

schwz

Generated automatically from mixed-precision-solve

Generated by Doxygen 1.8.13

Contents

1	Main Page	1
2	# Installation Instructions	3
3	Testing Instructions	5
4	Benchmarking.	7
5	Module Documentation	11
5.1	Communicate	11
5.1.1	Detailed Description	11
5.2	Initialization	12
5.2.1	Detailed Description	12
5.3	Schwarz Class	13
5.3.1	Detailed Description	13
5.4	Solve	14
5.4.1	Detailed Description	14
5.5	Utils	15
5.5.1	Detailed Description	15
6	Namespace Documentation	17
6.1	ProcessTopology Namespace Reference	17
6.1.1	Detailed Description	17
6.2	schwz Namespace Reference	17
6.2.1	Detailed Description	18
6.3	schwz::CommHelpers Namespace Reference	18
6.3.1	Detailed Description	18
6.4	schwz::conv_tools Namespace Reference	18
6.4.1	Detailed Description	18
6.5	schwz::PartitionTools Namespace Reference	19
6.5.1	Detailed Description	19
6.6	schwz::SolverTools Namespace Reference	19
6.6.1	Detailed Description	19

7	Class Documentation	21
7.1	BadDimension Class Reference	21
7.1.1	Detailed Description	21
7.1.2	Constructor & Destructor Documentation	21
7.1.2.1	BadDimension()	21
7.2	schwz::Settings::comm_settings Struct Reference	22
7.2.1	Detailed Description	23
7.3	schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct Struct Reference	23
7.3.1	Detailed Description	24
7.3.2	Member Data Documentation	24
7.3.2.1	global_get	24
7.3.2.2	global_put	25
7.3.2.3	is_local_neighbor	25
7.3.2.4	local_get	25
7.3.2.5	local_put	26
7.3.2.6	remote_get	26
7.3.2.7	remote_put	26
7.4	schwz::Communicate< ValueType, IndexType, MixedValueType > Class Template Reference	27
7.4.1	Detailed Description	27
7.4.2	Member Function Documentation	28
7.4.2.1	exchange_boundary()	28
7.4.2.2	local_to_global_vector()	28
7.4.2.3	setup_windows()	29
7.4.2.4	update_boundary()	29
7.5	schwz::Settings::convergence_settings Struct Reference	30
7.5.1	Detailed Description	30
7.6	CudaError Class Reference	30
7.6.1	Detailed Description	31
7.6.2	Constructor & Destructor Documentation	31
7.6.2.1	CudaError()	31

7.7	CusparsError Class Reference	31
7.7.1	Detailed Description	32
7.7.2	Constructor & Destructor Documentation	32
7.7.2.1	CusparsError()	32
7.8	schwz::device_guard Class Reference	32
7.8.1	Detailed Description	32
7.9	schwz::Initialize< ValueType, IndexType > Class Template Reference	33
7.9.1	Detailed Description	33
7.9.2	Member Function Documentation	34
7.9.2.1	generate_rhs()	34
7.9.2.2	partition()	34
7.9.2.3	setup_global_matrix()	35
7.9.2.4	setup_local_matrices()	37
7.9.2.5	setup_vectors()	37
7.10	schwz::Metadata< ValueType, IndexType > Struct Template Reference	38
7.10.1	Detailed Description	40
7.10.2	Member Data Documentation	40
7.10.2.1	local_solver_tolerance	40
7.10.2.2	tolerance	40
7.11	MetisError Class Reference	40
7.11.1	Detailed Description	41
7.11.2	Constructor & Destructor Documentation	41
7.11.2.1	MetisError()	41
7.12	schwz::Metadata< ValueType, IndexType >::post_process_data Struct Reference	41
7.12.1	Detailed Description	42
7.13	schwz::SchwarzBase< ValueType, IndexType, MixedValueType > Class Template Reference	42
7.13.1	Detailed Description	43
7.13.2	Constructor & Destructor Documentation	43
7.13.2.1	SchwarzBase()	43
7.13.3	Member Function Documentation	44

7.13.3.1	<code>print_matrix()</code>	44
7.13.3.2	<code>print_vector()</code>	45
7.13.3.3	<code>run()</code>	45
7.14	<code>schwz::Settings</code> Struct Reference	48
7.14.1	Detailed Description	49
7.14.2	Member Data Documentation	49
7.14.2.1	<code>enable_logging</code>	50
7.14.2.2	<code>explicit_laplacian</code>	50
7.14.2.3	<code>naturally_ordered_factor</code>	50
7.15	<code>schwz::Solve< ValueType, IndexType, MixedValueType ></code> Class Template Reference	50
7.15.1	Detailed Description	50
7.16	<code>schwz::SolverRAS< ValueType, IndexType, MixedValueType ></code> Class Template Reference	51
7.16.1	Detailed Description	51
7.16.2	Constructor & Destructor Documentation	52
7.16.2.1	<code>SolverRAS()</code>	52
7.16.3	Member Function Documentation	52
7.16.3.1	<code>exchange_boundary()</code>	52
7.16.3.2	<code>setup_local_matrices()</code>	53
7.16.3.3	<code>setup_windows()</code>	56
7.16.3.4	<code>update_boundary()</code>	59
7.17	<code>UmpackError</code> Class Reference	60
7.17.1	Detailed Description	60
7.17.2	Constructor & Destructor Documentation	60
7.17.2.1	<code>UmpackError()</code>	60
7.18	<code>schwz::Utils< ValueType, IndexType ></code> Struct Template Reference	61
7.18.1	Detailed Description	61
Index		63

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.

The flag `-DSCHWARZ_BUILD_BENCHMARKING` (default ON) enables the examples and benchmarking snippets.

If `schwarz-lib` has been built with `deal.ii`, then the `deal.ii` examples, `ex_6` and `ex_9` are also built, else only the `bench_ras` example is built. The following command line options are available for this example. This is setup using `gflags`.

The executable is run in the following fashion:

```
[MPI_COMMAND] [MPI_OPTIONS] PATH_TO_EXECUTABLE [FLAGS]
```

Where `FLAGS` are the options below with the template `flag_name [type] [default_value]`. For example, to set the number of iterations of the RAS solver to 100 one would add `--num_iters=100` to the executable command above.

Generic settings

- `executor [std::string][reference]` : The executor used to run the solver, one of `reference`, `cuda` or `omp`.
- `explicit_laplacian [bool][false]` : Use the explicit laplacian instead of `deal.ii`'s matrix.
- `set_1d_laplacian_size [uint32][16]` : The number of grid points in one dimension for the 2D laplacian problem.
- `enable_random_rhs [bool][false]` : Use a random rhs instead of the default 1.0's .
- `overlap [uint32][2]` : Overlap between the domains.
- `timings_file [std::string][null]` : The filename for the timings.
- `partition [std::string][regular]` : The partitioner used. The choices are `metis`, `regular` or `regular2d`.
- `metis_objtype [std::string][null]` : The objective type to minimize for the metis partitioner. The choices are `edgcut` and `totalvol`.
- `num_threads [uint32][1]` : Number of threads to bind to a process.
- `non_symmetric_matrix [bool][false]` : Explicitly state that the matrix is non-symmetric so that the local GMRES solver is used.
- `use_mixed_precision [bool][false]` : Use mixed precision in the communication.

Input settings

- `matrix_filename` [std::string][null] : The matrix file to read the global system matrix from.

