#">dCSRmat</a> matrix
$Is$	Pointer to selected rows
$Js$	Pointer to selected columns
$m$	Number of selected rows
$n$	Number of selected columns

## Returns

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 39 of file `sparse_block.c`.

## 9.92 `sparse_bsr.c` File Reference

Sparse matrix operations for [dBSRmat](#) matrices.

```
#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 memeory 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\\_getdiaginv](#) ([dBSRmat](#) \*A)

- Get  $D^{-1}$  of matrix  $A$ .
- `dBSRmat fasp_dbsr_diaginv (dBSRmat *A)`  
Compute  $B := D^{-1} * A$ , where 'D' is the block diagonal part of  $A$ .
- `dBSRmat fasp_dbsr_diaginv2 (dBSRmat *A, REAL *diaginv)`  
Compute  $B := D^{-1} * A$ , where 'D' is the block diagonal part of  $A$ .
- `dBSRmat fasp_dbsr_diaginv3 (dBSRmat *A, REAL *diaginv)`  
Compute  $B := D^{-1} * A$ , where 'D' is the block diagonal part of  $A$ .
- `dBSRmat fasp_dbsr_diaginv4 (dBSRmat *A, REAL *diaginv)`  
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.

### 9.92.1 Detailed Description

Sparse matrix operations for `dBSRmat` matrices.

Definition in file `sparse_bsr.c`.

### 9.92.2 Function Documentation

9.92.2.1 `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 each block
<i>storage_manner</i>	Storage manner for each sub-block
<i>A</i>	Pointer to new <code>dBSRmat</code> matrix

Author

Xiaozhe Hu

Date

10/26/2010

Definition at line 84 of file `sparse_bsr.c`.

9.92.2.2 `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 178 of file sparse\_bsr.c.

9.92.2.3 [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 each 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 33 of file sparse\_bsr.c.

9.92.2.4 [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 502 of file sparse\_bsr.c.

**9.92.2.5 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 664 of file sparse\_bsr.c.

**9.92.2.6 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 766 of file sparse\_bsr.c.

**9.92.2.7 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 1124 of file sparse\_bsr.c.

**9.92.2.8 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 289 of file sparse\_bsr.c.

**9.92.2.9 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 130 of file sparse\_bsr.c.

**9.92.2.10 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 1417 of file sparse\_bsr.c.

**9.92.2.11 dvector fasp\_dbsr\_getdiaginv ( dBSRmat \* A )**

Get  $D^{-1}$  of matrix A.

**Parameters**

<b>A</b>	Pointer to the <a href="#">dBSRmat</a> matrix
----------	---

**Author**

Xiaozhe Hu

**Date**

02/19/2013

**Note**

Works for general nb (Xiaozhe)

Definition at line 398 of file sparse\_bsr.c.

**9.92.2.12 void fasp\_dbsr\_null ( dBSRmat \* A )**

Initialize sparse matrix on structured grid.

**Parameters**

<b>A</b>	Pointer to the <a href="#">dBSRmat</a> matrix
----------	---

**Author**

Xiaozhe Hu

**Date**

10/26/2010

Definition at line 155 of file sparse\_bsr.c.

**9.92.2.13 INT fasp\_dbsr\_trans ( dBSRmat \* A, dBSRmat \* AT )**

Find  $A^T$  from given [dBSRmat](#) matrix A.



## Parameters

<i>A</i>	Pointer to the <a href="#">dBSRmat</a> matrix
<i>AT</i>	Pointer to the transpose of <a href="#">dBSRmat</a> matrix <i>A</i>

## Author

Chunsheng FENG

## Date

2011/06/08

Modified by Xiaozhe Hu (08/06/2011)

Definition at line 205 of file sparse\_bsr.c.

## 9.93 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.*

### 9.93.1 Detailed Description

Sparse matrix operations for [dCOOmat](#) matrices.

Definition in file [sparse\\_coo.c](#).

### 9.93.2 Function Documentation

#### 9.93.2.1 void fasp\_dcoo\_alloc ( const [INT](#) *m*, const [INT](#) *n*, const [INT](#) *nnz*, [dCOOmat](#) \* *A* )

Allocate COO sparse matrix memory space.

## Parameters

$m$	Number of rows
$n$	Number of columns
$nnz$	Number of nonzeros
$A$	Pointer to the <a href="#">dCSRmat</a> matrix

## Author

Xiaozhe Hu

## Date

03/25/2013

Definition at line 62 of file sparse\_coo.c.

**9.93.2.2 dCOOmat fasp\_dcoo\_create ( INT  $m$ , INT  $n$ , INT  $nnz$  )**

Create IJ sparse matrix data memory space.

