

schwz

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# 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 -DSCHWARZ_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

<i>file</i>	The name of the offending source file
<i>line</i>	The source code line number where the error occurred
<i>func</i>	The function name where the error occurred
<i>op_name</i>	The name of the operator
<i>op_num_rows</i>	The row dimension of the operator
<i>op_num_cols</i>	The column dimension of the operator
<i>clarification</i>	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 (10366ee)

## 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 (10366ee)

## 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` (10366ee)

## 7.4 schwz::Communicate&lt; ValueType, IndexType &gt; 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

<i>ValueType</i>	The type of the floating point values.
<i>IndexType</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>global_solution</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>local_vector</i>	The local vector in question.
<i>global_vector</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>main_buffer</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>local_solution</i>	The local solution vector in the subdomain.
<i>local_rhs</i>	The local right hand side vector in the subdomain.
<i>global_solution</i>	The workspace solution vector.
<i>global_old_solution</i>	The global solution vector of the previous iteration.
<i>interface_matrix</i>	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 \(10366ee\)](#)
- [/home/runner/work/schwarz-lib/schwarz-lib/source/communicate.cpp \(10366ee\)](#)

## 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 \(10366ee\)](#)

## 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

<i>file</i>	The name of the offending source file
<i>line</i>	The source code line number where the error occurred
<i>func</i>	The name of the CUDA routine that failed
<i>error_code</i>	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 (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (10366ee)

## 7.7 CusparsedError Class Reference

[CusparsedError](#) is thrown when a cuSPARSE routine throws a non-zero error code.

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

### Public Member Functions

- [CusparsedError](#) (const std::string &file, int line, const std::string &func, int error\_code)  
*Initializes a cuSPARSE error.*

#### 7.7.1 Detailed Description

[CusparsedError](#) is thrown when a cuSPARSE routine throws a non-zero error code.

#### 7.7.2 Constructor & Destructor Documentation

##### 7.7.2.1 CusparsedError()

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

Initializes a cuSPARSE error.

#### Parameters

<i>file</i>	The name of the offending source file
<i>line</i>	The source code line number where the error occurred
<i>func</i>	The name of the cuSPARSE routine that failed
<i>error_code</i>	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 (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (10366ee)

## 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` (10366ee)

## 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

<i>ValueType</i>	The type of the floating point values.
<i>IndexType</i>	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

<i>rhs</i>	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

<i>rhs</i>	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

<i>rhs</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>global_matrix</i>	The global matrix.
<i>partition_indices</i>	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

<i>oned_laplacian_size</i>	The size of the one d laplacian grid.
<i>global_matrix</i>	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 *
257             oned_laplacian_size;
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

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

## Parameters

<i>interface_matrix</i>	The interface matrix containing the interface and the overlap data mainly used for exchanging values between different sub-domains.
<i>local_perm</i>	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

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

References [schwz::Settings::executor](#), [schwz::Metadata< ValueType, IndexType >::first\\_row](#), [schwz::Metadata< ValueType, IndexType >::global\\_size](#), [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.global_size, 1));
403 }

```

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

- initialization.hpp (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/initialization.cpp (10366ee)

## 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

<i>ValueType</i>	The type of the floating point values.
<i>IndexType</i>	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 (10366ee)

## 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

<i>file</i>	The name of the offending source file
<i>line</i>	The source code line number where the error occurred
<i>func</i>	The name of the METIS routine that failed
<i>error_code</i>	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 (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (10366ee)

## 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 (10366ee)

## 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

<i>ValueType</i>	The type of the floating point values.
<i>IndexType</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	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

<i>matrix</i>	The matrix to be printed.
<i>subd</i>	The subdomain on which the vector exists.
<i>name</i>	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

<i>vector</i>	The vector to be printed.
<i>subd</i>	The subdomain on which the vector exists.
<i>name</i>	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

<i>solution</i>	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], rcv_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(rcv_name, "rcv");
379     strcat(rcv_name, pe_str);
380     strcat(rcv_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(rcv_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         // Check for the convergence of the solver.
407         // num_converged_procs = 0;
408         MEASURE_ELAPSED_FUNC_TIME(
409             (Solve<ValueType, IndexType>::check_convergence(
410                 settings, metadata, this->comm_struct, this->convergence_vector,
411                 global_solution, this->local_solution, this->
local_matrix,
412                 work_vector, local_residual_norm, local_residual_norm0,
413                 global_residual_norm, global_residual_norm0,
414                 num_converged_procs)),
415             2, metadata.my_rank, convergence_check, metadata.iter_count);
416
417         // break if the solution diverges.
418         if (std::isnan(global_residual_norm) || global_residual_norm > 1e12) {
419             std::cout << " Rank " << metadata.my_rank << " diverged in "
420                 << metadata.iter_count << " iters " << std::endl;
421             std::exit(-1);
422         }
423
424         // break if all processes detect that all other processes have
425         // converged otherwise continue iterations.
426         if (num_converged_procs == metadata.num_subdomains) {
427             break;
428         } else {
429             MEASURE_ELAPSED_FUNC_TIME(