Output settings

- `enable_debug_write` [bool][false] : Enable some debugging outputs to stdout.
- `write_comm_data` [bool][false] : Write the number of sends and recvs of each subdomain to files.
- `write_perm_data` [bool][false] : Write the permutation data from CHOLMOD to a file.
- `print_config` [bool][true] : Print the configuration of the run.
- `print_matrices` [bool][false] : Print the local system matrices to a file.
- `debug` [bool][false] : Enable some possible expensive debug checks.
- `enable_logging` [bool][false] : Enable some possible expensive logging from Ginkgo.

Solver settings**Generic settings**

- `num_iters` [uint32][100] : The number of outer iterations for the RAS solver.
- `set_tol` [double][1e-6] : The Outer tolerance for the RAS solver.
- `local_tol` [double][1e-12] : The Inner tolerance for the local iterative solver.

Communication settings

- `enable_onesided` [bool][false] : Enable the onesided asynchronous communication.
- `enable_twosided` [bool][true] : Enable the twosided asynchronous communication. A dummy flag.
- `enable_one_by_one` [bool][false] : Enable putting/getting of each element in onesided communication.
- `enable_put_all_local_residual_norms` [bool][false] : Enable putting of all local residual norms"
- `enable_comm_overlap` [bool][false] : Enable overlap of communication and computation.
- `flush_type` [std::string][flush-all] : The window flush strategy. The choices are `flush-local` and `flush-all`.
- `lock_type` [std::string][lock-all] : The window lock strategy. The choices are `lock-local` and `lock-all`.
- `remote_comm_type` [std::string][get] : The type of the remote communication. `get` uses `MPI_Get` and `put` uses `MPI_Put`.

Convergence settings

- `enable_global_check` [bool][false] : Use the global convergence check for twosided.
- `global_convergence_type` [std::string][centralized-tree] : Choose the convergence detection algorithm for onesided.
- `enable_decentralized_accumulate` [bool][false] : Use accumulate strategy for decentralized convergence check..
- `enable_global_check_iter_offset` [bool][false] : Enable global convergence check only after a certain number of iterations.

Local solver settings

- `local_solver` [std::string][iterative-ginkgo] : The local solver used in the local domains. The current choices are `direct-cholmod`, `direct-ginkgo` or `iterative-ginkgo`.
- `local_factorization` [std::string][cholmod] : The factorization for the local direct solver "cholmod" or "umfpack".
- `local_reordering` [std::string][none] : The reordering for the local direct solver "none", "metis_reordering" or "rcm_reordering".
- `factor_ordering_natural` [bool][false] : If true uses natural ordering instead of the default optimized ordering. This is needed for CUDA runs as the factorization ordering needs to be given to the solver.
- `enable_local_precond` [bool][false] : If true uses the Block jacobi preconditioning for the local iterative solver.
- `precond_max_block_size` [uint32][16] : Maximum size of the blocks for the block jacobi preconditioner
- `shifted_iter` [uint32][1] : The number of iterations to communicate for the local subdomains.
- `local_max_iters` [int32][-1] : The maximum number of iterations for the local iterative solver.
- `restart_iter` [uint32][1] : The restart iter for the GMRES solver.
- `reset_local_crit_iter` [int32][-1] : The RAS iteration to reset the local iteration count.

Poisson solver using Restricted Additive Schwarz with overlap.

This example runs is written within the `benchmarking/bench_ras.cpp` file. This demonstrates the basic capabilities of `schwarz-lib`. You can use it to solve the 2D Poisson equation with a 5 point stencil or solve a generic matrix by providing it a matrix file.

Examples with deal.ii

These examples use `deal.ii`'s capabilities to generate a matrix and solution is computed with the RAS method.

Possible settings are:

- `num_refine_cycles` [uint32][1][disabled] : The number of refinement cycles when used with `deal.ii`.
- `init_refine_level` [uint32][4] : The initial refinement level of the problem. This sets the initial number of dof's.
- `dealii_orig` [bool][false] : Solve with the `deal.ii` iterative CG instead of the RAS solver.
- `vis_sol` [bool][false] : Print the solution for visualization.

Solving the n-dimensional Poisson equation with FEM.

The `benchmarking/dealii_ex_6.cpp` demonstrates the solution of the Poisson equation with adaptive refinement as explained on the [deal.ii example documentation page](#)

Solving the Advection equation with FEM.

The `benchmarking/dealii_ex_9.cpp` demonstrates the solution of the Advection equation with adaptive refinement as explained on the [deal.ii example documentation page](#)

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, MixedValueType >](#)
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, MixedValueType >](#)
An implementation of the solver interface using the RAS solver.
- class [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >](#)
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](#), [MixedValueType](#) >
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 (35a1195)

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 (92dbd95)

7.3 schwz::Communicate< ValueType, IndexType, MixedValueType >::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 (always allocated).

 - `std::shared_ptr< gko::matrix::Dense< MixedValueType > >` [mixedt_send_buffer](#)

The mixed 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 (always allocated).

 - `std::shared_ptr< gko::matrix::Dense< MixedValueType > >` [mixedt_recv_buffer](#)

The mixed precision recv buffer used for the actual communication for both one-sided and two-sided.

 - `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, typename MixedValueType>
struct schwz::Communicate< ValueType, IndexType, MixedValueType >::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 , typename MixedValueType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType, MixedValueType >::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, MixedValueType >::initialize()`, `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_comm_buffers()`, and `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_windows()`.

7.3.2.2 global_put

```
template<typename ValueType , typename IndexType , typename MixedValueType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType, MixedValueType >::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, MixedValueType >::initialize()`, `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_comm_buffers()`, and `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_windows()`.

7.3.2.3 is_local_neighbor

```
template<typename ValueType , typename IndexType , typename MixedValueType >
std::vector<bool> schwz::Communicate< ValueType, IndexType, MixedValueType >::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, MixedValueType >::initialize()`, `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_comm_buffers()`, and `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_windows()`.

7.3.2.4 local_get

```
template<typename ValueType , typename IndexType , typename MixedValueType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType, MixedValueType >::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_get[p][i]` contains the index of the solution vector to be received from subdomain `p`.

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

7.3.2.5 local_put

```
template<typename ValueType , typename IndexType , typename MixedValueType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType, Mixed←
ValueType >::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, MixedValueType >::setup_comm_buffers()`, and `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_windows()`.

7.3.2.6 remote_get

```
template<typename ValueType , typename IndexType , typename MixedValueType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType, Mixed←
ValueType >::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, MixedValueType >::setup_comm_buffers()`, and `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_windows()`.

7.3.2.7 remote_put

```
template<typename ValueType , typename IndexType , typename MixedValueType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType, Mixed←
ValueType >::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, MixedValueType >::setup_comm_buffers()`, and `schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_windows()`.

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

- `communicate.hpp` (7c9a9f7)

7.4 schwz::Communicate< ValueType, IndexType, MixedValueType > 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, const std::shared_ptr< gko::matrix::Dense< ValueType >> &prev_global_solution, std::shared_ptr< gko::matrix::Dense< ValueType >> &global_solution)=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, typename MixedValueType>
class schwz::Communicate< ValueType, IndexType, MixedValueType >
```

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 , typename MixedValueType >
void schwz::Communicate< ValueType, IndexType, MixedValueType >::exchange_boundary (
    const Settings & settings,
    const Metadata< ValueType, IndexType > & metadata,
    const std::shared_ptr< gko::matrix::Dense< ValueType >> & prev_global_solution,
    std::shared_ptr< gko::matrix::Dense< ValueType >> & global_solution ) [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, MixedValueType >](#).

Referenced by [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::run\(\)](#).

7.4.2.2 local_to_global_vector()

```
template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::Communicate< ValueType, IndexType, MixedValueType >::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.

