schwz

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Contents

Chapter 1

Main Page

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

Modules

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

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

Chapter 2

Installation Instructions

Building

Use the standard cmake build procedure:

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

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

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

Tips

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

Chapter 3

Testing Instructions

Chapter 4

Benchmarking.

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 `edgecut` 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 .
- schwz::EventHelpers

  The EventHelper 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 .
- EventHelpers

  The EventHelper 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::EventHelpers Namespace Reference

The EventHelper namespace .

6.5.1 Detailed Description

The EventHelper namespace .

event_helpers

6.6 schwz::PartitionTools Namespace Reference

The PartitionTools namespace .

6.6.1 Detailed Description

The PartitionTools namespace .

part_tools

6.7 schwz::SolverTools Namespace Reference

The SolverTools namespace .

6.7.1 Detailed Description

The SolverTools namespace .

solver_tools

Chapter 7

Class Documentation

7.1 BadDimension Class Reference

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

`#include <exception.hpp>`

Public Member Functions

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

  Initializes a bad dimension error.

7.1.1 Detailed Description

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

7.1.2 Constructor & Destructor Documentation

7.1.2.1 BadDimension()

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

Initializes a bad dimension error.

Parameters

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

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

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

- exception.hpp (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 (b6471e3)

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.
- int num_recv
  The total number of elements received from all neighbors.
- int num_send
  The total number of elements sent to all neighbors.
- 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::matrix::Dense< ValueType > > extra_buffer

  The extrapolation buffer used for extrapolation of values at the receiver.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_recv_bdy

  The last received boundary values for each of the in neighbors for extrapolation.
- std::shared_ptr< gko::matrix::Dense< ValueType > > curr_send_avg

  Average of values in the send buffer for each of the out neighbors.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_send_avg

  Average of values in the last send buffer for each of the out neighbors.
- std::shared_ptr< gko::matrix::Dense< ValueType > > curr_recv_avg

  Average of values in the recv buffer for each of the out neighbors.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_recv_avg

  Average of values in the last recv buffer for each of the out neighbors.
- std::shared_ptr< gko::Array< IndexType > > msg_count

  Number of messages sent.
- std::shared_ptr< gko::Array< IndexType > > last_recv_iter

  Iteration stamp of last received values.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_recv_slopes

  Last recv slopes.
- std::shared_ptr< gko::matrix::Dense< ValueType > > last_sent_slopes_avg

  Last sent slopes.
- std::shared_ptr< gko::Array< IndexType > > last_sent_iter

  Iteration stamp of last received values.
- std::shared_ptr< gko::matrix::Dense< ValueType > > thres

  Threshold.
- 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, Mixed↩
ValueType >::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, Mixed↩
ValueType >::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, Mixed↩
ValueType >::comm_struct::local_get
```

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

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

Referenced by schwz::SolverRAS< ValueType, IndexType, 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 (b6471e3)

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, std::shared_ptr< gko::matrix::Dense< ValueType >> &prev_event_solution, std::ofstream &fps, std::ofstream &fpr)=0

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

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

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

  Clears the data.

7.4.1 Detailed Description

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

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

Template Parameters

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

Communicate

7.4.2 Member Function Documentation

7.4.2.1 exchange_boundary()

```
template<typename ValueType , typename IndexType , 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,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & prev_event_solution,
            std::ofstream & fps,
            std::ofstream & fpr )  [pure virtual]
```

Exchanges the elements of the solution vector.

Parameters

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

Implemented in schwz::SolverRAS< ValueType, IndexType, 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

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

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

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

7.4.2.3 setup_windows()

```
template<typename ValueType , typename IndexType , 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

settings	The settings struct.
metadata	The metadata struct.
main_buffer	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

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

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

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

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

- communicate.hpp (b6471e3)
- /home/runner/work/schwarz-lib/schwarz-lib/source/communicate.cpp (b6471e3)

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 (b6471e3)

7.6 CudaError Class Reference

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

`#include <exception.hpp>`

Public Member Functions

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

7.6.1 Detailed Description

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

7.6.2 Constructor & Destructor Documentation

7.6.2.1 CudaError()

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

Initializes a CUDA error.

Parameters

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

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

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

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

7.7 CusparseError Class Reference

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

`#include <exception.hpp>`

Public Member Functions

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

7.7.1 Detailed Description

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

7.7.2 Constructor & Destructor Documentation

7.7.2.1 CusparseError()

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

Initializes a cuSPARSE error.

Parameters

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

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

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

- exception.hpp (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 generate_dipole_rhs (std::vector< ValueType > &rhs)

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

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

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

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

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

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

Public Attributes

- std::vector< unsigned int > partition_indices

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

  The cell weights for the partition algorithm.

Additional Inherited Members

7.9.1 Detailed Description

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

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

Template Parameters

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

Initialization

7.9.2 Member Function Documentation

7.9.2.1 generate_dipole_rhs()

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

Generates a dipole right hand side vector.

Parameters

rhs	The rhs vector.

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

```
101 {
102     auto oned_laplacian_size = metadata.oned_laplacian_size;
103
104     // Placing dipole at 1/4 and 3/4 of Y-dim at the middle of X-dim
105     for (int i = 0; i < oned_laplacian_size; i++) {
106         for (int j = 0; j < oned_laplacian_size; j++) {
107             if (i == oned_laplacian_size / 4 && j == oned_laplacian_size / 2)
108                 rhs[i * oned_laplacian_size + j] = 100.0;
```

```
109             else if (i == 3 * oned_laplacian_size / 4 &&
110                      j == oned_laplacian_size / 2)
111                 rhs[i * oned_laplacian_size + j] = -100.0;
112             else
113                 rhs[i * oned_laplacian_size + j] = 0.0;
114         }
115     }
116 }
```

7.9.2.2 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

rhs	The rhs vector.

