schwz

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Contents

Chapter 1

Main Page

This is the main page for the Schwarz library pdf documentation. The repository is hosted on `github`. Documentation on aspects such as the build system, can be found at the # Installation Instructions page.

Modules

The structure of the Schwarz Library code is divided into different `modules` :

- Initialization : Handles the initialization of the problem and the solver.
- Communicate : Handles the communication.
- Solve : Handles the local solution and the convergence detection.
- Schwarz Class : The Classes related to the Schwarz solvers.
- Utils : Provides some basic utilities.

Chapter 2

Installation Instructions

Building

Use the standard cmake build procedure:

```
mkdir build; cd build
cmake -G "Unix Makefiles" [OPTIONS] .. && make
```

Replace `[OPTIONS]` with desired cmake options for your build. The library adds the following additional switches to control what is being built:

- `-DSCHWARZ_BUILD_BENCHMARKING={ON, OFF}` Builds some example benchmarks. Default is `ON`
- `-DSCHWARZ_BUILD_METIS={ON, OFF}` Builds with support for the `METIS` partitioner. User needs to provide the path to the installation of the `METIS` library in `METIS_DIR`, preferably as an environment variable. Default is `OFF`
- `-DSCHWARZ_BUILD_CHOLMOD={ON, OFF}` Builds with support for the `CHOLMOD` module from the Suitesparse library. User needs to set an environment variable `CHOLMOD_DIR` to the path containing the `CHOLMOD` installation. Default is `OFF`
- `-DSCHWARZ_BUILD_CUDA={ON, OFF}` Builds with CUDA support. Though Ginkgo provides most of the required CUDA support, we do need to link to CUDA for explicit setting of GPU affinities, some custom gather and scatter operations. Default is `OFF`.
- `-DSCHWARZ_BUILD_CLANG_TIDY={ON, OFF}` Builds with support for `clang-tidy` Default is `OFF`
- `-DSCHWARZ_BUILD_DEALII={ON, OFF}` Builds with support for the finite element library `deal.ii` Default is `OFF`
- `-DSCHWARZ_WITH_HWLOC={ON, OFF}` Builds with support for the hardware locality library used for binding hardware. `hwloc` is distributed as a part of the Open-MPI project. Default is `ON`
- `-DSCHWARZ_DEVEL_TOOLS={ON, OFF}` Builds with some developer tools support. Default is `ON`. In particular uses `git-cmake-format` to automatically format the source files with `clang-format`.

Tips

- If you are having CUDA problems and you are not using CUDA, then feel free to switch the CUDA module off with `-DSCHWARZ_BUILD_CUDA=off`.
- Installing CHOLMOD can be a bit annoying. TODO add some details on fixing Suitesparse compilation.
- When doing merge commits it is possible that make format does not work. You can run `cmake -DSCH↩ WARZ_DEVEL_TOOLS=OFF ..` to temporarily switch off the formatting. Please switch it on again when committing normally.

Chapter 3

Testing Instructions

Chapter 4

Benchmarking.

Benchmark example 1.

Poisson solver using Restricted Additive Schwarz with overlap.

The flag `-DSCHWARZ_BUILD_BENCHMARKING` (default `ON`) enables the example and benchmarking snippets. The following command line options are available for this example. This is setup using `gflags`.

The executable is run in the following fashion:

“‘sh [MPI_COMMAND] [MPI_OPTIONS]

Chapter 5

Module Documentation

5.1 Communicate

A module dedicated to the Communication interface in schwarz-lib.

Namespaces

- schwz::CommHelpers

  The CommHelper namespace .
- ProcessTopology

  The ProcessTopology namespace .

Classes

- class schwz::Communicate< ValueType, IndexType >

  The communication class that provides the methods for the communication between the subdomains.
- struct schwz::Metadata< ValueType, IndexType >

  The solver metadata struct.

5.1.1 Detailed Description

A module dedicated to the Communication interface in schwarz-lib.

5.2 Initialization

A module dedicated to the initialization and setup and usage of the solvers in schwarz-lib.

Namespaces

- schwz::PartitionTools

  The PartitionTools namespace .
- ProcessTopology

  The ProcessTopology namespace .

Classes

- class schwz::device_guard

  This class defines a device guard for the cuda functions and the cuda module.
- class schwz::Initialize< ValueType, IndexType >

  The initialization class that provides methods for initialization of the solver.
- struct schwz::Settings

  The struct that contains the solver settings and the parameters to be set by the user.
- struct schwz::Metadata< ValueType, IndexType >

  The solver metadata struct.

5.2.1 Detailed Description

A module dedicated to the initialization and setup and usage of the solvers in schwarz-lib.

5.3 Schwarz Class

A module dedicated to the Schwarz solver classes in schwarz-lib.

Classes

- class schwz::SolverRAS< ValueType, IndexType >

  An implementation of the solver interface using the RAS solver.
- class schwz::SchwarzBase< ValueType, IndexType >

  The Base solver class is meant to be the class implementing the common implementations for all the schwarz methods.

5.3.1 Detailed Description

A module dedicated to the Schwarz solver classes in schwarz-lib.

5.4 Solve

A module dedicated to the solvers including local solution and convergence detection in schwarz-lib.

Namespaces

- schwz::conv_tools

  The conv_tools namespace .
- schwz::SolverTools

  The SolverTools namespace .

Classes

- struct schwz::Metadata< ValueType, IndexType >

  The solver metadata struct.
- class schwz::Solve< ValueType, IndexType >

  The Solver class the provides the solver and the convergence checking methods.

5.4.1 Detailed Description

A module dedicated to the solvers including local solution and convergence detection in schwarz-lib.

5.5 Utils

A module dedicated to the utilities in schwarz-lib.

Classes

- struct schwz::Utils< ValueType, IndexType >

  The utilities class which provides some checks and basic utilities.

5.5.1 Detailed Description

A module dedicated to the utilities in schwarz-lib.

Chapter 6

Namespace Documentation

6.1 ProcessTopology Namespace Reference

The ProcessTopology namespace .

6.1.1 Detailed Description

The ProcessTopology namespace .

proc_topo

6.2 schwz Namespace Reference

The Schwarz wrappers namespace.

Namespaces

- CommHelpers

  The CommHelper namespace .
- conv_tools

  The conv_tools namespace .
- PartitionTools

  The PartitionTools namespace .
- SolverTools

  The SolverTools namespace .

Classes

- class Communicate

  The communication class that provides the methods for the communication between the subdomains.
- class device_guard

  This class defines a device guard for the cuda functions and the cuda module.
- class Initialize

  The initialization class that provides methods for initialization of the solver.
- struct Metadata

  The solver metadata struct.
- class SchwarzBase

  The Base solver class is meant to be the class implementing the common implementations for all the schwarz methods.
- struct Settings

  The struct that contains the solver settings and the parameters to be set by the user.
- class Solve

  The Solver class the provides the solver and the convergence checking methods.
- class SolverRAS

  An implementation of the solver interface using the RAS solver.
- struct Utils

  The utilities class which provides some checks and basic utilities.

6.2.1 Detailed Description

The Schwarz wrappers namespace.

6.3 schwz::CommHelpers Namespace Reference

The CommHelper namespace .

6.3.1 Detailed Description

The CommHelper namespace .

comm_helpers

6.4 schwz::conv_tools Namespace Reference

The conv_tools namespace .

6.4.1 Detailed Description

The conv_tools namespace .

conv_tools

6.5 schwz::PartitionTools Namespace Reference

The PartitionTools namespace .

6.5.1 Detailed Description

The PartitionTools namespace .

part_tools

6.6 schwz::SolverTools Namespace Reference

The SolverTools namespace .

6.6.1 Detailed Description

The SolverTools namespace .

solver_tools

Chapter 7

Class Documentation

7.1 BadDimension Class Reference

BadDimension is thrown if an operation is being applied to a LinOp with bad dimensions.

`#include <exception.hpp>`

Public Member Functions

- BadDimension (const std::string &file, int line, const std::string &func, const std::string &op_name, std::size_t op_num_rows, std::size_t op_num_cols, const std::string &clarification)

  Initializes a bad dimension error.

7.1.1 Detailed Description

BadDimension is thrown if an operation is being applied to a LinOp with bad dimensions.

7.1.2 Constructor & Destructor Documentation

7.1.2.1 BadDimension()

```
BadDimension::BadDimension (
            const std::string & file,
            int line,
            const std::string & func,
            const std::string & op_name,
            std::size_t op_num_rows,
            std::size_t op_num_cols,
            const std::string & clarification )  [inline]
```

Initializes a bad dimension error.

Parameters

file	The name of the offending source file
line	The source code line number where the error occurred
func	The function name where the error occurred
op_name	The name of the operator
op_num_rows	The row dimension of the operator
op_num_cols	The column dimension of the operator
clarification	An additional message further describing the error

```
115         : Error(file, line,
116                 func + ": Object " + op_name + " has dimensions [" +
117                     std::to_string(op_num_rows) + " x " +
118                     std::to_string(op_num_cols) + "]: " + clarification)
119     {}
```

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

- exception.hpp (4633d6a)

7.2 schwz::Settings::comm_settings Struct Reference

The settings for the various available communication paradigms.

`#include <settings.hpp>`

Public Attributes

- bool enable_onesided = false

  Enable one-sided communication.
- bool enable_overlap = false

  Enable explicit overlap between communication and computation.
- bool enable_put = false

  Put the data to the window using MPI_Put rather than get.
- bool enable_get = true

  Get the data to the window using MPI_Get rather than put.
- bool enable_one_by_one = false

  Push each element separately directly into the buffer.
- bool enable_flush_local = false

  Use local flush.
- bool enable_flush_all = true

  Use flush all.
- bool enable_lock_local = false

  Use local locks.
- bool enable_lock_all = true

  Use lock all.

7.2.1 Detailed Description

The settings for the various available communication paradigms.

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

- settings.hpp (4633d6a)

7.3 schwz::Communicate< ValueType, IndexType >::comm_struct Struct Reference

The communication struct used to store the communication data.

`#include <communicate.hpp>`

Public Attributes

- int num_neighbors_in
  The number of neighbors this subdomain has to receive data from.
- int num_neighbors_out
  The number of neighbors this subdomain has to send data to.
- std::shared_ptr< gko::Array< IndexType > > neighbors_in
  The neighbors this subdomain has to receive data from.
- std::shared_ptr< gko::Array< IndexType > > neighbors_out
  The neighbors this subdomain has to send data to.
- std::vector< bool > is_local_neighbor
  The bool vector which is true if the neighbors of a subdomain are in one node.
- int local_num_neighbors_in
  The number of neighbors this subdomain has to receive data from.
- int local_num_neighbors_out
  The number of neighbors this subdomain has to send data to.
- std::shared_ptr< gko::Array< IndexType > > local_neighbors_in
  The neighbors this subdomain has to receive data from.
- std::shared_ptr< gko::Array< IndexType > > local_neighbors_out
  The neighbors this subdomain has to send data to.
- std::shared_ptr< gko::Array< IndexType * > > global_put
  The array containing the number of elements that each subdomain sends from the other.
- std::shared_ptr< gko::Array< IndexType * > > local_put
  The array containing the number of elements that each subdomain sends from the other.
- std::shared_ptr< gko::Array< IndexType * > > remote_put
  The array containing the number of elements that each subdomain sends from the other.
- std::shared_ptr< gko::Array< IndexType * > > global_get
  The array containing the number of elements that each subdomain gets from the other.
- std::shared_ptr< gko::Array< IndexType * > > local_get
  The array containing the number of elements that each subdomain gets from the other.
- std::shared_ptr< gko::Array< IndexType * > > remote_get
  The array containing the number of elements that each subdomain gets from the other.
- std::shared_ptr< gko::Array< IndexType > > window_ids
  The RDMA window ids.