Referenced by [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::run\(\)](#).

```
70 {
71     using vec = gko::matrix::Dense<ValueType>;
```

```

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

```

7.4.2.3 setup_windows()

```

template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::Communicate< ValueType, IndexType, MixedValueType >::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, MixedValueType >](#).

Referenced by [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::run\(\)](#).

7.4.2.4 update_boundary()

```

template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::Communicate< ValueType, IndexType, MixedValueType >::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, MixedValueType >](#).

Referenced by [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::run\(\)](#).

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

- [communicate.hpp \(7c9a9f7\)](#)
- [/home/runner/work/schwarz-lib/schwarz-lib/source/communicate.cpp \(7c9a9f7\)](#)

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 \(92dbd95\)](#)

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 (35a1195)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (35a1195)

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 (35a1195)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (35a1195)

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 (5a15602)

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_rhs](#) (std::vector< ValueType > &rhs)
Generates the 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)
Setup the vectors with default values and allocate memory 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_rhs()

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

Generates the 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, MixedValueType >::initialize()`.

```
90 {
91     std::uniform_real_distribution<double> unif(0.0, 1.0);
92     std::default_random_engine engine;
93     for (gko::size_type i = 0; i < rhs.size(); ++i) {
94         rhs[i] = unif(engine);
95     }
96 }
```

7.9.2.2 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, MixedValueType >::initialize().

```

284 {
285     partition_indices.resize(metadata.global_size);
286     if (metadata.my_rank == 0) {
287         auto partition_settings =
288             (Settings::partition_settings::partition_zoltan |
289              Settings::partition_settings::partitionmetis |
290              Settings::partition_settings::partition_regular |
291              Settings::partition_settings::partition_regular2d |
292              Settings::partition_settings::partition_custom) &
293             settings.partition;
294
295         if (partition_settings ==
296             Settings::partition_settings::partition_zoltan) {
297             SCHWARZ_NOT_IMPLEMENTED;
298         } else if (partition_settings ==
299                     Settings::partition_settings::partitionmetis) {
300             if (metadata.my_rank == 0) {
301                 std::cout << " METIS partition" << std::endl;
302             }
303             PartitionTools::PartitionMetis(
304                 settings, global_matrix, this->cell_weights,
305                 metadata.num_subdomains, partition_indices);
306         } else if (partition_settings ==
307                     Settings::partition_settings::partition_regular) {
308             if (metadata.my_rank == 0) {
309                 std::cout << " Regular 1D partition" << std::endl;
310             }
311             PartitionTools::PartitionRegular(
312                 global_matrix, metadata.num_subdomains, partition_indices);
313         } else if (partition_settings ==
314                     Settings::partition_settings::partition_regular2d) {
315             if (metadata.my_rank == 0) {
316                 std::cout << " Regular 2D partition" << std::endl;
317             }
318             PartitionTools::PartitionRegular2D(
319                 global_matrix, settings.write_debug_out,
320                 metadata.num_subdomains, partition_indices);
321         } else if (partition_settings ==
322                     Settings::partition_settings::partition_custom) {
323             // User partitions mesh manually
324             SCHWARZ_NOT_IMPLEMENTED;
325         } else {
326             SCHWARZ_NOT_IMPLEMENTED;
327         }
328     }
329 }

```

7.9.2.3 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_rhs()`, and `schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::initialize()`.

```

200 {
201     using index_type = IndexType;
202     using value_type = ValueType;
203     using mtx = gko::matrix::Csr<value_type, index_type>;
204     if (settings.matrix_filename != "null") {
205         auto input_file = std::ifstream(filename, std::ios::in);
206         if (!input_file) {
207             std::cerr << "Could not find the file \"" << filename
208                 << "\", which is required for this test.\n";
209         }
210         global_matrix =
211             gko::read<mtx>(input_file, settings.executor->get_master());
212         global_matrix->sort_by_column_index();
213         std::cout << "Matrix from file " << filename << std::endl;
214     } else if (settings.matrix_filename == "null" &&
215         settings.explicit_laplacian) {
216         std::cout << "Laplacian 2D Matrix (generated in house) " << std::endl;
217         gko::size_type global_size = oned_laplacian_size *
218             oned_laplacian_size;
219         global_matrix = mtx::create(settings.executor->get_master(),
220             gko::dim<2>(global_size), 5 * global_size);
221         value_type *values = global_matrix->get_values();
222         index_type *row_ptrs = global_matrix->get_row_ptrs();
223         index_type *col_idxs = global_matrix->get_col_idxs();
224
225         std::vector<gko::size_type> exclusion_set;
226
227         std::map<IndexType, ValueType> stencil_map = {
228             {-oned_laplacian_size, -1}, {-1, -1}, {0, 4}, {1, -1},
229             {oned_laplacian_size, -1},
230         };
231         for (auto i = 2; i < global_size; ++i) {
232             gko::size_type index = (i - 1) * oned_laplacian_size;
233             if (index * index < global_size * global_size) {
234                 exclusion_set.push_back(
235                     linearize_index(index, index - 1, global_size));
236                 exclusion_set.push_back(
237                     linearize_index(index - 1, index, global_size));
238             }
239         }
240
241         std::sort(exclusion_set.begin(),
242             exclusion_set.begin() + exclusion_set.size());
243
244         IndexType pos = 0;
245         IndexType col_idx = 0;
246         row_ptrs[0] = pos;
247         gko::size_type cur_idx = 0;
248         for (IndexType i = 0; i < global_size; ++i) {
249             for (auto ofs : stencil_map) {
250                 auto in_exclusion_flag =
251                     (exclusion_set[cur_idx] ==
252                     linearize_index(i, i + ofs.first, global_size));
253                 if (0 <= i + ofs.first && i + ofs.first < global_size &&
254                     !in_exclusion_flag) {
255                     values[pos] = ofs.second;
256                     col_idxs[pos] = i + ofs.first;
257                     ++pos;
258                 }
259                 if (in_exclusion_flag) {
260                     cur_idx++;
261                 }
262                 col_idx = row_ptrs[i + 1] - pos;
263             }
264             row_ptrs[i + 1] = pos;
265         }
266     } else {
267         std::cerr << " Need to provide a matrix or enable the default "
268             "laplacian matrix."
269             << std::endl;
270         std::exit(-1);
271     }
272 }

```

7.9.2.4 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.
<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, MixedValueType >](#).

Referenced by [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::initialize\(\)](#).