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 }
```

7.9.2.3 generate_sin_rhs()

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

Generates a sinusoidal right hand side vector.

Parameters

rhs	The rhs vector.

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

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

```
121 {
122     auto PI = (ValueType)(atan(1.0) * 4);
123     auto oned_laplacian_size = metadata.oned_laplacian_size;
```

```
124
125     // Source = sin(x)sin(y)
126     for (int i = 0; i < oned_laplacian_size; i++) {
127         for (int j = 0; j < oned_laplacian_size; j++) {
128             rhs[i * oned_laplacian_size + j] =
129                 sin(2 * PI * i / oned_laplacian_size) *
130                 sin(2 * PI * j / oned_laplacian_size);
131         }
132     }
133 }
```

7.9.2.4 partition()

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

The partitioning function.

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

Parameters

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

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

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

```
320 {
321     partition_indices.resize(metadata.global_size);
322     if (metadata.my_rank == 0) {
323         auto partition_settings =
324             (Settings::partition_settings::partition_zoltan |
325              Settings::partition_settings::partition_metis |
326              Settings::partition_settings::partition_regular |
327              Settings::partition_settings::partition_regular2d |
328              Settings::partition_settings::partition_custom) &
329             settings.partition;
330
331         if (partition_settings ==
332             Settings::partition_settings::partition_zoltan) {
333             SCHWARZ_NOT_IMPLEMENTED;
334         } else if (partition_settings ==
335                    Settings::partition_settings::partition_metis) {
336             if (metadata.my_rank == 0) {
337                 std::cout << " METIS partition" << std::endl;
338             }
339             PartitionTools::PartitionMetis(
340                 settings, global_matrix, this->cell_weights,
341                 metadata.num_subdomains, partition_indices);
342         } else if (partition_settings ==
343                    Settings::partition_settings::partition_regular) {
```

```
344             if (metadata.my_rank == 0) {
345                 std::cout << " Regular 1D partition" << std::endl;
346             }
347             PartitionTools::PartitionRegular(
348                 global_matrix, metadata.num_subdomains, partition_indices);
349         } else if (partition_settings ==
350                    Settings::partition_settings::partition_regular2d) {
351             if (metadata.my_rank == 0) {
352                 std::cout << " Regular 2D partition" << std::endl;
353             }
354             PartitionTools::PartitionRegular2D(
355                 global_matrix, settings.write_debug_out,
356                 metadata.num_subdomains, partition_indices);
357         } else if (partition_settings ==
358                    Settings::partition_settings::partition_custom) {
359             // User partitions mesh manually
360             SCHWARZ_NOT_IMPLEMENTED;
361         } else {
362             SCHWARZ_NOT_IMPLEMENTED;
363         }
364     }
365 }
```

7.9.2.5 setup_global_matrix()

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

Generates the 2D global laplacian matrix.

Parameters

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

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

```
236 {
237     using index_type = IndexType;
238     using value_type = ValueType;
239     using mtx = gko::matrix::Csr<value_type, index_type>;
240     if (settings.matrix_filename != "null") {
241         auto input_file = std::ifstream(filename, std::ios::in);
242         if (!input_file) {
243             std::cerr << "Could not find the file \"" << filename
244                       << "\", which is required for this test.\n";
245         }
246         global_matrix =
247             gko::read<mtx>(input_file, settings.executor->get_master());
248         global_matrix->sort_by_column_index();
249         std::cout << "Matrix from file " << filename << std::endl;
250     } else if (settings.matrix_filename == "null" &&
251                settings.explicit_laplacian) {
252         std::cout << "Laplacian 2D Matrix (generated in house) " << std::endl;
253         gko::size_type global_size = oned_laplacian_size *
    oned_laplacian_size;
254
255         global_matrix = mtx::create(settings.executor->get_master(),
256                                     gko::dim<2>(global_size), 5 * global_size);
257         value_type *values = global_matrix->get_values();
258         index_type *row_ptrs = global_matrix->get_row_ptrs();
259         index_type *col_idxs = global_matrix->get_col_idxs();
260
```

```
261         std::vector<gko::size_type> exclusion_set;
262
263         std::map<IndexType, ValueType> stencil_map = {
264             {-oned_laplacian_size, -1}, {-1, -1}, {0, 4}, {1, -1},
265             {oned_laplacian_size, -1},
266         };
267         for (auto i = 2; i < global_size; ++i) {
268             gko::size_type index = (i - 1) * oned_laplacian_size;
269             if (index * index < global_size * global_size) {
270                 exclusion_set.push_back(
271                     linearize_index(index, index - 1, global_size));
272                 exclusion_set.push_back(
273                     linearize_index(index - 1, index, global_size));
274             }
275         }
276
277         std::sort(exclusion_set.begin(),
278                   exclusion_set.begin() + exclusion_set.size());
279
280         IndexType pos = 0;
281         IndexType col_idx = 0;
282         row_ptrs[0] = pos;
283         gko::size_type cur_idx = 0;
284         for (IndexType i = 0; i < global_size; ++i) {
285             for (auto ofs : stencil_map) {
286                 auto in_exclusion_flag =
287                     (exclusion_set[cur_idx] ==
288                      linearize_index(i, i + ofs.first, global_size));
289                 if (0 <= i + ofs.first && i + ofs.first < global_size &&
290                     !in_exclusion_flag) {
291                     values[pos] = ofs.second;
292                     col_idxs[pos] = i + ofs.first;
293                     ++pos;
294                 }
295                 if (in_exclusion_flag) {
296                     cur_idx++;
297                 }
298                 col_idx = row_ptrs[i + 1] - pos;
299             }
300             row_ptrs[i + 1] = pos;
301         }
302     } else {
303         std::cerr << " Need to provide a matrix or enable the default "
304                      "laplacian matrix."
305                   << std::endl;
306         std::exit(-1);
307     }
308 }
```

7.9.2.6 setup_local_matrices()

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

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

Parameters

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

Parameters

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

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

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

7.9.2.7 setup_vectors()

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

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

Parameters

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

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

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