```

```

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

```

```

515         << std::endl;
516         if (num_converged_procs < metadata.num_subdomains)
517         {
518             std::cout << " Did not converge in " << metadata.iter_count
519                 << " iterations."
520                 << std::endl;
521         }
522     }
523     // clang-format on
524     if (metadata.my_rank == 0) {
525         solution->copy_from(global_solution.get());
526     }
527
528     // Communicate<ValueType, IndexType>::clear(settings);
529 }

```

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

- schwarz\_base.hpp (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/schwarz\_base.cpp (10366ee)

## 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 (10366ee)

## 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

<i>ValueType</i>	The type of the floating point values.
<i>IndexType</i>	The type of the index type values.

#### [Solve](#)

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

- solve.hpp (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/solve.cpp (10366ee)

## 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

<i>ValueType</i>	The type of the floating point values.
<i>IndexType</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>data</i>	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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>global_solution</i>	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,
1146             last_solution, fps, fpr);
1147     }
1148     else
1149     {
1150         exchange_boundary_twosided<ValueType, IndexType>(
1151             settings, metadata, this->comm_struct, global_solution);
1152     }
1153 }

```

## 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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>partition_indices</i>	The array containing the partition indices.
<i>global_matrix</i>	The global system matrix.
<i>local_matrix</i>	The local system matrix.
<i>interface_matrix</i>	The interface matrix containing the interface and the overlap data mainly used for exchanging values between different sub-domains.
<i>local_perm</i>	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_idxes = global_matrix->get_col_idxes();
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_idxes()[nnz] =
153                     i_permutation[gmat_col_idxes[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[
168 my_rank + 1]; i++)
169     {
170         global_to_local[i] = 1 + num;
171         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_idxes[j]] == 0)
184                 {
185                     local_to_global[num] = gmat_col_idxes[j];
186                     global_to_local[gmat_col_idxes[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_idxes[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_idxes[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_idxes = local_matrix_compute->get_col_idxes();
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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>main_buffer</i>	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\\_rcv\\_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\\_rcv\\_avg](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::last\\_rcv\\_bdy](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::last\\_rcv\\_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::rcv\\_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\\_rcv\\_bdy](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::sec\\_last\\_rcv\\_iter](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::send\\_buffer](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::third\\_last\\_rcv\\_bdy](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::third\\_last\\_rcv\\_iter](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::window\\_rcv\\_buffer](#), [schwz::Communicate< ValueType, IndexType >::comm\\_struct::window\\_send\\_buffer](#), and [schwz::Communicate< ValueType, IndexType >::comm\\_struct::window\\_x](#).