7.9.2.5 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 )
```

Setup the vectors with default values and allocate memory 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 >::local_size_x`, and `schwz::Metadata< ValueType, IndexType >::my_rank`.

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

```

339 {
340     using vec = gko::matrix::Dense<ValueType>;
341     auto my_rank = metadata.my_rank;
342     auto first_row = metadata.first_row->get_data()[my_rank];
343
344     // Copy the global rhs vector to the required executor.
345     gko::Array<ValueType> temp_rhs{settings.executor->get_master(), rhs.begin(),
346                                   rhs.end()};
347     global_rhs = vec::create(settings.executor,
348                             gko::dim<2>{metadata.global_size, 1}, temp_rhs, 1);
349
350     local_rhs =
351         vec::create(settings.executor, gko::dim<2>(metadata.local_size_x, 1));
352     // Extract the local rhs from the global rhs. Also takes into account the
353     // overlap.
354     SolverTools::extract_local_vector(settings, metadata, local_rhs.get(),
355                                       global_rhs.get(), first_row);
356
357     local_solution =
358         vec::create(settings.executor, gko::dim<2>(metadata.local_size_x, 1));
359 }
```

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

- `initialization.hpp` (200bbde)
- `/home/runner/work/schwarz-lib/schwarz-lib/source/initialization.cpp` (92dbd95)

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.*

 - IndexType `updated_max_iters`
- The updated 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.*

 - 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 (92dbd95)

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 (35a1195)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (35a1195)

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 (92dbd95)

7.13 schwz::SchwarzBase< ValueType, IndexType, MixedValueType > 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 > >` [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, typename MixedValueType = gko::
::default_precision>
class schwz::SchwarzBase< ValueType, IndexType, MixedValueType >
```

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 , typename MixedValueType >
schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::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`.

```

76     : Initialize<ValueType, IndexType>(settings, metadata),
77     settings(settings),
78     metadata(metadata)
79 {
80     using vec_itype = gko::Array<IndexType>;
81     using vec_vecshared = gko::Array<IndexType *>;
82     metadata.my_local_rank =
83         Utils<ValueType, IndexType>::get_local_rank(metadata.mpi_communicator);
84     metadata.local_num_procs = Utils<ValueType, IndexType>::get_local_num_procs(
85         metadata.mpi_communicator);
86     auto my_local_rank = metadata.my_local_rank;
87     if (settings.executor_string == "omp") {
88         settings.executor = gko::OmpExecutor::create();
89         auto exec_info =
90             static_cast<gko::OmpExecutor *>(settings.executor.get())
91             ->get_exec_info();
92         exec_info->bind_to_core(metadata.my_local_rank);
93     } else if (settings.executor_string == "cuda") {
94         int num_devices = 0;
95         #if SCHW_HAVE_CUDA
96         SCHWARZ_ASSERT_NO_CUDA_ERRORS(cudaGetDeviceCount(&num_devices));
97         #else
98         SCHWARZ_NOT_IMPLEMENTED;
99         #endif
100         Utils<ValueType, IndexType>::assert_correct_cuda_devices(
101             num_devices, metadata.my_rank);
102         settings.executor = gko::CudaExecutor::create(
103             my_local_rank, gko::OmpExecutor::create());
104         auto exec_info = static_cast<gko::OmpExecutor *>(
105             settings.executor->get_master().get())
106             ->get_exec_info();
107         exec_info->bind_to_core(my_local_rank);
108         settings.cuda_device_guard =
109             std::make_shared<schwz::device_guard>(my_local_rank);
110
111         std::cout << " Rank " << metadata.my_rank << " with local rank "
112             << my_local_rank << " has "
113             << (static_cast<gko::CudaExecutor *>(settings.executor.get()))
114             ->get_device_id()
115             << " id of gpu" << std::endl;
116         MPI_Barrier(metadata.mpi_communicator);
117     } else if (settings.executor_string == "reference") {
118         settings.executor = gko::ReferenceExecutor::create();
119         auto exec_info =
120             static_cast<gko::ReferenceExecutor *>(settings.executor.get())
121             ->get_exec_info();
122         exec_info->bind_to_core(my_local_rank);
123     }
124 }
125 }
```

7.13.3 Member Function Documentation

7.13.3.1 print_matrix()

```

template<typename ValueType = gko::default_precision, typename IndexType = gko::int32, typename
MixedValueType = gko::default_precision>
```

```
void schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::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, typename
MixedValueType = gko::default_precision>
void schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::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 , typename MixedValueType >
void schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::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, MixedValueType >::exchange_boundary()`, `schwz::Settings::executor`, `schwz::Settings::executor_string`, `schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_matrix`, `schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_rhs`, `schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_solution`, `schwz::SchwarzBase< ValueType,`

IndexType, MixedValueType >::interface_matrix, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::local_inv_perm, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::local_matrix, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::local_perm, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::local_rhs, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::local_solution, schwz::Communicate< ValueType, IndexType, MixedValueType >::local_to_global_vector(), schwz::Communicate< ValueType, IndexType, MixedValueType >::setup_windows(), schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::triangular_factor_l, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::triangular_factor_u, schwz::Communicate< ValueType, IndexType, MixedValueType >::update_boundary(), and schwz::Settings::write_iters_and_residuals.

```

319 {
320     using vec_vtype = gko::matrix::Dense<ValueType>;
321     if (!solution.get()) {
322         solution =
323             vec_vtype::create(settings.executor->get_master(),
324                               gko::dim<2>(this->metadata.global_size, 1));
325     }
326     MixedValueType dummy1 = 0.0;
327     ValueType dummy2 = 1.0;
328
329     if (metadata.my_rank == 0) {
330         std::cout << " MixedValueType: " << typeid(dummy1).name()
331                   << " ValueType: " << typeid(dummy2).name() << std::endl;
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     // The previous iteration solution vector
337     std::shared_ptr<vec_vtype> prev_global_solution = vec_vtype::create(
338         this->settings.executor, gko::dim<2>(this->metadata.global_size, 1));
339     // A work vector.
340     std::shared_ptr<vec_vtype> work_vector = vec_vtype::create(
341         settings.executor, gko::dim<2>(2 * this->metadata.local_size_x, 1));
342     // An initial guess.
343     std::shared_ptr<vec_vtype> init_guess = vec_vtype::create(
344         settings.executor, gko::dim<2>(this->metadata.local_size_x, 1));
345     // init_guess->copy_from(local_rhs.get());
346
347     if (settings.executor_string == "omp") {
348         ValueType sum_rhs = std::accumulate(
349             local_rhs->get_values(),
350             local_rhs->get_values() + local_rhs->get_size()[0], 0.0);
351         std::cout << " Rank " << this->metadata.my_rank << " sum local rhs "
352                   << sum_rhs << std::endl;
353     }
354
355     // std::vector<IndexType> local_converged_iter_count;
356
357     // Setup the windows for the onesided communication.
358     this->setup_windows(this->settings, this->metadata, global_solution);
359
360     const auto solver_settings =
361         (Settings::local_solver_settings::direct_solver_cholmod |
362          Settings::local_solver_settings::direct_solver_umfpack |
363          Settings::local_solver_settings::direct_solver_ginkgo |
364          Settings::local_solver_settings::iterative_solver_dealii |
365          Settings::local_solver_settings::iterative_solver_ginkgo) &
366         settings.local_solver;
367     prev_global_solution->copy_from(gko::lend(global_solution));
368
369     ValueType local_residual_norm = -1.0, local_residual_norm0 = -1.0,
370         global_residual_norm = 0.0, global_residual_norm0 = -1.0;
371     metadata.iter_count = 0;
372     auto start_time = std::chrono::steady_clock::now();
373     int num_converged_procs = 0;
374
375     for (; metadata.iter_count < metadata.max_iters; ++(metadata.iter_count)) {
376         // Exchange the boundary values. The communication part.
377         MEASURE_ELAPSED_FUNC_TIME(
378             this->exchange_boundary(settings, metadata, prev_global_solution,
379                                     global_solution),
380             0, metadata.my_rank, boundary_exchange, metadata.iter_count);
381         prev_global_solution->copy_from(gko::lend(global_solution));
382
383         // Update the boundary and interior values after the exchanging from
384         // other processes.
385         MEASURE_ELAPSED_FUNC_TIME(
386             this->update_boundary(settings, metadata, this->
387 local_solution,
388                                     this->local_rhs, global_solution,
389                                     this->interface_matrix),
390             1, metadata.my_rank, boundary_update, metadata.iter_count);

```