```
375 {
376     using vec = gko::matrix::Dense<ValueType>;
377     auto my_rank = metadata.my_rank;
378     auto first_row = metadata.first_row->get_data()[my_rank];
379
380     // Copy the global rhs vector to the required executor.
381     gko::Array<ValueType> temp_rhs{settings.executor->get_master(), rhs.begin(),
382                                    rhs.end()};
383     global_rhs = vec::create(settings.executor,
384                              gko::dim<2>{metadata.global_size, 1}, temp_rhs, 1);
385
386     local_rhs =
387         vec::create(settings.executor, gko::dim<2>(metadata.local_size_x, 1));
388     // Extract the local rhs from the global rhs. Also takes into account the
389     // overlap.
390     SolverTools::extract_local_vector(settings, metadata, local_rhs.get(),
391                                       global_rhs.get(), first_row);
392
393     local_solution =
394         vec::create(settings.executor, gko::dim<2>(metadata.local_size_x, 1));
395 }
```

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

- initialization.hpp (b6471e3)
- /home/runner/work/schwarz-lib/schwarz-lib/source/initialization.cpp (b6471e3)

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.
- ValueType constant = 0.0

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

  Value of gamma for event threshold Relevant for cgammak threshold.
- ValueType horizon = 0.0

  Value of horizon for the event threshold Relevant for slope-based threshold.
- ValueType decay_param = 0.0

  Value of decay parameter for the event threshold Relevant for slope-based threshold.
- IndexType sent_history = 0

  Value of history at the sender.
- IndexType recv_history = 0

  Value of history at the receiver.
- IndexType comm_start_iters = 0

  Number of iterations to communicate before event comm.
- std::vector< std::tuple< int, int, int, std::string, std::vector< ValueType > > > time_struct

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

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

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

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

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

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

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

  The inverse permutation used for the re-ordering.

7.10.1 Detailed Description

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

The solver metadata struct.

Template Parameters

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

7.10.2 Member Data Documentation

7.10.2.1 local_solver_tolerance

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

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

The residual norm reduction required.

7.10.2.2 tolerance

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

The tolerance of the complete solver.

The residual norm reduction required.

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

- settings.hpp (b6471e3)

7.11 MetisError Class Reference

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

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

Public Member Functions

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

7.11.1 Detailed Description

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

7.11.2 Constructor & Destructor Documentation

7.11.2.1 MetisError()

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

Initializes a METIS error.

Parameters

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

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

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

- exception.hpp (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 (b6471e3)

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 > > prev_event_solution
  The (local+overlap) solution vector at time of previous event of communication The size of this vector is considered global_size to account for overlap.
- std::shared_ptr< gko::matrix::Dense< ValueType > > global_solution
  The global solution vector.
- std::vector< ValueType > local_residual_vector_out
  The global residual vector.
- std::vector< std::vector< ValueType > > global_residual_vector_out
  The local residual vector.

Additional Inherited Members

7.13.1 Detailed Description

template<typename ValueType = gko::default_precision, typename IndexType = gko::int32, 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

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

7.13.2 Constructor & Destructor Documentation

7.13.2.1 SchwarzBase()

```
template<typename ValueType , typename IndexType , 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

settings	The settings struct.
metadata	The metadata struct.

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

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

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

7.13.3.2 print_vector()

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

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

7.13.3.3 run()

```
template<typename ValueType , typename IndexType , 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

solution	The solution vector.

References schwz::Settings::debug_print, 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 >::comm_struct::msg_count, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::neighbors_out, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::num_neighbors_out, schwz::Settings::overlap, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::prev_event_solution, schwz::Communicate< ValueType, IndexType, MixedValueType >::setup_windows(), schwz::Settings::thres_type, 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.

```
328 {
329     using vec_vtype = gko::matrix::Dense<ValueType>;
330     if (!solution.get()) {
331         solution =
332             vec_vtype::create(settings.executor->get_master(),
```

```
333                             gko::dim<2>(this->metadata.global_size, 1));
334     }
335     MixedValueType dummy1 = 0.0;
336     ValueType dummy2 = 1.0;
337
338     auto num_neighbors_out = this->comm_struct.num_neighbors_out;
339     auto neighbors_out = this->comm_struct.neighbors_out->get_data();
340
341     if (metadata.my_rank == 0) {
342         std::cout << " MixedValueType: " << typeid(dummy1).name()
343                   << " ValueType: " << typeid(dummy2).name() << std::endl;
344     }
345     // The main solution vector
346     std::shared_ptr<vec_vtype> global_solution = vec_vtype::create(
347         this->settings.executor, gko::dim<2>(this->metadata.global_size, 1));
348
349     // The previous iteration solution vector
350     std::shared_ptr<vec_vtype> prev_global_solution = vec_vtype::create(
351         this->settings.executor, gko::dim<2>(this->metadata.global_size, 1));
352
353     // The solution vector at the previous event of communication
354     std::shared_ptr<vec_vtype> prev_event_solution = vec_vtype::create(
355         settings.executor, gko::dim<2>(metadata.global_size, 1));
356
357     // A work vector.
358     std::shared_ptr<vec_vtype> work_vector = vec_vtype::create(
359         settings.executor, gko::dim<2>(2 * this->metadata.local_size_x, 1));
360
361     // An initial guess.
362     std::shared_ptr<vec_vtype> init_guess = vec_vtype::create(
363         settings.executor, gko::dim<2>(this->metadata.local_size_x, 1));
364     // init_guess->copy_from(local_rhs.get());
365
366     if (settings.executor_string == "omp") {
367         ValueType sum_rhs = std::accumulate(
368             local_rhs->get_values(),
369             local_rhs->get_values() + local_rhs->get_size()[0], 0.0);
370         std::cout << " Rank " << this->metadata.my_rank << " sum local rhs "
371                   << sum_rhs << std::endl;
372     }
373
374     // Initialize all vectors - tbd
375
376     // std::vector<IndexType> local_converged_iter_count;
377
378     // Setup the windows for the onesided communication.
379     this->setup_windows(this->settings, this->metadata, global_solution);
380
381     const auto solver_settings =
382         (Settings::local_solver_settings::direct_solver_cholmod |
383          Settings::local_solver_settings::direct_solver_umfpack |
384          Settings::local_solver_settings::direct_solver_ginkgo |
385          Settings::local_solver_settings::iterative_solver_dealii |
386          Settings::local_solver_settings::iterative_solver_ginkgo) &
387         settings.local_solver;
388     prev_global_solution->copy_from(gko::lend(global_solution));
389
390     ValueType local_residual_norm = -1.0, local_residual_norm0 = -1.0,
391               global_residual_norm = 0.0, global_residual_norm0 = -1.0;
392     metadata.iter_count = 0;
393     int num_converged_procs = 0;
394
395     std::string rank_string = std::to_string(metadata.my_rank);
396     if (metadata.my_rank < 10) {
397         rank_string = "0" + std::to_string(metadata.my_rank);
398     }
399
400     std::ofstream fps;  // file for sending log
401     std::ofstream fpr;  // file for receiving log
402     if (settings.debug_print) {
403         // Opening files for event logs
404         fps.open("send" + rank_string + ".txt");
405         fpr.open("recv" + rank_string + ".txt");
406     }
407
408     if (metadata.my_rank == 0) {
409         std::cout << "Send history - " << metadata.sent_history
410                   << ", Recv history - " << metadata.recv_history << std::endl;
411         std::cout << "Thres type - " << settings.thres_type << std::endl;
412         std::cout << "Overlap - " << settings.overlap << std::endl;
413     }
414
415     auto start_time = std::chrono::steady_clock::now();
416
417     for (; metadata.iter_count < metadata.max_iters; ++(metadata.iter_count)) {
418         // Exchange the boundary values. The communication part.
419         MEASURE_ELAPSED_FUNC_TIME(
```

