schwz

Generated automatically from mixed-precision-solve

Contents

Chapter 1

Main Page

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

Modules

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

- Initialization : Handles the initialization of the problem and the solver.

- Communicate : Handles the communication.

- Solve : Handles the local solution and the convergence detection.

- Schwarz Class : The Classes related to the Schwarz solvers.

- Utils : Provides some basic utilities.

Chapter 2

Installation Instructions

Building

Use the standard cmake build procedure:

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

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

- `-DSCHWARZ_BUILD_BENCHMARKING={ON, OFF}` Builds some example benchmarks. Default is `ON`

- `-DSCHWARZ_BUILD_METIS={ON, OFF}` Builds with support for the `METIS` partitioner. User needs to provide the path to the installation of the `METIS` library in `METIS_DIR`, preferably as an environment variable. Default is `OFF`

- `-DSCHWARZ_BUILD_CHOLMOD={ON, OFF}` Builds with support for the `CHOLMOD` module from the Suitesparse library. User needs to set an environment variable `CHOLMOD_DIR` to the path containing the `CHOLMOD` installation. Default is `OFF`

- `-DSCHWARZ_BUILD_CUDA={ON, OFF}` Builds with CUDA support. Though Ginkgo provides most of the required CUDA support, we do need to link to CUDA for explicit setting of GPU affinities, some custom gather and scatter operations. Default is `OFF`.

- `-DSCHWARZ_BUILD_CLANG_TIDY={ON, OFF}` Builds with support for `clang-tidy` Default is `OFF`

- `-DSCHWARZ_BUILD_DEALII={ON, OFF}` Builds with support for the finite element library `deal.ii` Default is `OFF`

- `-DSCHWARZ_WITH_HWLOC={ON, OFF}` Builds with support for the hardware locality library used for binding hardware. `hwloc` is distributed as a part of the Open-MPI project. Default is `ON`

- `-DSCHWARZ_DEVEL_TOOLS={ON, OFF}` Builds with some developer tools support. Default is `ON`. In particular uses `git-cmake-format` to automatically format the source files with `clang-format`.

Tips

- If you are having CUDA problems and you are not using CUDA, then feel free to switch the CUDA module off with `-DSCHWARZ_BUILD_CUDA=off`.

- Installing CHOLMOD can be a bit annoying. TODO add some details on fixing Suitesparse compilation.

- When doing merge commits it is possible that make format does not work. You can run `cmake -DSCH`↩ `WARZ_DEVEL_TOOLS=OFF ..` to temporarily switch off the formatting. Please switch it on again when committing normally.

Chapter 3

Testing Instructions

Chapter 4

Benchmarking.

Benchmark example 1.

Poisson solver using Restricted Additive Schwarz with overlap.

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

The executable is run in the following fashion:

"'sh [MPI_COMMAND] [MPI_OPTIONS]

Chapter 5

Module Documentation

5.1 Communicate

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

Namespaces

- schwz::CommHelpers

    The CommHelper namespace .
- ProcessTopology

    The ProcessTopology namespace .

Classes

- class schwz::Communicate< ValueType, IndexType, MixedValueType >

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

    The solver metadata struct.

5.1.1 Detailed Description

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

5.2 Initialization

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

Namespaces

- schwz::PartitionTools

    The PartitionTools namespace .
- ProcessTopology

    The ProcessTopology namespace .

Classes

- class schwz::device_guard

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

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

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

    The solver metadata struct.

5.2.1 Detailed Description

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

5.3 Schwarz Class

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

Classes

- class schwz::SolverRAS< ValueType, IndexType, MixedValueType >

  An implementation of the solver interface using the RAS solver.

- class schwz::SchwarzBase< ValueType, IndexType, MixedValueType >

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

5.3.1 Detailed Description

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

5.4 Solve

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

Namespaces

- schwz::conv_tools

  The conv_tools namespace .
- schwz::SolverTools

  The SolverTools namespace .