```

390
391     // Check for the convergence of the solver.
392     // num_converged_procs = 0;
393     MEASURE_ELAPSED_FUNC_TIME(
394         (Solve<ValueType, IndexType, MixedValueType>::check_convergence(
395             settings, metadata, this->comm_struct, this->convergence_vector,
396             global_solution, this->local_solution, this->
397             local_matrix,
398             work_vector, local_residual_norm, local_residual_norm0,
399             global_residual_norm, global_residual_norm0,
400             num_converged_procs)),
401         2, metadata.my_rank, convergence_check, metadata.iter_count);
402
403     // break if the solution diverges.
404     if (std::isnan(global_residual_norm) || global_residual_norm > 1e12) {
405         std::cout << " Rank " << metadata.my_rank << " diverged in "
406             << metadata.iter_count << " iters " << std::endl;
407         std::exit(-1);
408     }
409
410     // break if all processes detect that all other processes have
411     // converged otherwise continue iterations.
412     if (num_converged_procs == metadata.num_subdomains) {
413         break;
414     } else {
415         MEASURE_ELAPSED_FUNC_TIME(
416             (Solve<ValueType, IndexType, MixedValueType>::local_solve(
417                 settings, metadata, this->local_matrix,
418                 this->triangular_factor_l, this->
419                 triangular_factor_u,
420                 this->local_perm, this->local_inv_perm, work_vector,
421                 init_guess, this->local_solution)),
422             3, metadata.my_rank, local_solve, metadata.iter_count);
423
424         // Gather the local vector into the locally global vector for
425         // communication.
426         MEASURE_ELAPSED_FUNC_TIME(
427             (Communicate<ValueType, IndexType, MixedValueType>::
428                 local_to_global_vector(settings, metadata,
429                 this->local_solution,
430                 global_solution)),
431             4, metadata.my_rank, expand_local_vec, metadata.iter_count);
432     }
433
434     MPI_Barrier(MPI_COMM_WORLD);
435     auto elapsed_time = std::chrono::duration<ValueType>(
436         std::chrono::steady_clock::now() - start_time);
437     // Write the residuals and iterations to files
438     if (settings.write_iters_and_residuals &&
439         solver_settings ==
440         Settings::local_solver_settings::iterative_solver_ginkgo) {
441         std::string rank_string = std::to_string(metadata.my_rank);
442         if (metadata.my_rank < 10) {
443             rank_string = "0" + std::to_string(metadata.my_rank);
444         }
445         std::string filename = "iter_res_" + rank_string + ".csv";
446         write_iters_and_residuals(
447             metadata.num_subdomains, metadata.my_rank,
448             metadata.post_process_data.local_residual_vector_out.size(),
449             metadata.post_process_data.local_residual_vector_out,
450             metadata.post_process_data.local_converged_iter_count,
451             metadata.post_process_data.local_converged_resnorm,
452             metadata.post_process_data.local_timestamp, filename);
453     }
454     if (num_converged_procs < metadata.num_subdomains) {
455         std::cout << "Rank " << metadata.my_rank << " did not converge in "
456             << metadata.iter_count << " iterations." << std::endl;
457     } else {
458         std::cout << " Rank " << metadata.my_rank << " converged in "
459             << metadata.iter_count << " iterations " << std::endl;
460         ValueType mat_norm = -1.0, rhs_norm = -1.0, sol_norm = -1.0,
461             residual_norm = -1.0;
462
463         // Compute the final residual norm. Also gathers the solution from all
464         // subdomains.
465         Solve<ValueType, IndexType, MixedValueType>::compute_residual_norm(
466             settings, metadata, global_matrix, global_rhs, global_solution,
467             mat_norm, rhs_norm, sol_norm, residual_norm);
468         gather_comm_data<ValueType, IndexType, MixedValueType>(
469             metadata.num_subdomains, this->comm_struct,
470             metadata.comm_data_struct);
471         // clang-format off
472         if (metadata.my_rank == 0)
473         {
474             std::cout
475                 << " residual norm " << residual_norm << "\n"
476                 << " relative residual norm of solution " << residual_norm/rhs_norm << "\n"

```

```

475         << " Time taken for solve " << elapsed_time.count()
476         << std::endl;
477     }
478     // clang-format on
479 }
480 if (metadata.my_rank == 0) {
481     solution->copy_from(global_solution.get());
482 }
483
484 // Communicate<ValueType, IndexType>::clear(settings);
485 }

```

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

- schwarz_base.hpp (ca00a18)
- /home/runner/work/schwarz-lib/schwarz-lib/source/schwarz_base.cpp (92dbd95)

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 `use_mixed_precision` = false
Flag if mixed precision should be used.
- 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.
- int `reset_local_crit_iter` = -1
The global iter at which to reset the local solver criterion.
- 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 `enable_logging` = false
Flag to enable logging for local iterative solvers.
- 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 enable_logging

```
bool schwz::Settings::enable_logging = false
```

Flag to enable logging for local iterative solvers.

Note: Probably will have a significant performance hit.

7.14.2.2 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, MixedValueType >::initialize()`.

7.14.2.3 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 (92dbd95)

7.15 schwz::Solve< ValueType, IndexType, MixedValueType > 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, typename MixedValueType = gko↵
::default_precision>
class schwz::Solve< ValueType, IndexType, MixedValueType >
```

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 (228ce7a)
- /home/runner/work/schwarz-lib/schwarz-lib/source/solve.cpp (92dbd95)

7.16 schwz::SolverRAS< ValueType, IndexType, MixedValueType > 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, const std::shared_ptr< gko::matrix::Dense< ValueType >> &prev_global_solution, std::shared_ptr< gko::matrix::Dense< ValueType >> &global_solution) 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, typename MixedValueType = gko::default_precision>
class schwz::SolverRAS< ValueType, IndexType, MixedValueType >
```

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 , typename MixedValueType >
schwz::SolverRAS< ValueType, IndexType, MixedValueType >::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.

```
51      : SchwarzBase<ValueType, IndexType, MixedValueType>(settings, metadata)
52 {}
```

7.16.3 Member Function Documentation

7.16.3.1 exchange_boundary()

```
template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::SolverRAS< ValueType, IndexType, MixedValueType >::exchange_boundary (
    const Settings & settings,
    const Metadata< ValueType, IndexType > & metadata,
    const std::shared_ptr< gko::matrix::Dense< ValueType >> & prev_global_solution,
    std::shared_ptr< gko::matrix::Dense< ValueType >> & global_solution ) [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, MixedValueType >](#).

References [schwz::Settings::comm_settings::enable_onesided](#), and [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_solution](#).

```

967 {
968     if (settings.comm_settings.enable_onesided) {
969         exchange_boundary_onesided<ValueType, IndexType, MixedValueType>(
970             settings, metadata, this->comm_struct, prev_global_solution,
971             global_solution);
972     } else {
973         exchange_boundary_twosided<ValueType, IndexType, MixedValueType>(
974             settings, metadata, this->comm_struct, prev_global_solution,
975             global_solution);
976     }
977 }

```

7.16.3.2 setup_local_matrices()

```

template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::SolverRAS< ValueType, IndexType, MixedValueType >::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, MixedValueType >::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, MixedValueType >::interface_matrix](#), [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::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](#).