```
420             this->exchange_boundary(settings, metadata, prev_global_solution,
421                                     global_solution, prev_event_solution, fps,
422                                     fpr),
423             0, metadata.my_rank, boundary_exchange, metadata.iter_count);
424         prev_global_solution->copy_from(gko::lend(global_solution));
425 
426         // Update the boundary and interior values after the exchanging from
427         // other processes.
428         MEASURE_ELAPSED_FUNC_TIME(
429             this->update_boundary(settings, metadata, this->
    local_solution,
430                                   this->local_rhs, global_solution,
431                                   this->interface_matrix),
432             1, metadata.my_rank, boundary_update, metadata.iter_count);
433 
434         // Check for the convergence of the solver.
435         // num_converged_procs = 0;
436         MEASURE_ELAPSED_FUNC_TIME(
437             (Solve<ValueType, IndexType, MixedValueType>::check_convergence(
438                 settings, metadata, this->comm_struct, this->convergence_vector,
439                 global_solution, this->local_solution, this->
    local_matrix,
440                 work_vector, local_residual_norm, local_residual_norm0,
441                 global_residual_norm, global_residual_norm0,
442                 num_converged_procs)),
443             2, metadata.my_rank, convergence_check, metadata.iter_count);
444 
445         // break if the solution diverges.
446         if (std::isnan(global_residual_norm) || global_residual_norm > 1e12) {
447             std::cout << " Rank " << metadata.my_rank << " diverged in "
448                       << metadata.iter_count << " iters " << std::endl;
449             std::exit(-1);
450         }
451 
452         // break if all processes detect that all other processes have
453         // converged otherwise continue iterations.
454         if (num_converged_procs == metadata.num_subdomains) {
455             break;
456         } else {
457             MEASURE_ELAPSED_FUNC_TIME(
458                 (Solve<ValueType, IndexType, MixedValueType>::local_solve(
459                     settings, metadata, this->local_matrix,
460                     this->triangular_factor_l, this->
    triangular_factor_u,
461                     this->local_perm, this->local_inv_perm, work_vector,
462                     init_guess, this->local_solution)),
463                 3, metadata.my_rank, local_solve, metadata.iter_count);
464 
465             // Gather the local vector into the locally global vector for
466             // communication.
467             MEASURE_ELAPSED_FUNC_TIME(
468                 (Communicate<ValueType, IndexType, MixedValueType>::
469                      local_to_global_vector(settings, metadata,
470                                             this->local_solution,
471                                             global_solution)),
472                 4, metadata.my_rank, expand_local_vec, metadata.iter_count);
473         }
474     }
475     MPI_Barrier(MPI_COMM_WORLD);
476     auto elapsed_time = std::chrono::duration<ValueType>(
477         std::chrono::steady_clock::now() - start_time);
478 
479     if (settings.debug_print) {
480         // Closing event log files
481         fps.close();
482         fpr.close();
483     }
484 
485     // adding 1 to include the 0-th iteration
486     // metadata.iter_count = metadata.iter_count + 1;
487 
488     // number of messages a PE would send without event-based
489     int noevent_msg_count = metadata.iter_count * num_neighbors_out;
490 
491     int total_events = 0;
492 
493     // Printing msg count
494     if (settings.debug_print) {
495         for (int k = 0; k < num_neighbors_out; k++) {
496             std::cout << " Rank: " << metadata.my_rank << " to "
497                       << neighbors_out[k] << " : "
498                       << this->comm_struct.msg_count->get_data()[k];
499             total_events += this->comm_struct.msg_count->get_data()[k];
500         }
501         std::cout << std::endl;
502     }
503 
```