- std::shared_ptr< gko::Array< IndexType > > windows_from
  The RDMA window ids to receive data from.
- std::shared_ptr< gko::Array< IndexType > > windows_to
  The RDMA window ids to send data to.
- std::shared_ptr< gko::Array< MPI_Request > > put_request
  The put request array.
- std::shared_ptr< gko::Array< MPI_Request > > get_request
  The get request array.
- std::shared_ptr< gko::matrix::Dense< ValueType > > send_buffer
  The send buffer used for the actual communication for both one-sided and two-sided.
- std::shared_ptr< gko::matrix::Dense< ValueType > > recv_buffer
  The recv buffer used for the actual communication for both one-sided and two-sided.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_recv_bdy
  The last received boundary values for each of the in neighbors for extrapolation.
- std::shared_ptr< gko::matrix::Dense< ValueType > > sec_last_recv_bdy
  The second last received boundary values for each of the in neighbors for extrapolation.
- std::shared_ptr< gko::matrix::Dense< ValueType > > third_last_recv_bdy
  The second last received boundary values for each of the in neighbors for extrapolation.
- std::shared_ptr< gko::matrix::Dense< ValueType > > curr_send_avg
  Average of values in the send buffer for each of the out neighbors.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_send_avg
  Average of values in the last send buffer for each of the out neighbors.
- std::shared_ptr< gko::matrix::Dense< ValueType > > curr_recv_avg
  Average of values in the recv buffer for each of the out neighbors.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_recv_avg
  Average of values in the last recv buffer for each of the out neighbors.
- std::shared_ptr< gko::Array< IndexType > > msg_count
  Number of messages sent.
- std::shared_ptr< gko::Array< IndexType > > last_recv_iter
  Iteration stamp of last received values.
- std::shared_ptr< gko::Array< IndexType > > sec_last_recv_iter
  Iteration stamp of second last received values.
- std::shared_ptr< gko::Array< IndexType > > third_last_recv_iter
  Iteration stamp of third last received values.
- std::shared_ptr< gko::Array< IndexType > > get_displacements
  The displacements for the receiving of the buffer.
- std::shared_ptr< gko::Array< IndexType > > put_displacements
  The displacements for the sending of the buffer.
- MPI_Win window_recv_buffer
  The RDMA window for the recv buffer.
- MPI_Win window_send_buffer
  The RDMA window for the send buffer.
- MPI_Win window_x
  The RDMA window for the solution vector.

7.3.1 Detailed Description

template<typename ValueType, typename IndexType>
struct schwz::Communicate< ValueType, IndexType >::comm_struct

The communication struct used to store the communication data.

7.3.2 Member Data Documentation

7.3.2.1 global_get

```
template<typename ValueType , typename IndexType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType >::comm↩
_struct::global_get
```

The array containing the number of elements that each subdomain gets from the other.

For example. global_get[p][0] contains the overall number of elements to be received to subdomain p and global↩
_put[p][i] contains the index of the solution vector to be received from subdomain p.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize(), schwz::SolverRAS< ValueType, IndexType >::setup_comm_buffers(), and schwz::SolverRAS< ValueType, IndexType >::setup_windows().

7.3.2.2 global_put

```
template<typename ValueType , typename IndexType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType >::comm↩
_struct::global_put
```

The array containing the number of elements that each subdomain sends from the other.

For example. global_put[p][0] contains the overall number of elements to be sent to subdomain p and global_put[p][i] contains the index of the solution vector to be sent to subdomain p.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize(), schwz::SolverRAS< ValueType, IndexType >::setup_comm_buffers(), and schwz::SolverRAS< ValueType, IndexType >::setup_windows().

7.3.2.3 is_local_neighbor

```
template<typename ValueType , typename IndexType >
std::vector<bool> schwz::Communicate< ValueType, IndexType >::comm_struct::is_local_neighbor
```

The bool vector which is true if the neighbors of a subdomain are in one node.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize(), schwz::SolverRAS< ValueType, IndexType >::setup_comm_buffers(), and schwz::SolverRAS< ValueType, IndexType >::setup_windows().

7.3.2.4 local_get

```
template<typename ValueType , typename IndexType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType >::comm↩
_struct::local_get
```

The array containing the number of elements that each subdomain gets from the other.

For example. global_get[p][0] contains the overall number of elements to be received to subdomain p and global↩
_put[p][i] contains the index of the solution vector to be received from subdomain p.

Referenced by schwz::SolverRAS< ValueType, IndexType >::setup_comm_buffers(), and schwz::SolverRAS< ValueType, IndexType >::setup_windows().

7.3.2.5 local_put

```
template<typename ValueType , typename IndexType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType >::comm↩
_struct::local_put
```

The array containing the number of elements that each subdomain sends from the other.

For example. global_put[p][0] contains the overall number of elements to be sent to subdomain p and global_put[p][i] contains the index of the solution vector to be sent to subdomain p.

Referenced by schwz::SolverRAS< ValueType, IndexType >::setup_comm_buffers(), and schwz::SolverRAS< ValueType, IndexType >::setup_windows().

7.3.2.6 remote_get

```
template<typename ValueType , typename IndexType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType >::comm↩
_struct::remote_get
```

The array containing the number of elements that each subdomain gets from the other.

For example. global_get[p][0] contains the overall number of elements to be received to subdomain p and global↩
_put[p][i] contains the index of the solution vector to be received from subdomain p.

Referenced by schwz::SolverRAS< ValueType, IndexType >::setup_comm_buffers(), and schwz::SolverRAS< ValueType, IndexType >::setup_windows().

7.3.2.7 remote_put

```
template<typename ValueType , typename IndexType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType >::comm↩
_struct::remote_put
```

The array containing the number of elements that each subdomain sends from the other.

For example. global_put[p][0] contains the overall number of elements to be sent to subdomain p and global_put[p][i] contains the index of the solution vector to be sent to subdomain p.

Referenced by schwz::SolverRAS< ValueType, IndexType >::setup_comm_buffers(), and schwz::SolverRAS< ValueType, IndexType >::setup_windows().

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

- communicate.hpp (4633d6a)

7.4 schwz::Communicate< ValueType, IndexType > Class Template Reference

The communication class that provides the methods for the communication between the subdomains.

`#include <communicate.hpp>`

Classes

- struct comm_struct

  The communication struct used to store the communication data.

Public Member Functions

- virtual void setup_comm_buffers ()=0

  Sets up the communication buffers needed for the boundary exchange.
- virtual void setup_windows (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, std::shared_ptr< gko::matrix::Dense< ValueType >> &main_buffer)=0

  Sets up the windows needed for the asynchronous communication.
- virtual void exchange_boundary (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, std::shared_ptr< gko::matrix::Dense< ValueType >> &solution, std::shared_ptr< gko::matrix↩ ::Dense< ValueType >> &last_solution, std::ofstream &fps, std::ofstream &fpr)=0

  Exchanges the elements of the solution vector.
- void local_to_global_vector (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, const std::shared_ptr< gko::matrix::Dense< ValueType >> &local_vector, std::shared_ptr< gko::matrix::↩ Dense< ValueType >> &global_vector)

  Transforms data from a local vector to a global vector.
- virtual void update_boundary (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, std::shared_ptr< gko::matrix::Dense< ValueType >> &local_solution, const std::shared_ptr< gko↩ ::matrix::Dense< ValueType >> &local_rhs, const std::shared_ptr< gko::matrix::Dense< ValueType >> &global_solution, const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &interface_matrix)=0

  Update the values into local vector from obtained from the neighboring sub-domains using the interface matrix.
- void clear (Settings &settings)

  Clears the data.

7.4.1 Detailed Description

template<typename ValueType, typename IndexType>
class schwz::Communicate< ValueType, IndexType >

The communication class that provides the methods for the communication between the subdomains.

Template Parameters

ValueType	The type of the floating point values.
IndexType	The type of the index type values.

Communicate

7.4.2 Member Function Documentation

7.4.2.1 exchange_boundary()

```
template<typename ValueType , typename IndexType >
void schwz::Communicate< ValueType, IndexType >::exchange_boundary (
            const Settings & settings,
            const Metadata< ValueType, IndexType > & metadata,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & solution,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & last_solution,
            std::ofstream & fps,
            std::ofstream & fpr )  [pure virtual]
```

Exchanges the elements of the solution vector.

Parameters

settings	The settings struct.
metadata	The metadata struct.
global_solution	The solution vector being exchanged between the subdomains.

Implemented in schwz::SolverRAS< ValueType, IndexType >.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::run().

7.4.2.2 local_to_global_vector()

```
template<typename ValueType , typename IndexType >
void schwz::Communicate< ValueType, IndexType >::local_to_global_vector (
            const Settings & settings,
            const Metadata< ValueType, IndexType > & metadata,
            const std::shared_ptr< gko::matrix::Dense< ValueType >> & local_vector,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & global_vector )
```

Transforms data from a local vector to a global vector.

Parameters

settings	The settings struct.
metadata	The metadata struct.
local_vector	The local vector in question.
global_vector	The global vector in question.

```
71 {
72     using vec = gko::matrix::Dense<ValueType>;
73     auto alpha = gko::initialize<gko::matrix::Dense<ValueType>>(
74         {1.0}, settings.executor);
75     auto temp_vector = vec::create(
76         settings.executor, gko::dim<2>(metadata.local_size, 1),
77         gko::Array<ValueType>::view(
78             settings.executor, metadata.local_size,
79             &global_vector->get_values()[metadata.first_row
80                                          ->get_data()[metadata.my_rank]]),
81         1);
82
83     auto temp_vector2 = vec::create(
84         settings.executor, gko::dim<2>(metadata.local_size, 1),
85         gko::Array<ValueType>::view(settings.executor, metadata.local_size,
86                                     local_vector->get_values()),
87         1);
88     if (settings.convergence_settings.convergence_crit ==
89         Settings::convergence_settings::local_convergence_crit::
90             residual_based) {
91         local_vector->add_scaled(alpha.get(), temp_vector.get());
92         temp_vector->add_scaled(alpha.get(), local_vector.get());
93     } else {
94         temp_vector->copy_from(temp_vector2.get());
95     }
96 }
```

7.4.2.3 setup_windows()

```
template<typename ValueType , typename IndexType >
void schwz::Communicate< ValueType, IndexType >::setup_windows (
             const Settings & settings,
             const Metadata< ValueType, IndexType > & metadata,
             std::shared_ptr< gko::matrix::Dense< ValueType >> & main_buffer )  [pure virtual]
```

Sets up the windows needed for the asynchronous communication.

Parameters

settings	The settings struct.
metadata	The metadata struct.
main_buffer	The main buffer being exchanged between the subdomains.

Implemented in schwz::SolverRAS< ValueType, IndexType >.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::run().

7.4.2.4 update_boundary()

```
template<typename ValueType , typename IndexType >
void schwz::Communicate< ValueType, IndexType >::update_boundary (
            const Settings & settings,
            const Metadata< ValueType, IndexType > & metadata,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & local_solution,
            const std::shared_ptr< gko::matrix::Dense< ValueType >> & local_rhs,
            const std::shared_ptr< gko::matrix::Dense< ValueType >> & global_solution,
            const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & interface_↩
matrix )  [pure virtual]
```

Update the values into local vector from obtained from the neighboring sub-domains using the interface matrix.

Parameters

settings	The settings struct.
metadata	The metadata struct.
local_solution	The local solution vector in the subdomain.
local_rhs	The local right hand side vector in the subdomain.
global_solution	The workspace solution vector.
global_old_solution	The global solution vector of the previous iteration.
interface_matrix	The interface matrix containing the interface and the overlap data mainly used for exchanging values between different sub-domains.

Implemented in schwz::SolverRAS< ValueType, IndexType >.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::run().

The documentation for this class was generated from the following files:

- communicate.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/communicate.cpp (4633d6a)

7.5 schwz::Settings::convergence_settings Struct Reference

The various convergence settings available.

`#include <settings.hpp>`

7.5.1 Detailed Description

The various convergence settings available.