Classes

- struct schwz::Metadata< ValueType, IndexType >

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

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

5.4.1 Detailed Description

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

5.5 Utils

A module dedicated to the utilities in schwarz-lib.

Classes

- struct schwz::Utils< ValueType, IndexType >

  The utilities class which provides some checks and basic utilities.

5.5.1 Detailed Description

A module dedicated to the utilities in schwarz-lib.

Chapter 6

Namespace Documentation

6.1 ProcessTopology Namespace Reference

The ProcessTopology namespace .

6.1.1 Detailed Description

The ProcessTopology namespace .

proc_topo

6.2 schwz Namespace Reference

The Schwarz wrappers namespace.

Namespaces

- CommHelpers

    The CommHelper namespace .
- conv_tools

    The conv_tools namespace .
- PartitionTools

    The PartitionTools namespace .
- SolverTools

    The SolverTools namespace .

Classes

- class Communicate

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

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

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

  The solver metadata struct.
- class SchwarzBase

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

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

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

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

  The utilities class which provides some checks and basic utilities.

6.2.1 Detailed Description

The Schwarz wrappers namespace.

6.3 schwz::CommHelpers Namespace Reference

The CommHelper namespace .

6.3.1 Detailed Description

The CommHelper namespace .

comm_helpers

6.4 schwz::conv_tools Namespace Reference

The conv_tools namespace .

6.4.1 Detailed Description

The conv_tools namespace .

conv_tools

6.5 schwz::PartitionTools Namespace Reference

The PartitionTools namespace .

6.5.1 Detailed Description

The PartitionTools namespace .

part_tools

6.6 schwz::SolverTools Namespace Reference

The SolverTools namespace .

6.6.1 Detailed Description

The SolverTools namespace .

solver_tools

Chapter 7

Class Documentation

7.1 BadDimension Class Reference

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

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

Public Member Functions

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

  Initializes a bad dimension error.

7.1.1 Detailed Description

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

7.1.2 Constructor & Destructor Documentation

7.1.2.1 BadDimension()

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

Initializes a bad dimension error.

Parameters

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 (e9d2b7d)

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

The communication struct used to store the communication data.

```
#include <communicate.hpp>
```

Public Attributes

- int num_neighbors_in

    The number of neighbors this subdomain has to receive data from.
- int num_neighbors_out

    The number of neighbors this subdomain has to send data to.
- std::shared_ptr< gko::Array< IndexType > > neighbors_in

    The neighbors this subdomain has to receive data from.
- std::shared_ptr< gko::Array< IndexType > > neighbors_out

    The neighbors this subdomain has to send data to.
- std::vector< bool > is_local_neighbor

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

    The number of neighbors this subdomain has to receive data from.
- int local_num_neighbors_out

    The number of neighbors this subdomain has to send data to.
- std::shared_ptr< gko::Array< IndexType > > local_neighbors_in

    The neighbors this subdomain has to receive data from.
- std::shared_ptr< gko::Array< IndexType > > local_neighbors_out

    The neighbors this subdomain has to send data to.
- std::shared_ptr< gko::Array< IndexType * > > global_put

    The array containing the number of elements that each subdomain sends from the other.
- std::shared_ptr< gko::Array< IndexType * > > local_put

    The array containing the number of elements that each subdomain sends from the other.
- std::shared_ptr< gko::Array< IndexType * > > remote_put

    The array containing the number of elements that each subdomain sends from the other.
- std::shared_ptr< gko::Array< IndexType * > > global_get

    The array containing the number of elements that each subdomain gets from the other.
- std::shared_ptr< gko::Array< IndexType * > > local_get

    The array containing the number of elements that each subdomain gets from the other.
- std::shared_ptr< gko::Array< IndexType * > > remote_get

    The array containing the number of elements that each subdomain gets from the other.
- std::shared_ptr< gko::Array< IndexType > > window_ids

The RDMA window ids.