```
504     // Total no of messages in all PEs
505     MPI_Allreduce(MPI_IN_PLACE, &total_events, 1, MPI_INT, MPI_SUM,
506                   MPI_COMM_WORLD);
507     MPI_Allreduce(MPI_IN_PLACE, &noevent_msg_count, 1, MPI_INT, MPI_SUM,
508                   MPI_COMM_WORLD);
509
510     if (metadata.my_rank == 0) {
511         std::cout << "Total number of events - " << total_events << std::endl;
512         std::cout << "Total number of msgs without event - "
513                   << noevent_msg_count << std::endl;
514     }
515
516     // Write the residuals and iterations to files
517     if (settings.write_iters_and_residuals &&
518         solver_settings ==
519             Settings::local_solver_settings::iterative_solver_ginkgo) {
520         std::string filename = "iter_res_" + rank_string + ".csv";
521         write_iters_and_residuals(
522             metadata.num_subdomains, metadata.my_rank,
523             metadata.post_process_data.local_residual_vector_out.size(),
524             metadata.post_process_data.local_residual_vector_out,
525             metadata.post_process_data.local_converged_iter_count,
526             metadata.post_process_data.local_converged_resnorm,
527             metadata.post_process_data.local_timestamp, filename);
528     }
529     if (num_converged_procs < metadata.num_subdomains) {
530         std::cout << "Rank " << metadata.my_rank << " did not converge in "
531                   << metadata.iter_count << " iterations." << std::endl;
532     } else {
533         std::cout << " Rank " << metadata.my_rank << " converged in "
534                   << metadata.iter_count << " iterations " << std::endl;
535         ValueType mat_norm = -1.0, rhs_norm = -1.0, sol_norm = -1.0,
536                   residual_norm = -1.0;
537
538         // Compute the final residual norm. Also gathers the solution from all
539         // subdomains.
540         Solve<ValueType, IndexType, MixedValueType>::compute_residual_norm(
541             settings, metadata, global_matrix, global_rhs, global_solution,
542             mat_norm, rhs_norm, sol_norm, residual_norm);
543         gather_comm_data<ValueType, IndexType, MixedValueType>(
544             metadata.num_subdomains, this->comm_struct,
545             metadata.comm_data_struct);
546         // clang-format off
547         if (metadata.my_rank == 0)
548           {
549             std::cout
550               << " residual norm " << residual_norm << "\n"
551               << " relative residual norm of solution " << residual_norm/rhs_norm << "\n"
552               << " Time taken for solve " << elapsed_time.count()
553               << std::endl;
554           }
555         // clang-format on
556     }
557     if (metadata.my_rank == 0) {
558         solution->copy_from(global_solution.get());
559     }
560
561     // Communicate<ValueType, IndexType>::clear(settings);
562 }
```

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

- schwarz_base.hpp (b6471e3)
- /home/runner/work/schwarz-lib/schwarz-lib/source/schwarz_base.cpp (b6471e3)

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.
- std::string rhs_type = "ones"

  Flag to enable a random rhs.
- std::string thres_type = "cgammak"

  Flag to choose thres type.
- std::string norm_type = "L1"

  Flag to choose norm type.
- 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.
- int restart_iter = 1

  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.

7.14.2.4 norm_type

```
std::string schwz::Settings::norm_type = "L1"
```

Flag to choose norm type.

Choices are "L1" or "L2"

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

7.14.2.5 thres_type

```
std::string schwz::Settings::thres_type = "cgammak"
```

Flag to choose thres type.

Choices are "cgammak" or "slope"

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

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

- settings.hpp (b6471e3)

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

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

Solve

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

- solve.hpp (b6471e3)
- /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, std::shared_ptr< gko::matrix::Dense< ValueType >> &prev_event_solution, std::ofstream &fps, std::ofstream &fpr) override

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

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

Additional Inherited Members

7.16.1 Detailed Description

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

An implementation of the solver interface using the RAS solver.

Template Parameters

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

7.16.2 Constructor & Destructor Documentation

7.16.2.1 SolverRAS()

```
template<typename ValueType , typename IndexType , 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

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

```
52     : SchwarzBase<ValueType, IndexType, MixedValueType>(settings, metadata)
53 {}
```

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,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & prev_event_solution,
            std::ofstream & fps,
            std::ofstream & fpr )  [override], [virtual]
```

Exchanges the elements of the solution vector.

Parameters

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

Implements schwz::Communicate< ValueType, IndexType, MixedValueType >.

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

```
1261 {
1262     if (settings.comm_settings.enable_onesided) {
1263         exchange_boundary_onesided<ValueType, IndexType, MixedValueType>(
1264             settings, metadata, this->comm_struct, prev_global_solution,
1265             global_solution, prev_event_solution, fps, fpr);
1266     } else {
1267         exchange_boundary_twosided<ValueType, IndexType, MixedValueType>(
1268             settings, metadata, this->comm_struct, prev_global_solution,
1269             global_solution);
1270     }
1271 }
```

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

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

Implements schwz::Initialize< ValueType, IndexType >.

References schwz::Metadata< ValueType, IndexType >::comm_size, schwz::Settings::executor, schwz::Metadata< ValueType, IndexType >::first_row, schwz::SchwarzBase< ValueType, IndexType, 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.