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

- settings.hpp (4633d6a)

7.6 CudaError Class Reference

CudaError is thrown when a CUDA routine throws a non-zero error code.

`#include <exception.hpp>`

Public Member Functions

- CudaError (const std::string &file, int line, const std::string &func, int error_code)
  Initializes a CUDA error.

7.6.1 Detailed Description

CudaError is thrown when a CUDA routine throws a non-zero error code.

7.6.2 Constructor & Destructor Documentation

7.6.2.1 CudaError()

```
CudaError::CudaError (
            const std::string & file,
            int line,
            const std::string & func,
            int error_code )  [inline]
```

Initializes a CUDA error.

Parameters

file	The name of the offending source file
line	The source code line number where the error occurred
func	The name of the CUDA routine that failed
error_code	The resulting CUDA error code

```
137         : Error(file, line, func + ": " + get_error(error_code))
138     {}
```

The documentation for this class was generated from the following files:

- exception.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (4633d6a)

7.7 CusparseError Class Reference

CusparseError is thrown when a cuSPARSE routine throws a non-zero error code.

`#include <exception.hpp>`

Public Member Functions

- CusparseError (const std::string &file, int line, const std::string &func, int error_code)
  Initializes a cuSPARSE error.

7.7.1 Detailed Description

CusparseError is thrown when a cuSPARSE routine throws a non-zero error code.

7.7.2 Constructor & Destructor Documentation

7.7.2.1 CusparseError()

```
CusparseError::CusparseError (
            const std::string & file,
            int line,
            const std::string & func,
            int error_code )  [inline]
```

Initializes a cuSPARSE error.

Parameters

file	The name of the offending source file
line	The source code line number where the error occurred
func	The name of the cuSPARSE routine that failed
error_code	The resulting cuSPARSE error code

```
159         : Error(file, line, func + ": " + get_error(error_code))
160     {}
```

The documentation for this class was generated from the following files:

- exception.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (4633d6a)

7.8 schwz::device_guard Class Reference

This class defines a device guard for the cuda functions and the cuda module.

`#include <device_guard.hpp>`

7.8.1 Detailed Description

This class defines a device guard for the cuda functions and the cuda module.

The guard is used to make sure that the device code is run on the correct cuda device, when run with multiple devices. The class records the current device id and uses `cudaSetDevice` to set the device id to the one being passed in. After the scope has been exited, the destructor sets the device_id back to the one before entering the scope.

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

- device_guard.hpp (4633d6a)

7.9 schwz::Initialize< ValueType, IndexType > Class Template Reference

The initialization class that provides methods for initialization of the solver.

`#include <initialization.hpp>`

Public Member Functions

- void generate_random_rhs (std::vector< ValueType > &rhs)

  Generates a random right hand side vector.
- void generate_dipole_rhs (std::vector< ValueType > &rhs)

  Generates a dipole right hand side vector.
- void generate_sin_rhs (std::vector< ValueType > &rhs)

  Generates a sinusoidal right hand side vector.
- void setup_global_matrix (const std::string &filename, const gko::size_type &oned_laplacian_size, std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &global_matrix)

  Generates the 2D global laplacian matrix.
- void partition (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &global_matrix, std::vector< unsigned int > &partition_indices)

  The partitioning function.
- void setup_vectors (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, std::vector< ValueType > &rhs, std::shared_ptr< gko::matrix::Dense< ValueType >> &local_rhs, std::shared_ptr< gko::matrix::Dense< ValueType >> &global_rhs, std::shared_ptr< gko::matrix::Dense< ValueType >> &local_solution, std::shared_ptr< gko::matrix::Dense< ValueType >> &last_solution)

  Setup the vectors with default values and allocate mameory if not allocated.
- virtual void setup_local_matrices (Settings &settings, Metadata< ValueType, IndexType > &metadata, std::vector< unsigned int > &partition_indices, std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &global_matrix, std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &local_matrix, std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &interface_matrix)=0

  Sets up the local and the interface matrices from the global matrix and the partition indices.

Public Attributes

- std::vector< unsigned int > partition_indices

  The partition indices containing the subdomains to which each row(vertex) of the matrix(graph) belongs to.
- std::vector< unsigned int > cell_weights

  The cell weights for the partition algorithm.

Additional Inherited Members

7.9.1 Detailed Description

template<typename ValueType = gko::default_precision, typename IndexType = gko::int32>
class schwz::Initialize< ValueType, IndexType >

The initialization class that provides methods for initialization of the solver.

Template Parameters

ValueType	The type of the floating point values.
IndexType	The type of the index type values.

Initialization

7.9.2 Member Function Documentation

7.9.2.1 generate_dipole_rhs()

```
template<typename ValueType , typename IndexType >
void schwz::Initialize< ValueType, IndexType >::generate_dipole_rhs (
            std::vector< ValueType > & rhs )
```

Generates a dipole right hand side vector.

Parameters

rhs	The rhs vector.

```
102 {
103     auto oned_laplacian_size = metadata.oned_laplacian_size;
104
105     //Placing dipole at 1/4 and 3/4 of Y-dim at the middle of X-dim
106     for (int i = 0; i < oned_laplacian_size; i++)
107     {
108         for (int j = 0; j < oned_laplacian_size; j++)
109         {
110             if (i == oned_laplacian_size / 4 && j == oned_laplacian_size / 2)
111                 rhs[i * oned_laplacian_size + j] = 100.0;
112             else if (i == 3 * oned_laplacian_size / 4 && j == oned_laplacian_size / 2)
```

```
113                 rhs[i * oned_laplacian_size + j] = -100.0;
114             else
115                 rhs[i * oned_laplacian_size + j] = 0.0;
116         }
117     }
118 }
```

7.9.2.2 generate_random_rhs()

```
template<typename ValueType , typename IndexType >
void schwz::Initialize< ValueType, IndexType >::generate_random_rhs (
             std::vector< ValueType > & rhs )
```

Generates a random right hand side vector.

Parameters

rhs	The rhs vector.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize().

```
91 {
92     std::uniform_real_distribution<double> unif(0.0, 1.0);
93     std::default_random_engine engine;
94     for (gko::size_type i = 0; i < rhs.size(); ++i) {
95         rhs[i] = unif(engine);
96     }
97 }
```

7.9.2.3 generate_sin_rhs()

```
template<typename ValueType , typename IndexType >
void schwz::Initialize< ValueType, IndexType >::generate_sin_rhs (
             std::vector< ValueType > & rhs )
```

Generates a sinusoidal right hand side vector.

Parameters

rhs	The rhs vector.

References schwz::Initialize< ValueType, IndexType >::setup_global_matrix().

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize().

```
122 {
123     auto PI = (ValueType) (atan(1.0) * 4);
124     auto oned_laplacian_size = metadata.oned_laplacian_size;
125
126     //Source = sin(x)sin(y)
```

```
127     for (int i = 0; i < oned_laplacian_size; i++)
128     {
129         for (int j = 0; j < oned_laplacian_size; j++)
130         {
131             rhs[i * oned_laplacian_size + j] = sin(2 * PI * i / oned_laplacian_size) *
132                                                sin(2 * PI * j / oned_laplacian_size);
133         }
134     }
135 }
```

7.9.2.4 partition()

```
template<typename ValueType , typename IndexType >
void schwz::Initialize< ValueType, IndexType >::partition (
             const Settings & settings,
             const Metadata< ValueType, IndexType > & metadata,
             const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & global_↩
matrix,
             std::vector< unsigned int > & partition_indices )
```

The partitioning function.

Allows the partition of the global matrix depending with METIS and a regular 1D decomposition.

Parameters

settings	The settings struct.
metadata	The metadata struct.
global_matrix	The global matrix.
partition_indices	The partition indices [OUTPUT].

References schwz::Metadata< ValueType, IndexType >::global_size, schwz::Metadata< ValueType, IndexType >::my_rank, schwz::Metadata< ValueType, IndexType >::num_subdomains, and schwz::Settings::write_debug_↩ out.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize().

```
323 {
324     partition_indices.resize(metadata.global_size);
325     if (metadata.my_rank == 0) {
326         auto partition_settings =
327             (Settings::partition_settings::partition_zoltan |
328              Settings::partition_settings::partition_metis |
329              Settings::partition_settings::partition_regular |
330              Settings::partition_settings::partition_regular2d |
331              Settings::partition_settings::partition_custom) &
332             settings.partition;
333
334         if (partition_settings ==
335             Settings::partition_settings::partition_zoltan) {
336             SCHWARZ_NOT_IMPLEMENTED;
337         } else if (partition_settings ==
338                    Settings::partition_settings::partition_metis) {
339             if (metadata.my_rank == 0) {
340                 std::cout << " METIS partition" << std::endl;
341             }
342             PartitionTools::PartitionMetis(
343                 settings, global_matrix, this->cell_weights,
344                 metadata.num_subdomains, partition_indices);
345         } else if (partition_settings ==
346                    Settings::partition_settings::partition_regular) {
347             if (metadata.my_rank == 0) {
```

```
348                 std::cout << " Regular 1D partition" << std::endl;
349             }
350             PartitionTools::PartitionRegular(
351                 global_matrix, metadata.num_subdomains, partition_indices);
352         } else if (partition_settings ==
353                    Settings::partition_settings::partition_regular2d) {
354             if (metadata.my_rank == 0) {
355                 std::cout << " Regular 2D partition" << std::endl;
356             }
357             PartitionTools::PartitionRegular2D(
358                 global_matrix, settings.write_debug_out,
359                 metadata.num_subdomains, partition_indices);
360         } else if (partition_settings ==
361                    Settings::partition_settings::partition_custom) {
362             // User partitions mesh manually
363             SCHWARZ_NOT_IMPLEMENTED;
364         } else {
365             SCHWARZ_NOT_IMPLEMENTED;
366         }
367     }
368 }
```

7.9.2.5 setup_global_matrix()

```
template<typename ValueType , typename IndexType >
void schwz::Initialize< ValueType, IndexType >::setup_global_matrix (
             const std::string & filename,
             const gko::size_type & oned_laplacian_size,
             std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & global_matrix )
```

Generates the 2D global laplacian matrix.

Parameters

oned_laplacian_size	The size of the one d laplacian grid.
global_matrix	The global matrix.