```

651 {
652     using vec_itype = gko::Array<IndexType>;
653     using vec_vtype = gko::matrix::Dense<ValueType>;
654     auto num_subdomains = metadata.num_subdomains;
655     auto local_size_o = metadata.local_size_o;
656     auto neighbors_in = this->comm_struct.neighbors_in->get_data();
657     auto global_get = this->comm_struct.global_get->get_data();
658     auto neighbors_out = this->comm_struct.neighbors_out->get_data();
659     auto global_put = this->comm_struct.global_put->get_data();
660
661     // set displacement for the MPI buffer
662     auto get_displacements = this->comm_struct.get_displacements->get_data();
663     auto put_displacements = this->comm_struct.put_displacements->get_data();
664     {
665         std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
666         tmp_num_comm_elems[0] = 0;
667         for (auto j = 0; j < this->comm_struct.num_neighbors_in; j++) {
668             if ((global_get[j])[0] > 0) {
669                 int p = neighbors_in[j];
670                 tmp_num_comm_elems[p + 1] = (global_get[j])[0];
671             }
672         }
673         for (auto j = 0; j < num_subdomains; j++) {
674             tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
675         }
676
677         auto mpi_itype = boost::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
678         MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, put_displacements,
679                     1, mpi_itype, MPI_COMM_WORLD);
680     }
681
682     {
683         std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
684         tmp_num_comm_elems[0] = 0;
685         for (auto j = 0; j < this->comm_struct.num_neighbors_out; j++) {
686             if ((global_put[j])[0] > 0) {
687                 int p = neighbors_out[j];
688                 tmp_num_comm_elems[p + 1] = (global_put[j])[0];
689             }
690         }
691         for (auto j = 0; j < num_subdomains; j++) {
692             tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
693         }
694
695         auto mpi_itype = boost::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
696         MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, get_displacements,
697                     1, mpi_itype, MPI_COMM_WORLD);
698     }
699
700     // setup windows
701     if (settings.comm_settings.enable_onesided)
702     {
703         // Onesided
704         MPI_Win_create(main_buffer->get_values(),
705                        main_buffer->get_size()[0] * sizeof(ValueType),
706                        sizeof(ValueType), MPI_INFO_NULL, MPI_COMM_WORLD,
707                        &(this->comm_struct.window_x));
708     }
709
710     if (settings.comm_settings.enable_onesided)
711     {
712         // MPI_Alloc_mem ? Custom allocator ? TODO
713         MPI_Win_create(this->local_residual_vector->get_values(),
714                        (num_subdomains) * sizeof(ValueType), sizeof(ValueType),
715                        MPI_INFO_NULL, MPI_COMM_WORLD,
716                        &(this->window_residual_vector));
717         std::vector<IndexType> zero_vec(num_subdomains, 0);
718         gko::Array<IndexType> temp_array(settings.executor->get_master(),
719                                         zero_vec.begin(), zero_vec.end());
720         this->convergence_vector = std::shared_ptr<vec_itype>(
721             new vec_itype(settings.executor->get_master(), temp_array),
722             std::default_delete<vec_itype>());
723         this->convergence_sent = std::shared_ptr<vec_itype>(
724             new vec_itype(settings.executor->get_master(), num_subdomains),
725             std::default_delete<vec_itype>());
726         this->convergence_local = std::shared_ptr<vec_itype>(
727             new vec_itype(settings.executor->get_master(), num_subdomains),
728             std::default_delete<vec_itype>());
729         MPI_Win_create(this->convergence_vector->get_data(),
730                        (num_subdomains) * sizeof(IndexType), sizeof(IndexType),
731                        MPI_INFO_NULL, MPI_COMM_WORLD,
732                        &(this->window_convergence));
733     }
734
735     if (settings.comm_settings.enable_onesided && num_subdomains > 1)
736     {
737         // 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

<i>settings</i>	The settings struct.
<i>metadata</i>	The metadata struct.
<i>local_solution</i>	The local solution vector in the subdomain.
<i>local_rhs</i>	The local right hand side vector in the subdomain.
<i>global_solution</i>	The workspace solution vector.
<i>global_old_solution</i>	The global solution vector of the previous iteration.
<i>interface_matrix</i>	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` (10366ee)
- `/home/runner/work/schwarz-lib/schwarz-lib/source/restricted_schwarz.cpp` (10366ee)

## 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

<i>file</i>	The name of the offending source file
<i>line</i>	The source code line number where the error occurred
<i>func</i>	The name of the METIS routine that failed
<i>error_code</i>	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 (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (10366ee)

## 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

<i>ValueType</i>	The type of the floating point values.
<i>IndexType</i>	The type of the index type values.

#### Utils

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

- utils.hpp (10366ee)
- /home/runner/work/schwarz-lib/schwarz-lib/source/utils.cpp (10366ee)



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