```
63 {
64     using mtx = gko::matrix::Csr<ValueType, IndexType>;
65     using vec_itype = gko::Array<IndexType>;
66     using perm_type = gko::matrix::Permutation<IndexType>;
67     using arr = gko::Array<IndexType>;
68     auto my_rank = metadata.my_rank;
69     auto comm_size = metadata.comm_size;
70     auto num_subdomains = metadata.num_subdomains;
71     auto global_size = metadata.global_size;
72     auto mpi_itype = schwz::mpi::get_mpi_datatype(*partition_indices.data());
73
74     MPI_Bcast(partition_indices.data(), global_size, mpi_itype, 0,
75               MPI_COMM_WORLD);
76
77     std::vector<IndexType> local_p_size(num_subdomains);
78     auto global_to_local = metadata.global_to_local->get_data();
79     auto local_to_global = metadata.local_to_global->get_data();
80
81     auto first_row = metadata.first_row->get_data();
82     auto permutation = metadata.permutation->get_data();
83     auto i_permutation = metadata.i_permutation->get_data();
84
85     auto nb = (global_size + num_subdomains - 1) /
    num_subdomains;
86     auto partition_settings =
87         (Settings::partition_settings::partition_zoltan |
88          Settings::partition_settings::partition_metis |
89          Settings::partition_settings::partition_regular |
90          Settings::partition_settings::partition_regular2d |
91          Settings::partition_settings::partition_custom) &
92         settings.partition;
93
94     IndexType *gmat_row_ptrs = global_matrix->get_row_ptrs();
95     IndexType *gmat_col_idxs = global_matrix->get_col_idxs();
96     ValueType *gmat_values = global_matrix->get_values();
97
98     // default local p size set for 1 subdomain.
99     first_row[0] = 0;
100     for (auto p = 0; p < num_subdomains; ++p) {
101         local_p_size[p] = std::min(global_size - first_row[p], nb);
102         first_row[p + 1] = first_row[p] + local_p_size[p];
103     }
104
105
106     if (partition_settings == Settings::partition_settings::partition_metis ||
107         partition_settings ==
108             Settings::partition_settings::partition_regular2d) {
109         if (num_subdomains > 1) {
110             for (auto p = 0; p < num_subdomains; p++) {
111                 local_p_size[p] = 0;
112             }
113             for (auto i = 0; i < global_size; i++) {
114                 local_p_size[partition_indices[i]]++;
115             }
116             first_row[0] = 0;
117             for (auto p = 0; p < num_subdomains; ++p) {
118                 first_row[p + 1] = first_row[p] + local_p_size[p];
119             }
120             // permutation
121             for (auto i = 0; i < global_size; i++) {
122                 permutation[first_row[partition_indices[i]]] = i;
123                 first_row[partition_indices[i]]++;
124             }
125             for (auto p = num_subdomains; p > 0; p--) {
126                 first_row[p] = first_row[p - 1];
127             }
128             first_row[0] = 0;
129
130             // iperm
131             for (auto i = 0; i < global_size; i++) {
132                 i_permutation[permutation[i]] = i;
133             }
```

```
134         }
135
136         auto gmat_temp = mtx::create(settings.executor->get_master(),
137                                      global_matrix->get_size(),
138                                      global_matrix->get_num_stored_elements());
139
140         auto nnz = 0;
141         gmat_temp->get_row_ptrs()[0] = 0;
142         for (auto row = 0; row < metadata.global_size; ++row) {
143             for (auto col = gmat_row_ptrs[permutation[row]];
144                  col < gmat_row_ptrs[permutation[row] + 1]; ++col) {
145                 gmat_temp->get_col_idxs()[nnz] =
146                     i_permutation[gmat_col_idxs[col]];
147                 gmat_temp->get_values()[nnz] = gmat_values[col];
148                 nnz++;
149             }
150             gmat_temp->get_row_ptrs()[row + 1] = nnz;
151         }
152         global_matrix->copy_from(gmat_temp.get());
153     }
154
155
156     for (auto i = 0; i < global_size; i++) {
157         global_to_local[i] = 0;
158         local_to_global[i] = 0;
159     }
160     auto num = 0;
161     for (auto i = first_row[my_rank]; i < first_row[
    my_rank + 1]; i++) {
162         global_to_local[i] = 1 + num;
163         local_to_global[num] = i;
164         num++;
165     }
166
167     IndexType old = 0;
168     for (auto k = 1; k < settings.overlap; k++) {
169         auto now = num;
170         for (auto i = old; i < now; i++) {
171             for (auto j = gmat_row_ptrs[local_to_global[i]];
172                  j < gmat_row_ptrs[local_to_global[i] + 1]; j++) {
173                 if (global_to_local[gmat_col_idxs[j]] == 0) {
174                     local_to_global[num] = gmat_col_idxs[j];
175                     global_to_local[gmat_col_idxs[j]] = 1 + num;
176                     num++;
177                 }
178             }
179         }
180         old = now;
181     }
182     metadata.local_size = local_p_size[my_rank];
183     metadata.local_size_x = num;
184     metadata.local_size_o = global_size;
185     auto local_size = metadata.local_size;
186     auto local_size_x = metadata.local_size_x;
187
188     metadata.overlap_size = num - metadata.local_size;
189     metadata.overlap_row = std::shared_ptr<vec_itype>(
190         new vec_itype(gko::Array<IndexType>::view(
191             settings.executor, metadata.overlap_size,
192             &(metadata.local_to_global->get_data()[metadata.local_size]))),
193         std::default_delete<vec_itype>());
194
195     auto nnz_local = 0;
196     auto nnz_interface = 0;
197
198     for (auto i = first_row[my_rank]; i < first_row[my_rank + 1]; ++i) {
199         for (auto j = gmat_row_ptrs[i]; j < gmat_row_ptrs[i + 1]; j++) {
200             if (global_to_local[gmat_col_idxs[j]] != 0) {
201                 nnz_local++;
202             } else {
203                 std::cout << " debug: invalid edge?" << std::endl;
204             }
205         }
206     }
207     auto temp = 0;
208     for (auto k = 0; k < metadata.overlap_size; k++) {
209         temp = metadata.overlap_row->get_data()[k];
210         for (auto j = gmat_row_ptrs[temp]; j < gmat_row_ptrs[temp + 1]; j++) {
211             if (global_to_local[gmat_col_idxs[j]] != 0) {
212                 nnz_local++;
213             } else {
214                 nnz_interface++;
215             }
216         }
217     }
218
219     std::shared_ptr<mtx> local_matrix_compute;
```