Referenced by schwz::Initialize< ValueType, IndexType >::generate_sin_rhs(), and schwz::SchwarzBase< ValueType, IndexType >::initialize().

```
239 {
240     using index_type = IndexType;
241     using value_type = ValueType;
242     using mtx = gko::matrix::Csr<value_type, index_type>;
243     if (settings.matrix_filename != "null") {
244         auto input_file = std::ifstream(filename, std::ios::in);
245         if (!input_file) {
246             std::cerr << "Could not find the file \"" << filename
247                       << "\", which is required for this test.\n";
248         }
249         global_matrix =
250             gko::read<mtx>(input_file, settings.executor->get_master());
251         global_matrix->sort_by_column_index();
252         std::cout << "Matrix from file " << filename << std::endl;
253     } else if (settings.matrix_filename == "null" &&
254                settings.explicit_laplacian) {
255         std::cout << "Laplacian 2D Matrix (generated in house) " << std::endl;
256         gko::size_type global_size = oned_laplacian_size *
      oned_laplacian_size;
257
258         global_matrix = mtx::create(settings.executor->get_master(),
259                                     gko::dim<2>(global_size), 5 * global_size);
260         value_type *values = global_matrix->get_values();
261         index_type *row_ptrs = global_matrix->get_row_ptrs();
262         index_type *col_idxs = global_matrix->get_col_idxs();
263
264         std::vector<gko::size_type> exclusion_set;
```

```
265
266         std::map<IndexType, ValueType> stencil_map = {
267             {-oned_laplacian_size, -1}, {-1, -1}, {0, 4}, {1, -1},
268             {oned_laplacian_size, -1},
269         };
270         for (auto i = 2; i < global_size; ++i) {
271             gko::size_type index = (i - 1) * oned_laplacian_size;
272             if (index * index < global_size * global_size) {
273                 exclusion_set.push_back(
274                     linearize_index(index, index - 1, global_size));
275                 exclusion_set.push_back(
276                     linearize_index(index - 1, index, global_size));
277             }
278         }
279
280         std::sort(exclusion_set.begin(),
281                   exclusion_set.begin() + exclusion_set.size());
282
283         IndexType pos = 0;
284         IndexType col_idx = 0;
285         row_ptrs[0] = pos;
286         gko::size_type cur_idx = 0;
287         for (IndexType i = 0; i < global_size; ++i) {
288             for (auto ofs : stencil_map) {
289                 auto in_exclusion_flag =
290                     (exclusion_set[cur_idx] ==
291                      linearize_index(i, i + ofs.first, global_size));
292                 if (0 <= i + ofs.first && i + ofs.first < global_size &&
293                     !in_exclusion_flag) {
294                     values[pos] = ofs.second;
295                     col_idxs[pos] = i + ofs.first;
296                     ++pos;
297                 }
298                 if (in_exclusion_flag) {
299                     cur_idx++;
300                 }
301                 col_idx = row_ptrs[i + 1] - pos;
302             }
303             row_ptrs[i + 1] = pos;
304         }
305     } else {
306         std::cerr << " Need to provide a matrix or enable the default "
307                      "laplacian matrix."
308                   << std::endl;
309         std::exit(-1);
310     }
311 }
```

7.9.2.6 setup_local_matrices()

```
template<typename ValueType , typename IndexType >
void schwz::Initialize< ValueType, IndexType >::setup_local_matrices (
              Settings & settings,
              Metadata< ValueType, IndexType > & metadata,
              std::vector< unsigned int > & partition_indices,
              std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & global_matrix,
              std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & local_matrix,
              std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & interface_matrix )
[pure virtual]
```

Sets up the local and the interface matrices from the global matrix and the partition indices.

Parameters

settings	The settings struct.
metadata	The metadata struct.
partition_indices	The array containing the partition indices.
global_matrix	The global system matrix.
local_matrix	The local system matrix.

Parameters

interface_matrix	The interface matrix containing the interface and the overlap data mainly used for exchanging values between different sub-domains.
local_perm	The local permutation, obtained through RCM or METIS.

Implemented in schwz::SolverRAS< ValueType, IndexType >.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize().

7.9.2.7 setup_vectors()

```
template<typename ValueType , typename IndexType >
void schwz::Initialize< ValueType, IndexType >::setup_vectors (
            const Settings & settings,
            const Metadata< ValueType, IndexType > & metadata,
            std::vector< ValueType > & rhs,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & local_rhs,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & global_rhs,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & local_solution,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & last_solution )
```

Setup the vectors with default values and allocate mameory if not allocated.

Parameters

settings	The settings struct.
metadata	The metadata struct.
local_rhs	The local right hand side vector in the subdomain.
global_rhs	The global right hand side vector.
local_solution	The local solution vector in the subdomain.

References schwz::Settings::executor, schwz::Metadata< ValueType, IndexType >::first_row, schwz::Metadata< ValueType, IndexType >::local_size_x, and schwz::Metadata< ValueType, IndexType >::my_rank.

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize().

```
379 {
380     using vec = gko::matrix::Dense<ValueType>;
381     auto my_rank = metadata.my_rank;
382     auto first_row = metadata.first_row->get_data()[my_rank];
383
384     // Copy the global rhs vector to the required executor.
385     gko::Array<ValueType> temp_rhs{settings.executor->get_master(), rhs.begin(),
386                                    rhs.end()};
387     global_rhs = vec::create(settings.executor,
388                              gko::dim<2>{metadata.global_size, 1}, temp_rhs, 1);
389
390     local_rhs =
391         vec::create(settings.executor, gko::dim<2>(metadata.local_size_x, 1));
392     // Extract the local rhs from the global rhs. Also takes into account the
393     // overlap.
394     SolverTools::extract_local_vector(settings, metadata, local_rhs.get(),
395                                       global_rhs.get(), first_row);
396
397     local_solution =
```

```
398         vec::create(settings.executor, gko::dim<2>(metadata.local_size_x, 1));
399
400     //contains the solution at the last event of communication
401     last_solution =
402         vec::create(settings.executor, gko::dim<2>(metadata.local_size_x, 1));
403 }
```

The documentation for this class was generated from the following files:

- initialization.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/initialization.cpp (4633d6a)

7.10 schwz::Metadata< ValueType, IndexType > Struct Template Reference

The solver metadata struct.

`#include <settings.hpp>`

Classes

- struct post_process_data

  The struct used for storing data for post-processing.

Public Attributes

- MPI_Comm mpi_communicator

  The MPI communicator.
- gko::size_type global_size = 0

  The size of the global matrix.
- gko::size_type oned_laplacian_size = 0

  The size of the 1 dimensional laplacian grid.
- gko::size_type local_size = 0

  The size of the local subdomain matrix.
- gko::size_type local_size_x = 0

  The size of the local subdomain matrix + the overlap.
- gko::size_type local_size_o = 0

  The size of the local subdomain matrix + the overlap.
- gko::size_type overlap_size = 0

  The size of the overlap between the subdomains.
- gko::size_type num_subdomains = 1

  The number of subdomains used within the solver.
- int my_rank

  The rank of the subdomain.
- int my_local_rank

  The local rank of the subdomain.
- int local_num_procs

  The local number of procs in the subdomain.
- int comm_size

  The number of subdomains used within the solver, size of the communicator.

- int num_threads

  The number of threads used within the solver for each subdomain.
- IndexType iter_count

  The iteration count of the solver.
- ValueType tolerance

  The tolerance of the complete solver.
- ValueType local_solver_tolerance

  The tolerance of the local solver in case of an iterative solve.
- IndexType max_iters

  The maximum iteration count of the Schwarz solver.
- IndexType local_max_iters

  The maximum iteration count of the local iterative solver.
- std::string local_precond

  Local preconditioner.
- unsigned int precond_max_block_size

  The maximum block size for the preconditioner.
- ValueType current_residual_norm = -1.0

  The current residual norm of the subdomain.
- ValueType min_residual_norm = -1.0

  The minimum residual norm of the subdomain.
- ValueType constant = 0.0

  Value of constant for event threshold.
- ValueType gamma = 0.0

  Value of gamma for event threshold.
- std::vector< std::tuple< int, int, int, std::string, std::vector< ValueType > > > time_struct

  The struct used to measure the timings of each function within the solver loop.
- std::vector< std::tuple< int, std::vector< std::tuple< int, int > >, std::vector< std::tuple< int, int > >, int, int > > comm_data_struct

  The struct used to measure the timings of each function within the solver loop.
- std::shared_ptr< gko::Array< IndexType > > global_to_local

  The mapping containing the global to local indices.
- std::shared_ptr< gko::Array< IndexType > > local_to_global

  The mapping containing the local to global indices.
- std::shared_ptr< gko::Array< IndexType > > overlap_row

  The overlap row indices.
- std::shared_ptr< gko::Array< IndexType > > first_row

  The starting row of each subdomain in the matrix.
- std::shared_ptr< gko::Array< IndexType > > permutation

  The permutation used for the re-ordering.
- std::shared_ptr< gko::Array< IndexType > > i_permutation

  The inverse permutation used for the re-ordering.

7.10.1 Detailed Description

template<typename ValueType, typename IndexType>
struct schwz::Metadata< ValueType, IndexType >

The solver metadata struct.

Template Parameters

ValueType	The type of the floating point values.
IndexType	The type of the index type values.

7.10.2 Member Data Documentation

7.10.2.1 local_solver_tolerance

```
template<typename ValueType, typename IndexType>
ValueType schwz::Metadata< ValueType, IndexType >::local_solver_tolerance
```

The tolerance of the local solver in case of an iterative solve.

The residual norm reduction required.

7.10.2.2 tolerance

```
template<typename ValueType, typename IndexType>
ValueType schwz::Metadata< ValueType, IndexType >::tolerance
```

The tolerance of the complete solver.

The residual norm reduction required.

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

- settings.hpp (4633d6a)

7.11 MetisError Class Reference

MetisError is thrown when a METIS routine throws a non-zero error code.

```
#include <exception.hpp>
```

Public Member Functions

- MetisError (const std::string &file, int line, const std::string &func, int error_code)
  Initializes a METIS error.

7.11.1 Detailed Description

MetisError is thrown when a METIS routine throws a non-zero error code.

7.11.2 Constructor & Destructor Documentation

7.11.2.1 MetisError()

```
MetisError::MetisError (
            const std::string & file,
            int line,
            const std::string & func,
            int error_code )  [inline]
```

Initializes a METIS error.

Parameters

file	The name of the offending source file
line	The source code line number where the error occurred
func	The name of the METIS routine that failed
error_code	The resulting METIS error code

```
182         : Error(file, line, func + ": " + get_error(error_code))
183     {}
```

The documentation for this class was generated from the following files:

- exception.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (4633d6a)

7.12 schwz::Metadata< ValueType, IndexType >::post_process_data Struct Reference

The struct used for storing data for post-processing.

```
#include <settings.hpp>
```

7.12.1 Detailed Description

template<typename ValueType, typename IndexType>
struct schwz::Metadata< ValueType, IndexType >::post_process_data

The struct used for storing data for post-processing.

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

- settings.hpp (4633d6a)

7.13 schwz::SchwarzBase< ValueType, IndexType > Class Template Reference

The Base solver class is meant to be the class implementing the common implementations for all the schwarz methods.

`#include <schwarz_base.hpp>`

Public Member Functions

- SchwarzBase (Settings &settings, Metadata< ValueType, IndexType > &metadata)
  The constructor that takes in the user settings and a metadata struct containing the solver metadata.
- void initialize ()
  Initialize the matrix and vectors.
- void run (std::shared_ptr< gko::matrix::Dense< ValueType >> &solution)
  The function that runs the actual solver and obtains the final solution.
- void print_vector (const std::shared_ptr< gko::matrix::Dense< ValueType >> &vector, int subd, std::string name)
  The auxiliary function that prints a passed in vector.
- void print_matrix (const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &matrix, int rank, std::string name)
  The auxiliary function that prints a passed in CSR matrix.

Public Attributes

- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > local_matrix
  The local subdomain matrix.
- std::shared_ptr< gko::matrix::Permutation< IndexType > > local_perm
  The local subdomain permutation matrix/array.
- std::shared_ptr< gko::matrix::Permutation< IndexType > > local_inv_perm
  The local subdomain inverse permutation matrix/array.
- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > triangular_factor_l
  The local lower triangular factor used for the triangular solves.
- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > triangular_factor_u
  The local upper triangular factor used for the triangular solves.
- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > interface_matrix
  The local interface matrix.
- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > global_matrix
  The global matrix.
- std::shared_ptr< gko::matrix::Dense< ValueType > > local_rhs
  The local right hand side.
- std::shared_ptr< gko::matrix::Dense< ValueType > > global_rhs
  The global right hand side.
- std::shared_ptr< gko::matrix::Dense< ValueType > > local_solution
  The local solution vector.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_solution
  The (local+overlap) solution vector at time of last event of communication The size of this vector is considered global↩ _size to account for overlap.
- std::shared_ptr< gko::matrix::Dense< ValueType > > global_solution
  The global solution vector.
- std::vector< ValueType > local_residual_vector_out
  The global residual vector.
- std::vector< std::vector< ValueType > > global_residual_vector_out
  The local residual vector.

Additional Inherited Members

7.13.1 Detailed Description

template<typename ValueType = gko::default_precision, typename IndexType = gko::int32>
class schwz::SchwarzBase< ValueType, IndexType >

The Base solver class is meant to be the class implementing the common implementations for all the schwarz methods.

It derives from the Initialization class, the Communication class and the Solve class all of which are templated.

Template Parameters

ValueType	The type of the floating point values.
IndexType	The type of the index type values.