## Parameters

$m$	Number of rows
$n$	Number of columns
$nnz$	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.

**9.93.2.3 void fasp\_dcoo\_free ( dCOOmat \*  $A$  )**

Free IJ sparse matrix data memeory space.

## Parameters

$A$	Pointer to the <a href="#">dCOOmat</a> matrix
-----	---

## Author

Chensong Zhang

## Date

2010/04/03

Definition at line 95 of file sparse\_coo.c.

## 9.93.2.4 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.

## 9.94 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  $abs(a_{ij}) \leq dtol$ .
- SHORT `fasp_dcsr_compress_inplace` (dCSRmat \**A*, REAL *dtol*)  
Compress a CSR matrix *A* IN PLACE by dropping small entries  $abs(a_{ij}) \leq dtol$ .
- void `fasp_dcsr_shift` (dCSRmat \**A*, INT *offset*)  
Reindex a REAL matrix in CSR format to make the index starting from 0 or 1.
- void `fasp_dcsr_symdiagscale` (dCSRmat \**A*, dvector \**diag*)  
Symmetric diagonal scaling  $D^{-1/2} A D^{-1/2}$ .
- dCSRmat `fasp_dcsr_sympat` (dCSRmat \**A*)  
Symmetrize the parttarn of a dCSRmat matrix.
- void `fasp_dcsr_multicoloring` (dCSRmat \**A*, INT \**flags*, INT \**groups*)  
Use the greedy multicoloring to get color groups of the adjacency graph of *A*.

### 9.94.1 Detailed Description

Sparse matrix operations for dCSRmat matrices.

Definition in file `sparse_csr.c`.

### 9.94.2 Function Documentation

#### 9.94.2.1 void fasp\_dcsr\_alloc ( const INT *m*, const INT *n*, const INT *nnz*, dCSRmat \* *A* )

Allocate CSR 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**

Chensong Zhang

**Date**

2010/04/06

Definition at line 125 of file sparse\_csr.c.

**9.94.2.2 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  $\text{abs}(a_{ij}) \leq \text{dtol}$ .**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.

**9.94.2.3 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.

9.94.2.4 void fasp\_dcsr\_cp ( dCSRmat \* *A*, dCSRmat \* *B* )

copy a dCSRmat to a new one B=A

## Parameters

<i>A</i>	Pointer to the dCSRmat matrix
<i>B</i>	Pointer to the dCSRmat 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.

9.94.2.5 dCSRmat fasp\_dcsr\_create ( const INT *m*, const INT *n*, const INT *nnz* )

Create CSR 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 dCSRmat matrix

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 34 of file sparse\_csr.c.

#### 9.94.2.6 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

<b>A</b>	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.

**9.94.2.7 void fasp\_dcsr\_free ( dCSRmat \* A )**

Free CSR sparse matrix data memeory space.

## Parameters

<b>A</b>	Pointer to the <a href="#">dCSRmat</a> matrix
----------	---

## Author

Chensong Zhang

## Date

2010/04/06

Definition at line 166 of file sparse\_csr.c.

**9.94.2.8 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 A ( $0 \leq n \leq A.col-1$ )
<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.

9.94.2.9 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 <i>n</i> =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.

9.94.2.10 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.

**9.94.2.11 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.

**9.94.2.12 dCSRmat fasp\_dcsr\_perm ( dCSRmat \* A, INT \* P )**

Apply permutation of A, i.e. Aperm=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.

**9.94.2.13 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(A) which is too close to zero to "value"

## Returns

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.

#### 9.94.2.14 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.

#### 9.94.2.15 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.

9.94.2.16 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.

9.94.2.17 [dCSRmat](#) fasp\_dcsr\_sympat ( [dCSRmat](#) \* *A* )Symmetrize the parttern of a [dCSRmat](#) matrix.

## Parameters

<i>*A</i>	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.

9.94.2.18 void fasp\_dcsr\_trans ( [dCSRmat](#) \* *A*, [dCSRmat](#) \* *AT* )Find tranpose of [dCSRmat](#) matrix *A*.

## Parameters

<i>A</i>	Pointer to the <a href="#">dCSRmat</a> matrix
<i>AT</i>	Pointer to the transpose of <a href="#">dCSRmat</a> matrix <i>A</i> (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.

9.94.2.19 void fasp\_icsr\_cp ( iCSRmat \* *A*, iCSRmat \* *B* )

Copy a iCSRmat to a new one B=A.

Parameters

<i>A</i>	Pointer to the iCSRmat matrix
<i>B</i>	Pointer to the iCSRmat matrix

Author

Chensong Zhang

Date

05/16/2013

Definition at line 697 of file sparse\_csr.c.