```
220     local_matrix_compute = mtx::create(settings.executor->get_master(),
221                                        gko::dim<2>(local_size_x), nnz_local);
222     IndexType *lmat_row_ptrs = local_matrix_compute->get_row_ptrs();
223     IndexType *lmat_col_idxs = local_matrix_compute->get_col_idxs();
224     ValueType *lmat_values = local_matrix_compute->get_values();
225
226     std::shared_ptr<mtx> interface_matrix_compute;
227     if (nnz_interface > 0) {
228         interface_matrix_compute =
229             mtx::create(settings.executor->get_master(),
230                         gko::dim<2>(local_size_x), nnz_interface);
231     } else {
232         interface_matrix_compute = mtx::create(settings.executor->get_master());
233     }
234
235     IndexType *imat_row_ptrs = interface_matrix_compute->get_row_ptrs();
236     IndexType *imat_col_idxs = interface_matrix_compute->get_col_idxs();
237     ValueType *imat_values = interface_matrix_compute->get_values();
238
239     num = 0;
240     nnz_local = 0;
241     auto nnz_interface_temp = 0;
242     lmat_row_ptrs[0] = nnz_local;
243     if (nnz_interface > 0) {
244         imat_row_ptrs[0] = nnz_interface_temp;
245     }
246     // Local interior matrix
247     for (auto i = first_row[my_rank]; i < first_row[my_rank + 1]; ++i) {
248         for (auto j = gmat_row_ptrs[i]; j < gmat_row_ptrs[i + 1]; ++j) {
249             if (global_to_local[gmat_col_idxs[j]] != 0) {
250                 lmat_col_idxs[nnz_local] =
251                     global_to_local[gmat_col_idxs[j]] - 1;
252                 lmat_values[nnz_local] = gmat_values[j];
253                 nnz_local++;
254             }
255         }
256         if (nnz_interface > 0) {
257             imat_row_ptrs[num + 1] = nnz_interface_temp;
258         }
259         lmat_row_ptrs[num + 1] = nnz_local;
260         num++;
261     }
262
263     // Interface matrix
264     if (nnz_interface > 0) {
265         nnz_interface = 0;
266         for (auto k = 0; k < metadata.overlap_size; k++) {
267             temp = metadata.overlap_row->get_data()[k];
268             for (auto j = gmat_row_ptrs[temp]; j < gmat_row_ptrs[temp + 1];
269                  j++) {
270                 if (global_to_local[gmat_col_idxs[j]] != 0) {
271                     lmat_col_idxs[nnz_local] =
272                         global_to_local[gmat_col_idxs[j]] - 1;
273                     lmat_values[nnz_local] = gmat_values[j];
274                     nnz_local++;
275                 } else {
276                     imat_col_idxs[nnz_interface] = gmat_col_idxs[j];
277                     imat_values[nnz_interface] = gmat_values[j];
278                     nnz_interface++;
279                 }
280             }
281             lmat_row_ptrs[num + 1] = nnz_local;
282             imat_row_ptrs[num + 1] = nnz_interface;
283             num++;
284         }
285     }
286     auto now = num;
287     for (auto i = old; i < now; i++) {
288         for (auto j = gmat_row_ptrs[local_to_global[i]];
289              j < gmat_row_ptrs[local_to_global[i] + 1]; j++) {
290             if (global_to_local[gmat_col_idxs[j]] == 0) {
291                 local_to_global[num] = gmat_col_idxs[j];
292                 global_to_local[gmat_col_idxs[j]] = 1 + num;
293                 num++;
294             }
295         }
296     }
297
298     local_matrix_compute->sort_by_column_index();
299     interface_matrix_compute->sort_by_column_index();
300
301     local_matrix = mtx::create(settings.executor);
302     local_matrix->copy_from(gko::lend(local_matrix_compute));
303     interface_matrix = mtx::create(settings.executor);
304     interface_matrix->copy_from(gko::lend(interface_matrix_compute));
305 }
```

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

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

Implements schwz::Communicate< ValueType, IndexType, MixedValueType >.

References schwz::Metadata< ValueType, IndexType >::comm_start_iters, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::curr_recv_avg, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::curr_send_avg, schwz::Settings::debug_print, 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::extra_buffer, 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::Metadata< ValueType, IndexType >::horizon, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::is_local_neighbor, schwz::Metadata< ValueType, IndexType >::iter_count, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::last_recv_avg, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::last_recv_iter, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::last_send_avg, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::last_sent_iter, 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_recv_buffer, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::mixedt_send_buffer, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::msg_count, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::neighbors_in, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::neighbors_out, schwz::Settings::norm_type, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::num_neighbors_in, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::num_neighbors_out, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::num_recv, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::num_send, schwz::Metadata< ValueType, IndexType >::num_subdomains, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::prev_event_solution, 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::recv_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::thres_type, schwz::Settings::use_mixed_precision, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::window_recv_buffer, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::window_send_buffer, and schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::window_x.