7.13.2 Constructor & Destructor Documentation

7.13.2.1 SchwarzBase()

```
template<typename ValueType , typename IndexType >
schwz::SchwarzBase< ValueType, IndexType >::SchwarzBase (
            Settings & settings,
            Metadata< ValueType, IndexType > & metadata )
```

The constructor that takes in the user settings and a metadata struct containing the solver metadata.

Parameters

settings	The settings struct.
metadata	The metadata struct.

References schwz::Settings::cuda_device_guard, schwz::Settings::executor, schwz::Settings::executor_string, schwz::Metadata< ValueType, IndexType >::local_num_procs, schwz::Metadata< ValueType, IndexType >::mpi_communicator, schwz::Metadata< ValueType, IndexType >::my_local_rank, and schwz::Metadata< ValueType, IndexType >::my_rank.

```
74     : Initialize<ValueType, IndexType>(settings, metadata),
75       settings(settings),
76       metadata(metadata)
77 {
78     using vec_itype = gko::Array<IndexType>;
79     using vec_vecshared = gko::Array<IndexType *>;
80     metadata.my_local_rank =
81         Utils<ValueType, IndexType>::get_local_rank(metadata.mpi_communicator);
82     metadata.local_num_procs = Utils<ValueType, IndexType>::get_local_num_procs(
83         metadata.mpi_communicator);
84     auto my_local_rank = metadata.my_local_rank;
85     if (settings.executor_string == "omp") {
```

```
86          settings.executor = gko::OmpExecutor::create();
87          auto exec_info =
88              static_cast<gko::OmpExecutor *>(settings.executor.get())
89                  ->get_exec_info();
90          exec_info->bind_to_core(metadata.my_local_rank);
91
92      } else if (settings.executor_string == "cuda") {
93          int num_devices = 0;
94  #if SCHW_HAVE_CUDA
95          SCHWARZ_ASSERT_NO_CUDA_ERRORS(cudaGetDeviceCount(&num_devices));
96  #else
97          SCHWARZ_NOT_IMPLEMENTED;
98  #endif
99          Utils<ValueType, IndexType>::assert_correct_cuda_devices(
100             num_devices, metadata.my_rank);
101         settings.executor = gko::CudaExecutor::create(
102             my_local_rank, gko::OmpExecutor::create());
103         auto exec_info = static_cast<gko::OmpExecutor *>(
104                              settings.executor->get_master().get())
105                              ->get_exec_info();
106         exec_info->bind_to_core(my_local_rank);
107         settings.cuda_device_guard =
108             std::make_shared<schwz::device_guard>(my_local_rank);
109
110         std::cout << " Rank " << metadata.my_rank << " with local rank "
111                   << my_local_rank << " has "
112                   << (static_cast<gko::CudaExecutor *>(settings.executor.get()))
113                          ->get_device_id()
114                   << " id of gpu" << std::endl;
115         MPI_Barrier(metadata.mpi_communicator);
116     } else if (settings.executor_string == "reference") {
117         settings.executor = gko::ReferenceExecutor::create();
118         auto exec_info =
119             static_cast<gko::ReferenceExecutor *>(settings.executor.get())
120                 ->get_exec_info();
121         exec_info->bind_to_core(my_local_rank);
122     }
123 }
```

7.13.3 Member Function Documentation

7.13.3.1 print_matrix()

```
template<typename ValueType = gko::default_precision, typename IndexType = gko::int32>
void schwz::SchwarzBase< ValueType, IndexType >::print_matrix (
             const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & matrix,
             int rank,
             std::string name )
```

The auxiliary function that prints a passed in CSR matrix.

Parameters

matrix	The matrix to be printed.
subd	The subdomain on which the vector exists.
name	The name of the matrix as a string.

7.13.3.2 print_vector()

```
template<typename ValueType = gko::default_precision, typename IndexType = gko::int32>
void schwz::SchwarzBase< ValueType, IndexType >::print_vector (
```

```
            const std::shared_ptr< gko::matrix::Dense< ValueType >> & vector,
            int subd,
            std::string name )
```

The auxiliary function that prints a passed in vector.

Parameters

vector	The vector to be printed.
subd	The subdomain on which the vector exists.
name	The name of the vector as a string.

7.13.3.3 run()

```
template<typename ValueType , typename IndexType >
void schwz::SchwarzBase< ValueType, IndexType >::run (
            std::shared_ptr< gko::matrix::Dense< ValueType >> & solution )
```

The function that runs the actual solver and obtains the final solution.

Parameters

solution	The solution vector.

References schwz::Communicate< ValueType, IndexType >::exchange_boundary(), schwz::Settings::executor, schwz::SchwarzBase< ValueType, IndexType >::global_matrix, schwz::SchwarzBase< ValueType, IndexType >::global_rhs, schwz::SchwarzBase< ValueType, IndexType >::global_solution, schwz::SchwarzBase< ValueType, IndexType >::interface_matrix, schwz::SchwarzBase< ValueType, IndexType >::last_solution, schwz::SchwarzBase< ValueType, IndexType >::local_inv_perm, schwz::SchwarzBase< ValueType, IndexType >::local_matrix, schwz::SchwarzBase< ValueType, IndexType >::local_perm, schwz::SchwarzBase< ValueType, IndexType >::local_rhs, schwz::SchwarzBase< ValueType, IndexType >::local_solution, schwz::Communicate< ValueType, IndexType >::comm_struct::msg_count, schwz::Communicate< ValueType, IndexType >::comm_struct::neighbors_out, schwz::Communicate< ValueType, IndexType >::comm_struct::num_neighbors_out, schwz::Communicate< ValueType, IndexType >::setup_windows(), schwz::SchwarzBase< ValueType, IndexType >::triangular_factor_l, schwz::SchwarzBase< ValueType, IndexType >::triangular_factor_u, schwz::Communicate< ValueType, IndexType >::update_boundary(), and schwz::Settings::write_iters_and_residuals.

```
326 {
327     using vec_vtype = gko::matrix::Dense<ValueType>;
328     if (!solution.get()) {
329         solution =
330             vec_vtype::create(settings.executor->get_master(),
331                               gko::dim<2>(this->metadata.global_size, 1));
332     }
333     // The main solution vector
334     std::shared_ptr<vec_vtype> global_solution = vec_vtype::create(
335         this->settings.executor, gko::dim<2>(this->metadata.global_size, 1));
336
337     //CHANGED
338     auto num_neighbors_out = this->comm_struct.num_neighbors_out;
339     auto neighbors_out = this->comm_struct.neighbors_out->get_data();
340
341     // The last communicated solution vector
342     std::shared_ptr<vec_vtype> last_solution = vec_vtype::create(
343         settings.executor, gko::dim<2>(metadata.global_size, 1));
344     //END CHANGED
345
346     // A work vector.
```

```
347     std::shared_ptr<vec_vtype> work_vector = vec_vtype::create(
348         settings.executor, gko::dim<2>(2 * this->metadata.local_size_x, 1));
349     // An initial guess.
350     std::shared_ptr<vec_vtype> init_guess = vec_vtype::create(
351         settings.executor, gko::dim<2>(this->metadata.local_size_x, 1));
352     init_guess->copy_from(local_rhs.get());
353 
354     // Setup the windows for the onesided communication.
355     this->setup_windows(this->settings, this->metadata, global_solution);
356 
357     const auto solver_settings =
358         (Settings::local_solver_settings::direct_solver_cholmod |
359          Settings::local_solver_settings::direct_solver_umfpack |
360          Settings::local_solver_settings::direct_solver_ginkgo |
361          Settings::local_solver_settings::iterative_solver_dealii |
362          Settings::local_solver_settings::iterative_solver_ginkgo) &
363         settings.local_solver;
364 
365     ValueType local_residual_norm = -1.0, local_residual_norm0 = -1.0,
366               global_residual_norm = 0.0, global_residual_norm0 = -1.0;
367     metadata.iter_count = 0;
368     int num_converged_procs = 0;
369 
370     //CHANGED - file writing
371     char send_name[30], recv_name[30], pe_str[3];
372     sprintf(pe_str, "%d", metadata.my_rank);
373 
374     strcpy(send_name, "send");
375     strcat(send_name, pe_str);
376     strcat(send_name, ".txt");
377 
378     strcpy(recv_name, "recv");
379     strcat(recv_name, pe_str);
380     strcat(recv_name, ".txt");
381 
382     std::ofstream fps; //file for sending log
383     fps.open(send_name);
384 
385     std::ofstream fpr; //file for receiving log
386     fpr.open(recv_name);
387 
388     if(metadata.my_rank == 0) std::cout << "Constant - " << metadata.constant << ", Gamma - " << metadata.
    gamma <<std::endl;
389     //END CHANGED
390     auto start_time = std::chrono::steady_clock::now();
391 
392     for (; metadata.iter_count < metadata.max_iters; ++(metadata.iter_count)) {
393         // Exchange the boundary values. The communication part.
394         MEASURE_ELAPSED_FUNC_TIME(
395             this->exchange_boundary(settings, metadata, global_solution, last_solution,
    fps, fpr), 0,
396             metadata.my_rank, boundary_exchange, metadata.iter_count);
397 
398         // Update the boundary and interior values after the exchanging from
399         // other processes.
400         MEASURE_ELAPSED_FUNC_TIME(
401             this->update_boundary(settings, metadata, this->
    local_solution,
402                                   this->local_rhs, global_solution,
403                                   this->interface_matrix),
404             1, metadata.my_rank, boundary_update, metadata.iter_count);
405 
406         fps << metadata.iter_count << ", " << local_residual_norm << std::endl;
407 
408         // Check for the convergence of the solver.
409         // num_converged_procs = 0;
410         MEASURE_ELAPSED_FUNC_TIME(
411             (Solve<ValueType, IndexType>::check_convergence(
412                 settings, metadata, this->comm_struct, this->convergence_vector,
413                 global_solution, this->local_solution, this->
    local_matrix,
414                 work_vector, local_residual_norm, local_residual_norm0,
415                 global_residual_norm, global_residual_norm0,
416                 num_converged_procs)),
417             2, metadata.my_rank, convergence_check, metadata.iter_count);
418 
419         // break if the solution diverges.
420         if (std::isnan(global_residual_norm) || global_residual_norm > 1e12) {
421             std::cout << " Rank " << metadata.my_rank << " diverged in "
422                       << metadata.iter_count << " iters " << std::endl;
423             std::exit(-1);
424         }
425 
426         // break if all processes detect that all other processes have
427         // converged otherwise continue iterations.
428         if (num_converged_procs == metadata.num_subdomains) {
429             break;
```

```
430         } else {
431             MEASURE_ELAPSED_FUNC_TIME(
432                 (Solve<ValueType, IndexType>::local_solve(
433                     settings, metadata, this->local_matrix,
434                     this->triangular_factor_l, this->
    triangular_factor_u,
435                     this->local_perm, this->local_inv_perm, work_vector,
436                     init_guess, this->local_solution)),
437                 3, metadata.my_rank, local_solve, metadata.iter_count);
438             // Gather the local vector into the locally global vector for
439             // communication.
440             MEASURE_ELAPSED_FUNC_TIME(
441                 (Communicate<ValueType, IndexType>::local_to_global_vector
    (
442                     settings, metadata, this->local_solution, global_solution)),
443                 4, metadata.my_rank, expand_local_vec, metadata.iter_count);
444         }
445     }
446
447     MPI_Barrier(MPI_COMM_WORLD);
448     auto elapsed_time = std::chrono::duration<ValueType>(
449         std::chrono::steady_clock::now() - start_time);
450
451     //CHANGED
452     //Closing file
453     fps.close();
454     fpr.close();
455
456     //adding 1 to include the 0-th iteration
457     metadata.iter_count = metadata.iter_count + 1;
458
459     //number of messages a PE would send without event-based
460     int noevent_msg_count = metadata.iter_count * num_neighbors_out;
461
462     int total_events = 0;
463
464     //Printing msg count
465     for (int k = 0; k < num_neighbors_out; k++) {
466     std::cout << " Rank: " << metadata.my_rank << " to "
467           << neighbors_out[k] << " : " << this->comm_struct.msg_count->get_data()[k];
468         total_events += this->comm_struct.msg_count->get_data()[k];
469     }
470     std::cout << std::endl;
471
472     //Total no of messages in all PEs
473     MPI_Allreduce(MPI_IN_PLACE, &total_events, 1, MPI_INT, MPI_SUM, MPI_COMM_WORLD);
474     MPI_Allreduce(MPI_IN_PLACE, &noevent_msg_count, 1, MPI_INT, MPI_SUM, MPI_COMM_WORLD);
475
476     if(metadata.my_rank == 0){
477       std::cout << "Total number of events - " << total_events << std::endl;
478       std::cout << "Total number of msgs without event - " << noevent_msg_count << std::endl;
479     }
480     //END CHANGED
481
482     std::cout << " Rank " << metadata.my_rank << " converged in "
483               << metadata.iter_count << " iters " << std::endl;
484     ValueType mat_norm = -1.0, rhs_norm = -1.0, sol_norm = -1.0,
485               residual_norm = -1.0;
486     // Write the residuals and iterations to files
487     if (settings.write_iters_and_residuals &&
488         solver_settings ==
489             Settings::local_solver_settings::iterative_solver_ginkgo) {
490         std::string rank_string = std::to_string(metadata.my_rank);
491         if (metadata.my_rank < 10) {
492             rank_string = "0" + std::to_string(metadata.my_rank);
493         }
494         std::string filename = "iter_res_" + rank_string + ".csv";
495         write_iters_and_residuals(
496             metadata.num_subdomains, metadata.my_rank,
497             metadata.post_process_data.local_residual_vector_out.size(),
498             metadata.post_process_data.local_residual_vector_out,
499             metadata.post_process_data.local_converged_iter_count,
500             metadata.post_process_data.local_converged_resnorm, filename);
501     }
502
503     // Compute the final residual norm. Also gathers the solution from all
504     // subdomains.
505     Solve<ValueType, IndexType>::compute_residual_norm(
506         settings, metadata, global_matrix, global_rhs, global_solution,
507         mat_norm, rhs_norm, sol_norm, residual_norm);
508     gather_comm_data<ValueType, IndexType>(
509         metadata.num_subdomains, this->comm_struct, metadata.comm_data_struct);
510     // clang-format off
511     if (metadata.my_rank == 0)
512       {
513         std::cout
514               << " residual norm " << residual_norm << "\n"
```

```
515               << " relative residual norm of solution " << residual_norm/rhs_norm << "\n"
516               << " Time taken for solve " << elapsed_time.count()
517               << std::endl;
518         if (num_converged_procs < metadata.num_subdomains)
519           {
520             std::cout << " Did not converge in " << metadata.iter_count
521                       << " iterations."
522                       << std::endl;
523           }
524       }
525     // clang-format on
526     if (metadata.my_rank == 0) {
527         solution->copy_from(global_solution.get());
528     }
529
530     // Communicate<ValueType, IndexType>::clear(settings);
531 }
```