```

62 {
63     using mtx = gko::matrix::Csr<ValueType, IndexType>;
64     using vec_type = gko::Array<IndexType>;
65     using perm_type = gko::matrix::Permutation<IndexType>;
66     using arr = gko::Array<IndexType>;
67     auto my_rank = metadata.my_rank;
68     auto comm_size = metadata.comm_size;
69     auto num_subdomains = metadata.num_subdomains;
70     auto global_size = metadata.global_size;
71     auto mpi_itype = schwz::mpi::get_mpi_datatype(*partition_indices.data());
72
73     MPI_Bcast(partition_indices.data(), global_size, mpi_itype, 0,
74             MPI_COMM_WORLD);
75
76     std::vector<IndexType> local_p_size(num_subdomains);
77     auto global_to_local = metadata.global_to_local->get_data();
78     auto local_to_global = metadata.local_to_global->get_data();
79
80     auto first_row = metadata.first_row->get_data();
81     auto permutation = metadata.permutation->get_data();
82     auto i_permutation = metadata.i_permutation->get_data();
83
84     auto nb = (global_size + num_subdomains - 1) /
num_subdomains;
85     auto partition_settings =
86     (Settings::partition_settings::partition_zoltan |
87     Settings::partition_settings::partition_metis |
88     Settings::partition_settings::partition_regular |
89     Settings::partition_settings::partition_regular2d |
90     Settings::partition_settings::partition_custom) &
91     settings.partition;
92
93     IndexType *gmat_row_ptrs = global_matrix->get_row_ptrs();
94     IndexType *gmat_col_idxes = global_matrix->get_col_idxes();
95     ValueType *gmat_values = global_matrix->get_values();
96
97     // default local p size set for 1 subdomain.
98     first_row[0] = 0;
99     for (auto p = 0; p < num_subdomains; ++p) {
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 ==
106         Settings::partition_settings::partition_regular2d) {
107         if (num_subdomains > 1) {
108             for (auto p = 0; p < num_subdomains; p++) {
109                 local_p_size[p] = 0;
110             }
111             for (auto i = 0; i < global_size; i++) {
112                 local_p_size[partition_indices[i]]++;
113             }
114             first_row[0] = 0;
115             for (auto p = 0; p < num_subdomains; ++p) {
116                 first_row[p + 1] = first_row[p] + local_p_size[p];
117             }
118             // permutation
119             for (auto i = 0; i < global_size; i++) {
120                 permutation[first_row[partition_indices[i]]] = i;
121                 first_row[partition_indices[i]]++;
122             }
123             for (auto p = num_subdomains; p > 0; p--) {
124                 first_row[p] = first_row[p - 1];
125             }
126             first_row[0] = 0;
127
128             // iperm
129             for (auto i = 0; i < global_size; i++) {
130                 i_permutation[permutation[i]] = i;
131             }
132         }
133     }
134
135     auto gmat_temp = mtx::create(settings.executor->get_master(),
136                                 global_matrix->get_size(),
137                                 global_matrix->get_num_stored_elements());
138
139     auto nnz = 0;
140     gmat_temp->get_row_ptrs()[0] = 0;
141     for (auto row = 0; row < metadata.global_size; ++row) {
142         for (auto col = gmat_row_ptrs[permutation[row]];
143              col < gmat_row_ptrs[permutation[row] + 1]; ++col) {
144             gmat_temp->get_col_idxes()[nnz] =
145                 i_permutation[gmat_col_idxes[col]];
146             gmat_temp->get_values()[nnz] = gmat_values[col];
147             nnz++;

```

```

148         }
149         gmat_temp->get_row_ptrs()[row + 1] = nnz;
150     }
151     global_matrix->copy_from(gmat_temp.get());
152 }
153
154
155     for (auto i = 0; i < global_size; i++) {
156         global_to_local[i] = 0;
157         local_to_global[i] = 0;
158     }
159     auto num = 0;
160     for (auto i = first_row[my_rank]; i < first_row[
my_rank + 1]; i++) {
161         global_to_local[i] = 1 + num;
162         local_to_global[num] = i;
163         num++;
164     }
165
166     IndexType old = 0;
167     for (auto k = 1; k < settings.overlap; k++) {
168         auto now = num;
169         for (auto i = old; i < now; i++) {
170             for (auto j = gmat_row_ptrs[local_to_global[i]];
171                  j < gmat_row_ptrs[local_to_global[i] + 1]; j++) {
172                 if (global_to_local[gmat_col_idx[j]] == 0) {
173                     local_to_global[num] = gmat_col_idx[j];
174                     global_to_local[gmat_col_idx[j]] = 1 + num;
175                     num++;
176                 }
177             }
178         }
179         old = now;
180     }
181     metadata.local_size = local_p_size[my_rank];
182     metadata.local_size_x = num;
183     metadata.local_size_o = global_size;
184     auto local_size = metadata.local_size;
185     auto local_size_x = metadata.local_size_x;
186
187     metadata.overlap_size = num - metadata.local_size;
188     metadata.overlap_row = std::shared_ptr<vec_itype>(
189         new vec_itype(gko::Array<IndexType>::view(
190             settings.executor, metadata.overlap_size,
191             &(metadata.local_to_global->get_data()[metadata.local_size])),
192         std::default_delete<vec_itype>());
193
194     auto nnz_local = 0;
195     auto nnz_interface = 0;
196
197     for (auto i = first_row[my_rank]; i < first_row[my_rank + 1]; ++i) {
198         for (auto j = gmat_row_ptrs[i]; j < gmat_row_ptrs[i + 1]; j++) {
199             if (global_to_local[gmat_col_idx[j]] != 0) {
200                 nnz_local++;
201             } else {
202                 std::cout << " debug: invalid edge?" << std::endl;
203             }
204         }
205     }
206     auto temp = 0;
207     for (auto k = 0; k < metadata.overlap_size; k++) {
208         temp = metadata.overlap_row->get_data()[k];
209         for (auto j = gmat_row_ptrs[temp]; j < gmat_row_ptrs[temp + 1]; j++) {
210             if (global_to_local[gmat_col_idx[j]] != 0) {
211                 nnz_local++;
212             } else {
213                 nnz_interface++;
214             }
215         }
216     }
217
218     std::shared_ptr<mtx> local_matrix_compute;
219     local_matrix_compute = mtx::create(settings.executor->get_master(),
220                                       gko::dim<2>(local_size_x), nnz_local);
221     IndexType *lmat_row_ptrs = local_matrix_compute->get_row_ptrs();
222     IndexType *lmat_col_idx = local_matrix_compute->get_col_idx();
223     ValueType *lmat_values = local_matrix_compute->get_values();
224
225     std::shared_ptr<mtx> interface_matrix_compute;
226     if (nnz_interface > 0) {
227         interface_matrix_compute =
228             mtx::create(settings.executor->get_master(),
229                       gko::dim<2>(local_size_x), nnz_interface);
230     } else {
231         interface_matrix_compute = mtx::create(settings.executor->get_master());
232     }
233

```