```
667 {
668     using vec_itype = gko::Array<IndexType>;
669     using vec_vtype = gko::matrix::Dense<ValueType>;
670     auto num_subdomains = metadata.num_subdomains;
671     auto local_size_o = metadata.local_size_o;
672     auto neighbors_in = this->comm_struct.neighbors_in->get_data();
673     auto global_get = this->comm_struct.global_get->get_data();
674     auto neighbors_out = this->comm_struct.neighbors_out->get_data();
675     auto global_put = this->comm_struct.global_put->get_data();
676 
677     // set displacement for the MPI buffer
678     auto get_displacements = this->comm_struct.get_displacements->get_data();
679     auto put_displacements = this->comm_struct.put_displacements->get_data();
680     {
681         std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
682         tmp_num_comm_elems[0] = 0;
683         for (auto j = 0; j < this->comm_struct.num_neighbors_in; j++) {
684             if ((global_get[j])[0] > 0) {
685                 int p = neighbors_in[j];
686                 tmp_num_comm_elems[p + 1] = (global_get[j])[0];
687             }
688         }
689         for (auto j = 0; j < num_subdomains; j++) {
690             tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
691         }
692 
693         auto mpi_itype = schwz::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
694         MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, put_displacements,
695                      1, mpi_itype, MPI_COMM_WORLD);
696     }
697 
698     {
699         std::vector<IndexType> tmp_num_comm_elems(num_subdomains + 1, 0);
700         tmp_num_comm_elems[0] = 0;
701         for (auto j = 0; j < this->comm_struct.num_neighbors_out; j++) {
702             if ((global_put[j])[0] > 0) {
703                 int p = neighbors_out[j];
704                 tmp_num_comm_elems[p + 1] = (global_put[j])[0];
705             }
706         }
707         for (auto j = 0; j < num_subdomains; j++) {
708             tmp_num_comm_elems[j + 1] += tmp_num_comm_elems[j];
709         }
710 
711         auto mpi_itype = schwz::mpi::get_mpi_datatype(tmp_num_comm_elems[0]);
712         MPI_Alltoall(tmp_num_comm_elems.data(), 1, mpi_itype, get_displacements,
713                      1, mpi_itype, MPI_COMM_WORLD);
714     }
715 
716     // setup windows
717     if (settings.comm_settings.enable_onesided) {
718         // Onesided
719 
720         for (int i = 0; i < main_buffer->get_size()[0]; i++) {
721             main_buffer->get_values()[i] = 0.0;
722         }
723 
724         MPI_Win_create(main_buffer->get_values(),
725                        main_buffer->get_size()[0] * sizeof(ValueType),
726                        sizeof(ValueType), MPI_INFO_NULL, MPI_COMM_WORLD,
727                        &(this->comm_struct.window_x));
728     }
729 
730 
731     if (settings.comm_settings.enable_onesided) {
732         // MPI_Alloc_mem ? Custom allocator ?  TODO
733 
734         for (int i = 0; i < num_subdomains; i++) {
735             this->local_residual_vector->get_values()[i] = 0.0;
736         }
737 
738         MPI_Win_create(this->local_residual_vector->get_values(),
739                        (num_subdomains) * sizeof(ValueType), sizeof(ValueType),
740                        MPI_INFO_NULL, MPI_COMM_WORLD,
741                        &(this->window_residual_vector));
```

```
742         std::vector<IndexType> zero_vec(num_subdomains, 0);
743         gko::Array<IndexType> temp_array{settings.executor->get_master(),
744                                          zero_vec.begin(), zero_vec.end()};
745         this->convergence_vector = std::shared_ptr<vec_itype>(
746             new vec_itype(settings.executor->get_master(), temp_array),
747             std::default_delete<vec_itype>());
748         this->convergence_sent = std::shared_ptr<vec_itype>(
749             new vec_itype(settings.executor->get_master(), num_subdomains),
750             std::default_delete<vec_itype>());
751         this->convergence_local = std::shared_ptr<vec_itype>(
752             new vec_itype(settings.executor->get_master(), num_subdomains),
753             std::default_delete<vec_itype>());
754 
755         for (int i = 0; i < num_subdomains; i++) {
756             this->convergence_vector->get_data()[i] = 0;
757             this->convergence_sent->get_data()[i] = 0;
758             this->convergence_local->get_data()[i] = 0;
759         }
760 
761         MPI_Win_create(this->convergence_vector->get_data(),
762                        (num_subdomains) * sizeof(IndexType), sizeof(IndexType),
763                        MPI_INFO_NULL, MPI_COMM_WORLD,
764                        &(this->window_convergence));
765     }
766 
767     if (settings.comm_settings.enable_onesided && num_subdomains > 1) {
768         // Lock all windows.
769         if (settings.comm_settings.enable_get &&
770             settings.comm_settings.enable_lock_all) {
771             MPI_Win_lock_all(0, this->comm_struct.window_send_buffer);
772         }
773         if (settings.comm_settings.enable_put &&
774             settings.comm_settings.enable_lock_all) {
775             MPI_Win_lock_all(0, this->comm_struct.window_recv_buffer);
776         }
777         if (settings.comm_settings.enable_one_by_one &&
778             settings.comm_settings.enable_lock_all) {
779             MPI_Win_lock_all(0, this->comm_struct.window_x);
780         }
781         MPI_Win_lock_all(0, this->window_residual_vector);
782         MPI_Win_lock_all(0, this->window_convergence);
783     }
784 }
```

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

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

Implements schwz::Communicate< ValueType, IndexType, MixedValueType >.

References schwz::Settings::executor, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_solution, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::interface_matrix, schwz::SchwarzBase< 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.

```
1282 {
1283     using vec_vtype = gko::matrix::Dense<ValueType>;
1284     auto one = gko::initialize<gko::matrix::Dense<ValueType>>(
1285         {1.0}, settings.executor);
1286     auto neg_one = gko::initialize<gko::matrix::Dense<ValueType>>(
1287         {-1.0}, settings.executor);
1288     auto local_size_x = metadata.local_size_x;
1289     local_solution->copy_from(local_rhs.get());
1290     if (metadata.num_subdomains > 1 && settings.overlap > 0) {
1291         auto temp_solution = vec_vtype::create(
1292             settings.executor, local_solution->get_size(),
1293             gko::Array<ValueType>::view(settings.executor,
1294                                         local_solution->get_size()[0],
1295                                         global_solution->get_values()),
1296             1);
1297         interface_matrix->apply(neg_one.get(), temp_solution.get(), one.get(),
1298                                 local_solution.get());
1299     }
1300 }
```

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

- restricted_schwarz.hpp (b6471e3)
- /home/runner/work/schwarz-lib/schwarz-lib/source/restricted_schwarz.cpp (b6471e3)

7.17 UmfpackError Class Reference

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

`#include <exception.hpp>`

Public Member Functions

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

7.17.1 Detailed Description

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

7.17.2 Constructor & Destructor Documentation

7.17.2.1 UmfpackError()

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

Initializes a METIS error.

Parameters

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

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

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

- exception.hpp (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

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

Utils

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

- utils.hpp (1cd0e3b)
- /home/runner/work/schwarz-lib/schwarz-lib/source/utils.cpp (f366659)

Index