The documentation for this class was generated from the following files:

- schwarz_base.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/schwarz_base.cpp (4633d6a)

7.14 schwz::Settings Struct Reference

The struct that contains the solver settings and the parameters to be set by the user.

`#include <settings.hpp>`

Classes

- struct comm_settings

  The settings for the various available communication paradigms.
- struct convergence_settings

  The various convergence settings available.

Public Types

- enum partition_settings

  The partition algorithm to be used for partitioning the matrix.
- enum local_solver_settings

  The local solver algorithm for the local subdomain solves.

Public Attributes

- std::string executor_string

  The string that contains the ginkgo executor paradigm.
- std::shared_ptr< gko::Executor > executor = gko::ReferenceExecutor::create()

  The ginkgo executor the code is to be executed on.
- std::shared_ptr< device_guard > cuda_device_guard

  The ginkgo executor the code is to be executed on.
- gko::int32 overlap = 2

  The overlap between the subdomains.

- std::string matrix_filename = "null"

  The string that contains the matrix file name to read from .
- bool explicit_laplacian = true

  Flag if the laplacian matrix should be generated within the library.
- bool enable_random_rhs = false

  Flag to enable a random rhs.
- bool print_matrices = false

  Flag to enable printing of matrices.
- bool debug_print = false

  Flag to enable some debug printing.
- bool non_symmetric_matrix = false

  Is the matrix non-symmetric ? , Use GMRES for local solves.
- unsigned int restart_iter = 1u

  The restart iter for the GMRES solver.
- bool naturally_ordered_factor = false

  Disables the re-ordering of the matrix before computing the triangular factors during the CHOLMOD factorization.
- std::string metis_objtype

  This setting defines the objective type for the metis partitioning.
- bool use_precond = false

  Enable the block jacobi local preconditioner for the local solver.
- bool write_debug_out = false

  Enable the writing of debug out to file.
- bool write_iters_and_residuals = false

  Enable writing the iters and residuals to a file.
- bool write_perm_data = false

  Enable the local permutations from CHOLMOD to a file.
- int shifted_iter = 1

  Iteration shift for node local communication.
- std::string factorization = "cholmod"

  The factorization for the local direct solver.
- std::string reorder

  The reordering for the local solve.

7.14.1 Detailed Description

The struct that contains the solver settings and the parameters to be set by the user.

settings

7.14.2 Member Data Documentation

7.14.2.1 explicit_laplacian

```
bool schwz::Settings::explicit_laplacian = true
```

Flag if the laplacian matrix should be generated within the library.

If false, an external matrix and rhs needs to be provided

Referenced by schwz::SchwarzBase< ValueType, IndexType >::initialize().

7.14.2.2 naturally_ordered_factor

```
bool schwz::Settings::naturally_ordered_factor = false
```

Disables the re-ordering of the matrix before computing the triangular factors during the CHOLMOD factorization.

Note

This is mainly to allow compatibility with GPU solution.

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

- settings.hpp (4633d6a)

7.15 schwz::Solve< ValueType, IndexType > Class Template Reference

The Solver class the provides the solver and the convergence checking methods.

```
#include <solve.hpp>
```

Additional Inherited Members

7.15.1 Detailed Description

template<typename ValueType = gko::default_precision, typename IndexType = gko::int32>
class schwz::Solve< ValueType, IndexType >

The Solver class the provides the solver and the convergence checking methods.

Template Parameters

ValueType	The type of the floating point values.
IndexType	The type of the index type values.

Solve

The documentation for this class was generated from the following files:

- solve.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/solve.cpp (4633d6a)

7.16 schwz::SolverRAS< ValueType, IndexType > Class Template Reference

An implementation of the solver interface using the RAS solver.

```
#include <restricted_schwarz.hpp>
```

Public Member Functions

- SolverRAS (Settings &settings, Metadata< ValueType, IndexType > &metadata)

  The constructor that takes in the user settings and a metadata struct containing the solver metadata.
- void setup_local_matrices (Settings &settings, Metadata< ValueType, IndexType > &metadata, std::vector< unsigned int > &partition_indices, std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &global_matrix, std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &local_matrix, std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &interface_matrix) override

  Sets up the local and the interface matrices from the global matrix and the partition indices.
- void setup_comm_buffers () override

  Sets up the communication buffers needed for the boundary exchange.
- void setup_windows (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, std::shared_ptr< gko::matrix::Dense< ValueType >> &main_buffer) override

  Sets up the windows needed for the asynchronous communication.
- void exchange_boundary (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, std::shared_ptr< gko::matrix::Dense< ValueType >> &solution, std::shared_ptr< gko::matrix::Dense< ValueType >> &last_solution, std::ofstream &fps, std::ofstream &fpr) override

  Exchanges the elements of the solution vector.
- void update_boundary (const Settings &settings, const Metadata< ValueType, IndexType > &metadata, std::shared_ptr< gko::matrix::Dense< ValueType >> &local_solution, const std::shared_ptr< gko::matrix::Dense< ValueType >> &local_rhs, const std::shared_ptr< gko::matrix::Dense< ValueType >> &global_solution, const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &interface_matrix) override

  Update the values into local vector from obtained from the neighboring sub-domains using the interface matrix.

Additional Inherited Members

7.16.1 Detailed Description

template<typename ValueType = gko::default_precision, typename IndexType = gko::int32>
class schwz::SolverRAS< ValueType, IndexType >

An implementation of the solver interface using the RAS solver.

Template Parameters

ValueType	The type of the floating point values.
IndexType	The type of the index type values.

7.16.2 Constructor & Destructor Documentation

7.16.2.1 SolverRAS()

```
template<typename ValueType , typename IndexType >
schwz::SolverRAS< ValueType, IndexType >::SolverRAS (
            Settings & settings,
            Metadata< ValueType, IndexType > & metadata )
```

The constructor that takes in the user settings and a metadata struct containing the solver metadata.

Parameters

settings	The settings struct.
metadata	The metadata struct.
data	The additional data struct.

```
50     : SchwarzBase<ValueType, IndexType>(settings, metadata)
51 {}
```

7.16.3 Member Function Documentation

7.16.3.1 exchange_boundary()

```
template<typename ValueType , typename IndexType >
void schwz::SolverRAS< ValueType, IndexType >::exchange_boundary (
             const Settings & settings,
             const Metadata< ValueType, IndexType > & metadata,
             std::shared_ptr< gko::matrix::Dense< ValueType >> & solution,
             std::shared_ptr< gko::matrix::Dense< ValueType >> & last_solution,
             std::ofstream & fps,
             std::ofstream & fpr )  [override], [virtual]
```

Exchanges the elements of the solution vector.

Parameters

settings	The settings struct.
metadata	The metadata struct.
global_solution	The solution vector being exchanged between the subdomains.

Implements schwz::Communicate< ValueType, IndexType >.

References schwz::Settings::comm_settings::enable_onesided, schwz::SchwarzBase< ValueType, IndexType >::global_solution, and schwz::SchwarzBase< ValueType, IndexType >::last_solution.

```
1141 {
1142     if (settings.comm_settings.enable_onesided)
1143     {
1144         exchange_boundary_onesided<ValueType, IndexType>(
1145             settings, metadata, this->comm_struct, global_solution,
      last_solution, fps, fpr);
1146     }
1147     else
1148     {
1149         exchange_boundary_twosided<ValueType, IndexType>(
1150             settings, metadata, this->comm_struct, global_solution);
1151     }
1152 }
```

7.16.3.2 setup_local_matrices()

```
template<typename ValueType , typename IndexType >
void schwz::SolverRAS< ValueType, IndexType >::setup_local_matrices (
            Settings & settings,
            Metadata< ValueType, IndexType > & metadata,
            std::vector< unsigned int > & partition_indices,
            std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & global_matrix,
            std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & local_matrix,
            std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & interface_matrix )
[override], [virtual]
```

Sets up the local and the interface matrices from the global matrix and the partition indices.

Parameters

settings	The settings struct.
metadata	The metadata struct.
partition_indices	The array containing the partition indices.
global_matrix	The global system matrix.
local_matrix	The local system matrix.
interface_matrix	The interface matrix containing the interface and the overlap data mainly used for exchanging values between different sub-domains.
local_perm	The local permutation, obtained through RCM or METIS.

Implements schwz::Initialize< ValueType, IndexType >.