```

234     IndexType *imat_row_ptrs = interface_matrix_compute->get_row_ptrs();
235     IndexType *imat_col_idxs = interface_matrix_compute->get_col_idxs();
236     ValueType *imat_values = interface_matrix_compute->get_values();
237
238     num = 0;
239     nnz_local = 0;
240     auto nnz_interface_temp = 0;
241     lmat_row_ptrs[0] = nnz_local;
242     if (nnz_interface > 0) {
243         imat_row_ptrs[0] = nnz_interface_temp;
244     }
245     // Local interior matrix
246     for (auto i = first_row[my_rank]; i < first_row[my_rank + 1]; ++i) {
247         for (auto j = gmat_row_ptrs[i]; j < gmat_row_ptrs[i + 1]; ++j) {
248             if (global_to_local[gmat_col_idxs[j]] != 0) {
249                 lmat_col_idxs[nnz_local] =
250                     global_to_local[gmat_col_idxs[j]] - 1;
251                 lmat_values[nnz_local] = gmat_values[j];
252                 nnz_local++;
253             }
254         }
255         if (nnz_interface > 0) {
256             imat_row_ptrs[num + 1] = nnz_interface_temp;
257         }
258         lmat_row_ptrs[num + 1] = nnz_local;
259         num++;
260     }
261
262     // Interface matrix
263     if (nnz_interface > 0) {
264         nnz_interface = 0;
265         for (auto k = 0; k < metadata.overlap_size; k++) {
266             temp = metadata.overlap_row->get_data()[k];
267             for (auto j = gmat_row_ptrs[temp]; j < gmat_row_ptrs[temp + 1];
268                 j++) {
269                 if (global_to_local[gmat_col_idxs[j]] != 0) {
270                     lmat_col_idxs[nnz_local] =
271                         global_to_local[gmat_col_idxs[j]] - 1;
272                     lmat_values[nnz_local] = gmat_values[j];
273                     nnz_local++;
274                 } else {
275                     imat_col_idxs[nnz_interface] = gmat_col_idxs[j];
276                     imat_values[nnz_interface] = gmat_values[j];
277                     nnz_interface++;
278                 }
279             }
280             lmat_row_ptrs[num + 1] = nnz_local;
281             imat_row_ptrs[num + 1] = nnz_interface;
282             num++;
283         }
284     }
285     auto now = num;
286     for (auto i = old; i < now; i++) {
287         for (auto j = gmat_row_ptrs[local_to_global[i]];
288             j < gmat_row_ptrs[local_to_global[i] + 1]; j++) {
289             if (global_to_local[gmat_col_idxs[j]] == 0) {
290                 local_to_global[num] = gmat_col_idxs[j];
291                 global_to_local[gmat_col_idxs[j]] = 1 + num;
292                 num++;
293             }
294         }
295     }
296
297     local_matrix_compute->sort_by_column_index();
298     interface_matrix_compute->sort_by_column_index();
299
300     local_matrix = mtx::create(settings.executor);
301     local_matrix->copy_from(gko::lend(local_matrix_compute));
302     interface_matrix = mtx::create(settings.executor);
303     interface_matrix->copy_from(gko::lend(interface_matrix_compute));
304 }

```

7.16.3.3 setup_windows()

```

template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::SolverRAS< ValueType, IndexType, MixedValueType >::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, MixedValueType >](#).

References [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::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::get_displacements](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::get_request](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::global_get](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::global_put](#), [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_solution](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::is_local_neighbor](#), [schwz::Metadata< ValueType, IndexType >::iter_count](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::local_get](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::local_neighbors_in](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::local_neighbors_out](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::local_num_neighbors_in](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::local_num_neighbors_out](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::local_put](#), [schwz::Metadata< ValueType, IndexType >::local_size_o](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::mixedt_rcv_buffer](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::mixedt_send_buffer](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::neighbors_in](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::neighbors_out](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::num_neighbors_in](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::num_neighbors_out](#), [schwz::Metadata< ValueType, IndexType >::num_subdomains](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::put_displacements](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::put_request](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::rcv_buffer](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::remote_get](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::remote_put](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::send_buffer](#), [schwz::Settings::use_mixed_precision](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::window_rcv_buffer](#), [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::window_send_buffer](#), and [schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::window_x](#).

```
560 {
561     using vec_itype = gko::Array<IndexType>;
562     using vec_vtype = gko::matrix::Dense<ValueType>;
563     auto num_subdomains = metadata.num_subdomains;
564     auto local_size_o = metadata.local_size_o;
565     auto neighbors_in = this->comm_struct.neighbors_in->get_data();
566     auto global_get = this->comm_struct.global_get->get_data();
567     auto neighbors_out = this->comm_struct.neighbors_out->get_data();
568     auto global_put = this->comm_struct.global_put->get_data();
569
570     // set displacement for the MPI buffer
571     auto get_displacements = this->comm_struct.get_displacements->get_data();
572     auto put_displacements = this->comm_struct.put_displacements->get_data();
573     {
574         std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
575         tmp_num_comm_elems[0] = 0;
576         for (auto j = 0; j < this->comm_struct.num_neighbors_in; j++) {
```

```

577         if ((global_get[j])[0] > 0) {
578             int p = neighbors_in[j];
579             tmp_num_comm_elems[p + 1] = (global_get[j])[0];
580         }
581     }
582     for (auto j = 0; j < num_subdomains; j++) {
583         tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
584     }
585
586     auto mpi_itype = schwz::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
587     MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, put_displacements,
588                 1, mpi_itype, MPI_COMM_WORLD);
589 }
590
591 {
592     std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
593     tmp_num_comm_elems[0] = 0;
594     for (auto j = 0; j < this->comm_struct.num_neighbors_out; j++) {
595         if ((global_put[j])[0] > 0) {
596             int p = neighbors_out[j];
597             tmp_num_comm_elems[p + 1] = (global_put[j])[0];
598         }
599     }
600     for (auto j = 0; j < num_subdomains; j++) {
601         tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
602     }
603
604     auto mpi_itype = schwz::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
605     MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, get_displacements,
606                 1, mpi_itype, MPI_COMM_WORLD);
607 }
608
609 // setup windows
610 if (settings.comm_settings.enable_onesided) {
611     // Onesided
612     MPI_Win_create(main_buffer->get_values(),
613                   main_buffer->get_size()[0] * sizeof(ValueType),
614                   sizeof(ValueType), MPI_INFO_NULL, MPI_COMM_WORLD,
615                   &(this->comm_struct.window_x));
616 }
617
618
619 if (settings.comm_settings.enable_onesided) {
620     // MPI_Alloc_mem ? Custom allocator ? TODO
621     MPI_Win_create(this->local_residual_vector->get_values(),
622                   (num_subdomains) * sizeof(ValueType), sizeof(ValueType),
623                   MPI_INFO_NULL, MPI_COMM_WORLD,
624                   &(this->window_residual_vector));
625     std::vector<IndexType> zero_vec(num_subdomains, 0);
626     gko::Array<IndexType> temp_array(settings.executor->get_master(),
627                                     zero_vec.begin(), zero_vec.end());
628     this->convergence_vector = std::shared_ptr<vec_itype>(
629         new vec_itype(settings.executor->get_master(), temp_array),
630         std::default_delete<vec_itype>());
631     this->convergence_sent = std::shared_ptr<vec_itype>(
632         new vec_itype(settings.executor->get_master(), num_subdomains),
633         std::default_delete<vec_itype>());
634     this->convergence_local = std::shared_ptr<vec_itype>(
635         new vec_itype(settings.executor->get_master(), num_subdomains),
636         std::default_delete<vec_itype>());
637     MPI_Win_create(this->convergence_vector->get_data(),
638                   (num_subdomains) * sizeof(IndexType), sizeof(IndexType),
639                   MPI_INFO_NULL, MPI_COMM_WORLD,
640                   &(this->window_convergence));
641 }
642
643 if (settings.comm_settings.enable_onesided && num_subdomains > 1) {
644     // Lock all windows.
645     if (settings.comm_settings.enable_get &&
646         settings.comm_settings.enable_lock_all) {
647         MPI_Win_lock_all(0, this->comm_struct.window_send_buffer);
648     }
649     if (settings.comm_settings.enable_put &&
650         settings.comm_settings.enable_lock_all) {
651         MPI_Win_lock_all(0, this->comm_struct.window_recv_buffer);
652     }
653     if (settings.comm_settings.enable_one_by_one &&
654         settings.comm_settings.enable_lock_all) {
655         MPI_Win_lock_all(0, this->comm_struct.window_x);
656     }
657     MPI_Win_lock_all(0, this->window_residual_vector);
658     MPI_Win_lock_all(0, this->window_convergence);
659 }
660 }

