schwz

Generated automatically from event-based-new

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 (1a4d86f)

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 (1bdbc6b)

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 (1bdbc6b)
- /home/runner/work/schwarz-lib/schwarz-lib/source/communicate.cpp (13a534d)

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 (1a4d86f)

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 & filename,
            const gko::size_type & oned_laplacian_size,
            std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> & global_matrix )
```

Generates the 2D global laplacian matrix.

Parameters

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

Referenced by schwz::Initialize< ValueType, IndexType >::generate_sin_rhs(), and schwz::SchwarzBase< ValueType, IndexType, 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 (b74805c)
- /home/runner/work/schwarz-lib/schwarz-lib/source/initialization.cpp (55ad704)

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 (1a4d86f)

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 (1a4d86f)

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**$\hookleftarrow$
::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$\hookleftarrow$ _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, Mixed←↩
ValueType >::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 (13a534d)
- /home/runner/work/schwarz-lib/schwarz-lib/source/schwarz_base.cpp (5a53b5f)

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 (1a4d86f)

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 (13a534d)
- /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, Index↩ Type >::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< Value←
Type, IndexType, MixedValueType >::comm_struct::curr_recv_avg, schwz::Communicate< ValueType, Index←
Type, 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< Value←
Type, IndexType, MixedValueType >::comm_struct::extra_buffer, schwz::Communicate< ValueType, Index←
Type, MixedValueType >::comm_struct::get_displacements, schwz::Communicate< ValueType, IndexType,
MixedValueType >::comm_struct::get_request, schwz::Communicate< ValueType, IndexType, MixedValue←
Type >::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< Value←
Type, 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, Index←
Type, MixedValueType >::comm_struct::remote_get, schwz::Communicate< ValueType, IndexType, MixedValue←
Type >::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< Value←
Type, 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::Schwarz↩
Base< ValueType, IndexType, MixedValueType >::local_rhs, schwz::Metadata< ValueType, IndexType >::local↩
_size_x, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::local_solution, schwz::Metadata<
ValueType, IndexType >::num_subdomains, and schwz::Settings::overlap.

```
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 (13a534d)
- /home/runner/work/schwarz-lib/schwarz-lib/source/restricted_schwarz.cpp (5df4d0a)

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)

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