References schwz::Metadata< ValueType, IndexType >::comm_size, schwz::Settings::executor, schwz::Metadata< ValueType, IndexType >::first_row, schwz::SchwarzBase< ValueType, IndexType >::global_matrix, schwz::Metadata< ValueType, IndexType >::global_size, schwz::Metadata< ValueType, IndexType >::global_to_local, schwz::Metadata< ValueType, IndexType >::i_permutation, schwz::SchwarzBase< ValueType, IndexType >::interface_matrix, schwz::SchwarzBase< ValueType, IndexType >::local_matrix, schwz::Metadata< ValueType, IndexType >::local_size, schwz::Metadata< ValueType, IndexType >::local_size_o, schwz::Metadata< ValueType, IndexType >::local_size_x, schwz::Metadata< ValueType, IndexType >::local_to_global, schwz::Metadata< ValueType, IndexType >::my_rank, schwz::Metadata< ValueType, IndexType >::num_subdomains, schwz::Settings::overlap, schwz::Metadata< ValueType, IndexType >::overlap_row, schwz::Metadata< ValueType, IndexType >::overlap_size, and schwz::Metadata< ValueType, IndexType >::permutation.

```
61 {
62     using mtx = gko::matrix::Csr<ValueType, IndexType>;
63     using vec_itype = gko::Array<IndexType>;
64     using perm_type = gko::matrix::Permutation<IndexType>;
65     using arr = gko::Array<IndexType>;
66     auto my_rank = metadata.my_rank;
67     auto comm_size = metadata.comm_size;
68     auto num_subdomains = metadata.num_subdomains;
69     auto global_size = metadata.global_size;
70     auto mpi_itype = boost::mpi::get_mpi_datatype(*partition_indices.data());
71
72     MPI_Bcast(partition_indices.data(), global_size, mpi_itype, 0,
73               MPI_COMM_WORLD);
74
75     std::vector<IndexType> local_p_size(num_subdomains);
76     auto global_to_local = metadata.global_to_local->get_data();
77     auto local_to_global = metadata.local_to_global->get_data();
78
79     auto first_row = metadata.first_row->get_data();
80     auto permutation = metadata.permutation->get_data();
81     auto i_permutation = metadata.i_permutation->get_data();
82
83     auto nb = (global_size + num_subdomains - 1) /
      num_subdomains;
84     auto partition_settings =
```

```
85          (Settings::partition_settings::partition_zoltan |
86           Settings::partition_settings::partition_metis |
87           Settings::partition_settings::partition_regular |
88           Settings::partition_settings::partition_regular2d |
89           Settings::partition_settings::partition_custom) &
90          settings.partition;
91
92      IndexType *gmat_row_ptrs = global_matrix->get_row_ptrs();
93      IndexType *gmat_col_idxs = global_matrix->get_col_idxs();
94      ValueType *gmat_values = global_matrix->get_values();
95
96      // default local p size set for 1 subdomain.
97      first_row[0] = 0;
98      for (auto p = 0; p < num_subdomains; ++p)
99      {
100          local_p_size[p] = std::min(global_size - first_row[p], nb);
101          first_row[p + 1] = first_row[p] + local_p_size[p];
102      }
103
104      if (partition_settings == Settings::partition_settings::partition_metis ||
105          partition_settings == Settings::partition_settings::partition_regular2d)
106      {
107          if (num_subdomains > 1)
108          {
109              for (auto p = 0; p < num_subdomains; p++)
110              {
111                  local_p_size[p] = 0;
112              }
113              for (auto i = 0; i < global_size; i++)
114              {
115                  local_p_size[partition_indices[i]]++;
116              }
117              first_row[0] = 0;
118              for (auto p = 0; p < num_subdomains; ++p)
119              {
120                  first_row[p + 1] = first_row[p] + local_p_size[p];
121              }
122              // permutation
123              for (auto i = 0; i < global_size; i++)
124              {
125                  permutation[first_row[partition_indices[i]]] = i;
126                  first_row[partition_indices[i]]++;
127              }
128              for (auto p = num_subdomains; p > 0; p--)
129              {
130                  first_row[p] = first_row[p - 1];
131              }
132              first_row[0] = 0;
133
134              // iperm
135              for (auto i = 0; i < global_size; i++)
136              {
137                  i_permutation[permutation[i]] = i;
138              }
139          }
140
141          auto gmat_temp = mtx::create(settings.executor->get_master(),
142                                       global_matrix->get_size(),
143                                       global_matrix->get_num_stored_elements());
144
145          auto nnz = 0;
146          gmat_temp->get_row_ptrs()[0] = 0;
147          for (auto row = 0; row < metadata.global_size; ++row)
148          {
149              for (auto col = gmat_row_ptrs[permutation[row]];
150                   col < gmat_row_ptrs[permutation[row] + 1]; ++col)
151              {
152                  gmat_temp->get_col_idxs()[nnz] =
153                      i_permutation[gmat_col_idxs[col]];
154                  gmat_temp->get_values()[nnz] = gmat_values[col];
155                  nnz++;
156              }
157              gmat_temp->get_row_ptrs()[row + 1] = nnz;
158          }
159          global_matrix->copy_from(gmat_temp.get());
160      }
161      for (auto i = 0; i < global_size; i++)
162      {
163          global_to_local[i] = 0;
164          local_to_global[i] = 0;
165      }
166      auto num = 0;
167      for (auto i = first_row[my_rank]; i < first_row[
    my_rank + 1]; i++)
168      {
169          global_to_local[i] = 1 + num;
170          local_to_global[num] = i;
```

```
171         num++;
172     }
173 
174     IndexType old = 0;
175     for (auto k = 1; k < settings.overlap; k++)
176     {
177         auto now = num;
178         for (auto i = old; i < now; i++)
179         {
180             for (auto j = gmat_row_ptrs[local_to_global[i]];
181                  j < gmat_row_ptrs[local_to_global[i] + 1]; j++)
182             {
183                 if (global_to_local[gmat_col_idxs[j]] == 0)
184                 {
185                     local_to_global[num] = gmat_col_idxs[j];
186                     global_to_local[gmat_col_idxs[j]] = 1 + num;
187                     num++;
188                 }
189             }
190         }
191         old = now;
192     }
193     metadata.local_size = local_p_size[my_rank];
194     metadata.local_size_x = num;
195     metadata.local_size_o = global_size;
196     auto local_size = metadata.local_size;
197     auto local_size_x = metadata.local_size_x;
198 
199     metadata.overlap_size = num - metadata.local_size;
200     metadata.overlap_row = std::shared_ptr<vec_itype>(
201         new vec_itype(gko::Array<IndexType>::view(
202             settings.executor, metadata.overlap_size,
203             &(metadata.local_to_global->get_data()[metadata.local_size]))),
204         std::default_delete<vec_itype>());
205 
206     auto nnz_local = 0;
207     auto nnz_interface = 0;
208 
209     for (auto i = first_row[my_rank]; i < first_row[my_rank + 1]; ++i)
210     {
211         for (auto j = gmat_row_ptrs[i]; j < gmat_row_ptrs[i + 1]; j++)
212         {
213             if (global_to_local[gmat_col_idxs[j]] != 0)
214             {
215                 nnz_local++;
216             }
217             else
218             {
219                 std::cout << " debug: invalid edge?" << std::endl;
220             }
221         }
222     }
223     auto temp = 0;
224     for (auto k = 0; k < metadata.overlap_size; k++)
225     {
226         temp = metadata.overlap_row->get_data()[k];
227         for (auto j = gmat_row_ptrs[temp]; j < gmat_row_ptrs[temp + 1]; j++)
228         {
229             if (global_to_local[gmat_col_idxs[j]] != 0)
230             {
231                 nnz_local++;
232             }
233             else
234             {
235                 nnz_interface++;
236             }
237         }
238     }
239 
240     std::shared_ptr<mtx> local_matrix_compute;
241     local_matrix_compute = mtx::create(settings.executor->get_master(),
242                                        gko::dim<2>(local_size_x), nnz_local);
243     IndexType *lmat_row_ptrs = local_matrix_compute->get_row_ptrs();
244     IndexType *lmat_col_idxs = local_matrix_compute->get_col_idxs();
245     ValueType *lmat_values = local_matrix_compute->get_values();
246 
247     std::shared_ptr<mtx> interface_matrix_compute;
248     if (nnz_interface > 0)
249     {
250         interface_matrix_compute =
251             mtx::create(settings.executor->get_master(),
252                         gko::dim<2>(local_size_x), nnz_interface);
253     }
254     else
255     {
256         interface_matrix_compute = mtx::create(settings.executor->get_master());
257     }
```

```
258
259     IndexType *imat_row_ptrs = interface_matrix_compute->get_row_ptrs();
260     IndexType *imat_col_idxs = interface_matrix_compute->get_col_idxs();
261     ValueType *imat_values = interface_matrix_compute->get_values();
262
263     num = 0;
264     nnz_local = 0;
265     auto nnz_interface_temp = 0;
266     lmat_row_ptrs[0] = nnz_local;
267     if (nnz_interface > 0)
268     {
269          imat_row_ptrs[0] = nnz_interface_temp;
270     }
271
272     // Local interior matrix
273     for (auto i = first_row[my_rank]; i < first_row[my_rank + 1]; ++i)
274     {
275         for (auto j = gmat_row_ptrs[i]; j < gmat_row_ptrs[i + 1]; ++j)
276         {
277             if (global_to_local[gmat_col_idxs[j]] != 0)
278             {
279                 lmat_col_idxs[nnz_local] =
280                     global_to_local[gmat_col_idxs[j]] - 1;
281                 lmat_values[nnz_local] = gmat_values[j];
282                 nnz_local++;
283             }
284         }
285         if (nnz_interface > 0)
286         {
287             imat_row_ptrs[num + 1] = nnz_interface_temp;
288         }
289         lmat_row_ptrs[num + 1] = nnz_local;
290         num++;
291     }
292
293     // Interface matrix
294     if (nnz_interface > 0)
295     {
296         nnz_interface = 0;
297         for (auto k = 0; k < metadata.overlap_size; k++)
298         {
299             temp = metadata.overlap_row->get_data()[k];
300             for (auto j = gmat_row_ptrs[temp]; j < gmat_row_ptrs[temp + 1];
301                  j++)
302             {
303                 if (global_to_local[gmat_col_idxs[j]] != 0)
304                 {
305                     lmat_col_idxs[nnz_local] =
306                         global_to_local[gmat_col_idxs[j]] - 1;
307                     lmat_values[nnz_local] = gmat_values[j];
308                     nnz_local++;
309                 }
310                 else
311                 {
312                     imat_col_idxs[nnz_interface] = gmat_col_idxs[j];
313                     imat_values[nnz_interface] = gmat_values[j];
314                     nnz_interface++;
315                 }
316             }
317             lmat_row_ptrs[num + 1] = nnz_local;
318             imat_row_ptrs[num + 1] = nnz_interface;
319             num++;
320         }
321     }
322     auto now = num;
323     for (auto i = old; i < now; i++)
324     {
325         for (auto j = gmat_row_ptrs[local_to_global[i]];
326              j < gmat_row_ptrs[local_to_global[i] + 1]; j++)
327         {
328             if (global_to_local[gmat_col_idxs[j]] == 0)
329             {
330                 local_to_global[num] = gmat_col_idxs[j];
331                 global_to_local[gmat_col_idxs[j]] = 1 + num;
332                 num++;
333             }
334         }
335     }
336
337     local_matrix = mtx::create(settings.executor);
338     local_matrix->copy_from(gko::lend(local_matrix_compute));
339     interface_matrix = mtx::create(settings.executor);
340     interface_matrix->copy_from(gko::lend(interface_matrix_compute));
341
342     local_matrix->sort_by_column_index();
343     interface_matrix->sort_by_column_index();
344 }
```

7.16.3.3 setup_windows()

```
template<typename ValueType , typename IndexType >
void schwz::SolverRAS< ValueType, IndexType >::setup_windows (
            const Settings & settings,
            const Metadata< ValueType, IndexType > & metadata,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & main_buffer )  [override],
[virtual]
```

Sets up the windows needed for the asynchronous communication.

Parameters

settings	The settings struct.
metadata	The metadata struct.
main_buffer	The main buffer being exchanged between the subdomains.

Implements schwz::Communicate< ValueType, IndexType >.