9.94.2.20 iCSRmat fasp\_icsr\_create ( const INT *m*, const INT *n*, const INT *nnz* )

Create CSR 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 iCSRmat matrix

Author

Chensong Zhang

Date

2010/04/06

Definition at line 80 of file sparse\_csr.c.

9.94.2.21 void fasp\_icsr\_free ( iCSRmat \* *A* )

Free CSR sparse matrix data memeory space.

Parameters

---

<i>A</i>	Pointer to the <a href="#">iCSRmat</a> matrix
----------	---

**Author**

Chensong Zhang

**Date**

2010/04/06

Definition at line 185 of file sparse\_csr.c.

**9.94.2.22 void fasp\_icsr\_null ( iCSRmat \* *A* )**

Initialize CSR sparse matrix.

**Parameters**

<i>A</i>	Pointer to the <a href="#">iCSRmat</a> matrix
----------	---

**Author**

Chensong Zhang

**Date**

2010/04/03

Definition at line 221 of file sparse\_csr.c.

**9.94.2.23 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 <i>A</i>
<i>AT</i>	Pointer to the <a href="#">iCSRmat</a> matrix <i>A</i> '

**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.

## 9.95 sparse\_csrl.c File Reference

Sparse matrix operations for [dCSRLmat](#) matrices.

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

### Functions

- [dCSRLmat](#) \* [fasp\\_dcsrl\\_create](#) ([INT](#) num\_rows, [INT](#) num\_cols, [INT](#) num\_nonzeros)  
*Create a [dCSRLmat](#) object.*
- void [fasp\\_dcsrl\\_free](#) ([dCSRLmat](#) \*A)  
*Destroy a [dCSRLmat](#) object.*

### 9.95.1 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\\_csrl.c](#).

### 9.95.2 Function Documentation

#### 9.95.2.1 [dCSRLmat](#) \* [fasp\\_dcsrl\\_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](#).

#### 9.95.2.2 void [fasp\\_dcsrl\\_free](#) ( [dCSRLmat](#) \* A )

Destroy a [dCSRLmat](#) object.



## Parameters

<b>A</b>	Pointer to the <a href="#">dCSRmat</a> type matrix
----------	--

## Author

Zhiyang Zhou

## Date

01/07/2011

Definition at line 58 of file sparse\_csrl.c.

## 9.96 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.*

#### 9.96.1 Detailed Description

Sparse matrix operations for [dSTRmat](#) matrices.Definition in file [sparse\\_str.c](#).

#### 9.96.2 Function Documentation

9.96.2.1 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.

9.96.2.2 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.

9.96.2.3 [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.

**9.96.2.4 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.

**9.96.2.5 void fasp\_dstr\_null ( dSTRmat \* A )**

Initialize sparse matrix on structured grid.

**Parameters**

<i>A</i>	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.

## 9.97 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  $R*A*P$ , 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  $v^t = w^t A$ , 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.*
- 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*

### 9.97.1 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](#).

### 9.97.2 Function Documentation

**9.97.2.1** 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.

**9.97.2.2** 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.

9.97.2.3 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>ja</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.

9.97.2.4 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.

9.97.2.5 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.

9.97.2.6 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.

9.97.2.7 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.

9.97.2.8 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.

9.97.2.9 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.

**9.97.2.10** 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 $w[jw]$ is nonzero
<i>w</i>	:I: the values of $w$
<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 $w$ (the length of $w$ )
<i>map</i>	:I: number of columns in $A$
<i>jv</i>	:O: indices such that $v[jv]$ is nonzero
<i>v</i>	:O: the result $v^t = w^t A$
<i>nvp</i>	:I: number of nonzeros in $v$

Definition at line 651 of file sparse\_util.c.

**9.97.2.11** 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>	:I: indices such that $w[jw]$ is nonzero
<i>ia</i>	:I: array of row pointers for A
<i>ja</i>	:I: array of column indices for A
<i>nwp</i>	:I: number of nonzeros in w (the length of w)
<i>map</i>	:I: number of columns in A
<i>jv</i>	:O: indices such that $v[jv]$ is nonzero
<i>nvp</i>	:I: 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.

**9.97.2.12** 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 :I: is input :O: is output :IO: is both

#### Parameters

<i>jy</i>	:I: indices such that $y[jy]$ is nonzero
<i>y</i>	:I: is a sparse vector.
<i>nyp</i>	:I: number of nonzeros in y
<i>jx</i>	:I: indices such that $x[jx]$ is nonzero
<i>x</i>	:I: is a sparse vector.