```


7.16.3.4 update_boundary()

```
template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::SolverRAS< ValueType, IndexType, MixedValueType >::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, MixedValueType >](#).

References [schwz::Settings::executor](#), [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_←_solution](#), [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::interface_matrix](#), [schwz::Schwarz_←Base< ValueType, IndexType, MixedValueType >::local_rhs](#), [schwz::Metadata< ValueType, IndexType >::local_←_size_x](#), [schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::local_solution](#), [schwz::Metadata< ValueType, IndexType >::num_subdomains](#), and [schwz::Settings::overlap](#).

```
988 {
989     using vec_vtype = gko::matrix::Dense<ValueType>;
990     auto one = gko::initialize<gko::matrix::Dense<ValueType>>(
991         {1.0}, settings.executor);
992     auto neg_one = gko::initialize<gko::matrix::Dense<ValueType>>(
993         {-1.0}, settings.executor);
994     auto local_size_x = metadata.local_size_x;
995     local_solution->copy_from(local_rhs.get());
996     if (metadata.num_subdomains > 1 && settings.overlap > 0) {
997         auto temp_solution = vec_vtype::create(
998             settings.executor, local_solution->get_size(),
999             gko::Array<ValueType>::view(settings.executor,
1000                                     local_solution->get_size()[0],
1001                                     global_solution->get_values()),
1002             1);
1003         interface_matrix->apply(neg_one.get(), temp_solution.get(), one.get(),
1004                               local_solution.get());
1005     }
1006 }
```

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

- [restricted_schwarz.hpp \(7c9a9f7\)](#)
- [/home/runner/work/schwarz-lib/schwarz-lib/source/restricted_schwarz.cpp \(92dbd95\)](#)

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 (35a1195)
- /home/runner/work/schwarz-lib/schwarz-lib/source/exception.cpp (35a1195)

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 \(1cd0e3b\)](#)
- [/home/runner/work/schwarz-lib/schwarz-lib/source/utils.cpp \(f366659\)](#)

Index

- BadDimension, [21](#)
 - BadDimension, [21](#)
- Communicate, [11](#)
- CudaError, [30](#)
 - CudaError, [31](#)
- CusparsError, [31](#)
 - CusparsError, [32](#)
- enable_logging
 - schwz::Settings, [49](#)
- exchange_boundary
 - schwz::Communicate, [28](#)
 - schwz::SolverRAS, [52](#)
- explicit_laplacian
 - schwz::Settings, [50](#)
- generate_rhs
 - schwz::Initialize, [34](#)
- global_get
 - schwz::Communicate::comm_struct, [24](#)
- global_put
 - schwz::Communicate::comm_struct, [24](#)
- Initialization, [12](#)
- is_local_neighbor
 - schwz::Communicate::comm_struct, [25](#)
- local_get
 - schwz::Communicate::comm_struct, [25](#)
- local_put
 - schwz::Communicate::comm_struct, [25](#)
- local_solver_tolerance
 - schwz::Metadata, [40](#)
- local_to_global_vector
 - schwz::Communicate, [28](#)
- MetisError, [40](#)
 - MetisError, [41](#)
- naturally_ordered_factor
 - schwz::Settings, [50](#)
- partition
 - schwz::Initialize, [34](#)
- print_matrix
 - schwz::SchwarzBase, [44](#)
- print_vector
 - schwz::SchwarzBase, [45](#)
- ProcessTopology, [17](#)
- remote_get
 - schwz::Communicate::comm_struct, [26](#)
- remote_put
 - schwz::Communicate::comm_struct, [26](#)
- run
 - schwz::SchwarzBase, [45](#)
- Schwarz Class, [13](#)
- SchwarzBase
 - schwz::SchwarzBase, [43](#)
- schwz, [17](#)
- schwz::CommHelpers, [18](#)
- schwz::Communicate
 - exchange_boundary, [28](#)
 - local_to_global_vector, [28](#)
 - setup_windows, [29](#)
 - update_boundary, [29](#)
- schwz::Communicate< ValueType, IndexType, Mixed<ValueType>, [27](#)
- schwz::Communicate< ValueType, IndexType, Mixed<ValueType>::comm_struct, [23](#)
- schwz::Communicate::comm_struct
 - global_get, [24](#)
 - global_put, [24](#)
 - is_local_neighbor, [25](#)
 - local_get, [25](#)
 - local_put, [25](#)
 - remote_get, [26](#)
 - remote_put, [26](#)
- schwz::Initialize
 - generate_rhs, [34](#)
 - partition, [34](#)
 - setup_global_matrix, [35](#)
 - setup_local_matrices, [36](#)
 - setup_vectors, [37](#)
- schwz::Initialize< ValueType, IndexType>, [33](#)
- schwz::Metadata
 - local_solver_tolerance, [40](#)
 - tolerance, [40](#)
- schwz::Metadata< ValueType, IndexType>, [38](#)
- schwz::Metadata< ValueType, IndexType>::post_
 - process_data, [41](#)
- schwz::PartitionTools, [19](#)
- schwz::SchwarzBase
 - print_matrix, [44](#)
 - print_vector, [45](#)
 - run, [45](#)
 - SchwarzBase, [43](#)
- schwz::SchwarzBase< ValueType, IndexType, Mixed<ValueType>, [42](#)
- schwz::Settings, [48](#)

- enable_logging, [49](#)
 - explicit_laplacian, [50](#)
 - naturally_ordered_factor, [50](#)
- schwz::Settings::comm_settings, [22](#)
- schwz::Settings::convergence_settings, [30](#)
- schwz::Solve< ValueType, IndexType, MixedValueType
 >, [50](#)
- schwz::SolverRAS< ValueType, IndexType, Mixed<←
 ValueType >, [51](#)
- schwz::SolverRAS
 - exchange_boundary, [52](#)
 - setup_local_matrices, [53](#)
 - setup_windows, [56](#)
 - SolverRAS, [52](#)
 - update_boundary, [58](#)
- schwz::SolverTools, [19](#)
- schwz::Utils< ValueType, IndexType >, [61](#)
- schwz::conv_tools, [18](#)
- schwz::device_guard, [32](#)
- setup_global_matrix
 - schwz::Initialize, [35](#)
- setup_local_matrices
 - schwz::Initialize, [36](#)
 - schwz::SolverRAS, [53](#)
- setup_vectors
 - schwz::Initialize, [37](#)
- setup_windows
 - schwz::Communicate, [29](#)
 - schwz::SolverRAS, [56](#)
- Solve, [14](#)
- SolverRAS
 - schwz::SolverRAS, [52](#)
- tolerance
 - schwz::Metadata, [40](#)
- UmfpackError, [60](#)
 - UmfpackError, [60](#)
- update_boundary
 - schwz::Communicate, [29](#)
 - schwz::SolverRAS, [58](#)
- Utils, [15](#)