References schwz::Metadata< ValueType, IndexType >::constant, schwz::Communicate< ValueType, IndexType >::comm_struct::curr_recv_avg, schwz::Communicate< ValueType, IndexType >::comm_struct::curr_send_avg, schwz::Settings::comm_settings::enable_flush_all, schwz::Settings::comm_settings::enable_flush_local, schwz::Settings::comm_settings::enable_get, schwz::Settings::comm_settings::enable_lock_all, schwz::Settings::comm_settings::enable_one_by_one, schwz::Settings::comm_settings::enable_onesided, schwz::Settings::comm_settings::enable_overlap, schwz::Settings::comm_settings::enable_put, schwz::Settings::executor, schwz::Metadata< ValueType, IndexType >::gamma, schwz::Communicate< ValueType, IndexType >::comm_struct::get_displacements, schwz::Communicate< ValueType, IndexType >::comm_struct::get_request, schwz::Communicate< ValueType, IndexType >::comm_struct::global_get, schwz::Communicate< ValueType, IndexType >::comm_struct::global_put, schwz::SchwarzBase< ValueType, IndexType >::global_solution, schwz::Communicate< ValueType, IndexType >::comm_struct::is_local_neighbor, schwz::Metadata< ValueType, IndexType >::iter_count, schwz::Communicate< ValueType, IndexType >::comm_struct::last_recv_avg, schwz::Communicate< ValueType, IndexType >::comm_struct::last_recv_bdy, schwz::Communicate< ValueType, IndexType >::comm_struct::last_recv_iter, schwz::Communicate< ValueType, IndexType >::comm_struct::last_send_avg, schwz::SchwarzBase< ValueType, IndexType >::last_solution, schwz::Communicate< ValueType, IndexType >::comm_struct::local_get, schwz::Communicate< ValueType, IndexType >::comm_struct::local_neighbors_in, schwz::Communicate< ValueType, IndexType >::comm_struct::local_neighbors_out, schwz::Communicate< ValueType, IndexType >::comm_struct::local_num_neighbors_in, schwz::Communicate< ValueType, IndexType >::comm_struct::local_num_neighbors_out, schwz::Communicate< ValueType, IndexType >::comm_struct::local_put, schwz::Metadata< ValueType, IndexType >::local_size_o, schwz::Communicate< ValueType, IndexType >::comm_struct::msg_count, schwz::Communicate< ValueType, IndexType >::comm_struct::neighbors_in, schwz::Communicate< ValueType, IndexType >::comm_struct::neighbors_out, schwz::Communicate< ValueType, IndexType >::comm_struct::num_neighbors_in, schwz::Communicate< ValueType, IndexType >::comm_struct::num_neighbors_out, schwz::Metadata< ValueType, IndexType >::num_subdomains, schwz::Communicate< ValueType, IndexType >::comm_struct::put_displacements, schwz::Communicate< ValueType, IndexType >::comm_struct::put_request, schwz::Communicate< ValueType, IndexType >::comm_struct::recv_buffer, schwz::Communicate< ValueType, IndexType >::comm_struct::remote_get, schwz::Communicate< ValueType, IndexType >::comm_struct::remote_put, schwz::Communicate< ValueType, IndexType >::comm_struct::sec_last_recv_bdy, schwz::Communicate< ValueType, IndexType >::comm_struct::sec_last_recv_iter, schwz::Communicate< ValueType, IndexType >::comm_struct::send_buffer, schwz::Communicate< ValueType, IndexType >::comm_struct::third_last_recv_bdy, schwz::Communicate< ValueType, IndexType >::comm_struct::third_last_recv_iter, schwz::Communicate< ValueType, IndexType >::comm_struct::window_recv_buffer, schwz::Communicate< ValueType, IndexType >::comm_struct::window_send_buffer, and schwz::Communicate< ValueType, IndexType >::comm_struct::window_x.

```
{
    using vec_itype = gko::Array<IndexType>;
    using vec_vtype = gko::matrix::Dense<ValueType>;
    auto num_subdomains = metadata.num_subdomains;
    auto local_size_o = metadata.local_size_o;
    auto neighbors_in = this->comm_struct.neighbors_in->get_data();
    auto global_get = this->comm_struct.global_get->get_data();
    auto neighbors_out = this->comm_struct.neighbors_out->get_data();
    auto global_put = this->comm_struct.global_put->get_data();

    // set displacement for the MPI buffer
    auto get_displacements = this->comm_struct.get_displacements->get_data();
    auto put_displacements = this->comm_struct.put_displacements->get_data();
    {
        std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
        tmp_num_comm_elems[0] = 0;
        for (auto j = 0; j < this->comm_struct.num_neighbors_in; j++) {
            if ((global_get[j])[0] > 0) {
                int p = neighbors_in[j];
                tmp_num_comm_elems[p + 1] = (global_get[j])[0];
            }
        }
        for (auto j = 0; j < num_subdomains; j++) {
            tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
        }

        auto mpi_itype = boost::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
        MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, put_displacements,
                     1, mpi_itype, MPI_COMM_WORLD);
    }

    {
        std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
        tmp_num_comm_elems[0] = 0;
        for (auto j = 0; j < this->comm_struct.num_neighbors_out; j++) {
            if ((global_put[j])[0] > 0) {
                int p = neighbors_out[j];
                tmp_num_comm_elems[p + 1] = (global_put[j])[0];
            }
        }
        for (auto j = 0; j < num_subdomains; j++) {
            tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
        }

        auto mpi_itype = boost::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
        MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, get_displacements,
                     1, mpi_itype, MPI_COMM_WORLD);
    }

    // setup windows
    if (settings.comm_settings.enable_onesided)
    {
        // Onesided
        MPI_Win_create(main_buffer->get_values(),
                       main_buffer->get_size()[0] * sizeof(ValueType),
                       sizeof(ValueType), MPI_INFO_NULL, MPI_COMM_WORLD,
                       &(this->comm_struct.window_x));
    }

    if (settings.comm_settings.enable_onesided)
    {
        // MPI_Alloc_mem ? Custom allocator ?  TODO
        MPI_Win_create(this->local_residual_vector->get_values(),
                       (num_subdomains) * sizeof(ValueType), sizeof(ValueType),
                       MPI_INFO_NULL, MPI_COMM_WORLD,
                       &(this->window_residual_vector));
        std::vector<IndexType> zero_vec(num_subdomains, 0);
        gko::Array<IndexType> temp_array{settings.executor->get_master(),
                                         zero_vec.begin(), zero_vec.end()};
        this->convergence_vector = std::shared_ptr<vec_itype>(
            new vec_itype(settings.executor->get_master(), temp_array),
            std::default_delete<vec_itype>());
        this->convergence_sent = std::shared_ptr<vec_itype>(
            new vec_itype(settings.executor->get_master(), num_subdomains),
            std::default_delete<vec_itype>());
        this->convergence_local = std::shared_ptr<vec_itype>(
            new vec_itype(settings.executor->get_master(), num_subdomains),
            std::default_delete<vec_itype>());
        MPI_Win_create(this->convergence_vector->get_data(),
                       (num_subdomains) * sizeof(IndexType), sizeof(IndexType),
                       MPI_INFO_NULL, MPI_COMM_WORLD,
                       &(this->window_convergence));
    }

    if (settings.comm_settings.enable_onesided && num_subdomains > 1)
    {
        // Lock all windows.
```

```
738         if (settings.comm_settings.enable_get &&
739             settings.comm_settings.enable_lock_all) {
740             MPI_Win_lock_all(0, this->comm_struct.window_send_buffer);
741         }
742         if (settings.comm_settings.enable_put &&
743             settings.comm_settings.enable_lock_all) {
744             MPI_Win_lock_all(0, this->comm_struct.window_recv_buffer);
745         }
746         if (settings.comm_settings.enable_one_by_one &&
747             settings.comm_settings.enable_lock_all) {
748             MPI_Win_lock_all(0, this->comm_struct.window_x);
749         }
750         MPI_Win_lock_all(0, this->window_residual_vector);
751         MPI_Win_lock_all(0, this->window_convergence);
752     }
753 }
```

7.16.3.4 update_boundary()

```
template<typename ValueType , typename IndexType >
void schwz::SolverRAS< ValueType, IndexType >::update_boundary (
             const Settings & settings,
             const Metadata< ValueType, IndexType > & metadata,
             std::shared_ptr< gko::matrix::Dense< ValueType >> & local_solution,
             const std::shared_ptr< gko::matrix::Dense< ValueType >> & local_rhs,
             const std::shared_ptr< gko::matrix::Dense< ValueType >> & global_solution,
             const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & interface_↩
matrix )  [override], [virtual]
```

Update the values into local vector from obtained from the neighboring sub-domains using the interface matrix.

Parameters

settings	The settings struct.
metadata	The metadata struct.
local_solution	The local solution vector in the subdomain.
local_rhs	The local right hand side vector in the subdomain.
global_solution	The workspace solution vector.
global_old_solution	The global solution vector of the previous iteration.
interface_matrix	The interface matrix containing the interface and the overlap data mainly used for exchanging values between different sub-domains.

Implements schwz::Communicate< ValueType, IndexType >.

References schwz::Settings::executor, schwz::SchwarzBase< ValueType, IndexType >::global_solution, schwz↩ ::SchwarzBase< ValueType, IndexType >::interface_matrix, schwz::SchwarzBase< ValueType, IndexType >↩ ::local_rhs, schwz::Metadata< ValueType, IndexType >::local_size_x, schwz::SchwarzBase< ValueType, Index↩ Type >::local_solution, schwz::Metadata< ValueType, IndexType >::num_subdomains, and schwz::Settings↩ ::overlap.

```
1163 {
1164     using vec_vtype = gko::matrix::Dense<ValueType>;
1165     auto one = gko::initialize<gko::matrix::Dense<ValueType>>(
1166         {1.0}, settings.executor);
1167     auto neg_one = gko::initialize<gko::matrix::Dense<ValueType>>(
1168         {-1.0}, settings.executor);
1169     auto local_size_x = metadata.local_size_x;
1170     local_solution->copy_from(local_rhs.get());
```

```
1171     if (metadata.num_subdomains > 1 && settings.overlap > 0) {
1172         auto temp_solution = vec_vtype::create(
1173             settings.executor, local_solution->get_size(),
1174             gko::Array<ValueType>::view(settings.executor,
1175                                         local_solution->get_size()[0],
1176                                         global_solution->get_values()),
1177             1);
1178         interface_matrix->apply(neg_one.get(), temp_solution.get(), one.get(),
1179                                 local_solution.get());
1180     }
1181 }
```

The documentation for this class was generated from the following files:

- restricted_schwarz.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/restricted_schwarz.cpp (4633d6a)

7.17 UmfpackError Class Reference

UmfpackError is thrown when a METIS routine throws a non-zero error code.

`#include <exception.hpp>`

Public Member Functions

- UmfpackError (const std::string &file, int line, const std::string &func, int error_code)

  Initializes a METIS error.

7.17.1 Detailed Description

UmfpackError is thrown when a METIS routine throws a non-zero error code.

7.17.2 Constructor & Destructor Documentation

7.17.2.1 UmfpackError()

```
UmfpackError::UmfpackError (
            const std::string & file,
            int line,
            const std::string & func,
            int error_code )  [inline]
```

Initializes a METIS error.

Parameters

file	The name of the offending source file
line	The source code line number where the error occurred
func	The name of the METIS routine that failed
error_code	The resulting METIS error code

```
205         : Error(file, line, func + ": " + get_error(error_code))
206     {}
```

The documentation for this class was generated from the following files:

- exception.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (4633d6a)

7.18 schwz::Utils< ValueType, IndexType > Struct Template Reference

The utilities class which provides some checks and basic utilities.

`#include <utils.hpp>`

7.18.1 Detailed Description

template<typename ValueType = gko::default_precision, typename IndexType = gko::int32>
struct schwz::Utils< ValueType, IndexType >

The utilities class which provides some checks and basic utilities.

Template Parameters

ValueType	The type of the floating point values.
IndexType	The type of the index type values.

Utils

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

- utils.hpp (4633d6a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/utils.cpp (4633d6a)

Index