<i>nxp</i>	:I: 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.

**9.97.2.13** void fasp\_sparse\_ytxbig\_ ( INT \* *jy*, REAL \* *y*, INT \* *nyp*, REAL \* *x*, REAL \* *s* )

Calculates  $s = y^t x$ . *y*-sparse, *x* - no.

#### Note

:I: is input :O: is output :IO: is both

#### Parameters

<i>jy</i>	:I: indices such that $y[jy]$ is nonzero
<i>y</i>	:I: is a sparse vector.
<i>nyp</i>	:I: number of nonzeros in v
<i>x</i>	:I: also a vector assumed to have entry for any $j=jy[i]-1$ ; for $i=1:nyp$ . This means that <i>x</i> here does not have to be sparse.
<i>s</i>	:O: $s = y^t x$ .

Definition at line 702 of file sparse\_util.c.

## 9.98 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.*

### 9.98.1 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:  $r_{k+1} = r_k - \alpha*(A*p_k)$ ;
- 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 [spbcgs.c](#) for a safer version

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

## 9.98.2 Function Documentation

**9.98.2.1** `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.

**9.98.2.2** `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.

**9.98.2.3** `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.

**9.98.2.4** `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.

## 9.99 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.*

### 9.99.1 Detailed Description

Krylov subspace methods – Preconditioned conjugate gradient with safe net. 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:  $x_{k+1} = x_k + \alpha*p_k$ ;
- check whether  $x$  is NAN;
- perform stagnation check;
- update residual:  $r_{k+1} = r_k - \alpha*(A*p_k)$ ;
- 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](#).

## 9.99.2 Function Documentation

9.99.2.1 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.

**9.99.2.2** `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.

**9.99.2.3** `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.

## 9.100 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.*

### 9.100.1 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](#).

### 9.100.2 Function Documentation

**9.100.2.1** `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.

**9.100.2.2** `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.

9.100.2.3 **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.

9.100.2.4 INT fasp\_solver\_dstr\_spgmres ( dSTRmat \* *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="#">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.

## 9.101 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*, 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.
- [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.
- [INT fasp\\_solver\\_dstr\\_spminres](#) (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  $Au=b$  with safe net.

### 9.101.1 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](#).

## 9.101.2 Function Documentation

9.101.2.1 **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.

9.101.2.2 **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.

9.101.2.3 **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.



## 9.102 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.*

### 9.102.1 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](#).

### 9.102.2 Function Documentation

**9.102.2.1** [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.

9.102.2.2 **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.

9.102.2.3 **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.

9.102.2.4 **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.

## 9.103 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.*

### 9.103.1 Detailed Description

Get and set number of threads and assigne work load for each thread.

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

### 9.103.2 Function Documentation

9.103.2.1 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.

## 9.104 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.*

### 9.104.1 Detailed Description

Timing subroutines.

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

### 9.104.2 Function Documentation

#### 9.104.2.1 [fasp\\_gettime](#) ( [REAL](#) \* *time* )

Get system time.

**Author**

Chunsheng Feng, Zheng LI

**Date**

11/10/2012

Definition at line 28 of file timing.c.

## 9.105 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  $D^{-1/2}b$ .*

### 9.105.1 Detailed Description

Simple operations for vectors.

#### Note

Every structures should be initialized before usage.

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

## 9.105.2 Function Documentation

### 9.105.2.1 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.

### 9.105.2.2 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.

### 9.105.2.3 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.

**9.105.2.4 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.

**9.105.2.5 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.

**9.105.2.6 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.

**9.105.2.7 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.

**9.105.2.8 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.

#### 9.105.2.9 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.

#### 9.105.2.10 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.

9.105.2.11 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.

9.105.2.12 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.

9.105.2.13 `void fasp_ivec_free ( ivec * u )`

Free vector data space of INT type.

## Parameters

$u$	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.

9.105.2.14 void fasp\_ivec\_set ( const INT  $m$ , ivector \*  $u$  )

Set ivector value to be  $m$ .

## Parameters

$m$	Integer value of ivector
$u$	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.

## 9.106 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\\_fwrapper\\_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\\_fwrapper\\_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)*

### 9.106.1 Detailed Description

Wrappers for accessing functions by advanced users.

#### Note

Input variables should not need [fasp.h](#)!!!

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

### 9.106.2 Function Documentation

9.106.2.1 void void [fasp\\_fwrapper\\_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.

9.106.2.2 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.

9.106.2.3 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.

9.106.2.4 `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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