- std::shared_ptr< gko::Array< IndexType > > windows_from

  The RDMA window ids to receive data from.

- std::shared_ptr< gko::Array< IndexType > > windows_to

  The RDMA window ids to send data to.

- std::shared_ptr< gko::Array< MPI_Request > > put_request

  The put request array.

- std::shared_ptr< gko::Array< MPI_Request > > get_request

  The get request array.

- std::shared_ptr< gko::matrix::Dense< ValueType > > send_buffer

  The send buffer used for the actual communication for both one-sided and two-sided (always allocated).

- std::shared_ptr< gko::matrix::Dense< MixedValueType > > mixedt_send_buffer

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

- std::shared_ptr< gko::matrix::Dense< ValueType > > recv_buffer

  The recv buffer used for the actual communication for both one-sided and two-sided (always allocated).

- std::shared_ptr< gko::matrix::Dense< MixedValueType > > mixedt_recv_buffer

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

- std::shared_ptr< gko::Array< IndexType > > get_displacements

  The displacements for the receiving of the buffer.

- std::shared_ptr< gko::Array< IndexType > > put_displacements

  The displacements for the sending of the buffer.

- MPI_Win window_recv_buffer

  The RDMA window for the recv buffer.

- MPI_Win window_send_buffer

  The RDMA window for the send buffer.

- MPI_Win window_x

  The RDMA window for the solution vector.

7.3.1 Detailed Description

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

The communication struct used to store the communication data.

7.3.2 Member Data Documentation

7.3.2.1 global_get

```
template<typename ValueType , typename IndexType , typename MixedValueType >
std::shared_ptr<gko::Array<IndexType *> > schwz::Communicate< ValueType, IndexType, 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 (7c9a9f7)

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

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

```
#include <communicate.hpp>
```

Classes

- struct comm_struct

  The communication struct used to store the communication data.

Public Member Functions

- virtual void setup_comm_buffers ()=0

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

  Sets up the windows needed for the asynchronous communication.
- virtual void exchange_boundary (const Settings &settings, const Metadata< ValueType, IndexType > &meta-data, const std::shared_ptr< gko::matrix::Dense< ValueType >> &prev_global_solution, std::shared_ptr< gko::matrix::Dense< ValueType >> &global_solution)=0

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

  Transforms data from a local vector to a global vector.
- virtual void update_boundary (const Settings &settings, const Metadata< ValueType, IndexType > &meta-data, 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 )  [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().

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

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

7.4.2.3 setup_windows()

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

Sets up the windows needed for the asynchronous communication.

Parameters

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 (7c9a9f7)
- /home/runner/work/schwarz-lib/schwarz-lib/source/communicate.cpp (7c9a9f7)

7.5 schwz::Settings::convergence_settings Struct Reference

The various convergence settings available.

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

7.5.1 Detailed Description

The various convergence settings available.

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

- settings.hpp (e9d2b7d)

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 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_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.

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

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

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

7.9.2.2 partition()

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

The partitioning function.

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

Parameters

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().

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

7.9.2.3 setup_global_matrix()

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

Generates the 2D global laplacian matrix.

Parameters

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

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

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

7.9.2.4 setup_local_matrices()

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

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

Parameters

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.

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

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

7.9.2.5 setup_vectors()

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

Setup the vectors with default values and allocate 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().

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

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

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

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

The solver metadata struct.

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

Classes

- struct post_process_data
    The struct used for storing data for post-processing.

Public Attributes

- MPI_Comm mpi_communicator
    The MPI communicator.
- gko::size_type global_size = 0
    The size of the global matrix.
- gko::size_type oned_laplacian_size = 0
    The size of the 1 dimensional laplacian grid.
- gko::size_type local_size = 0
    The size of the local subdomain matrix.
- gko::size_type local_size_x = 0
    The size of the local subdomain matrix + the overlap.
- gko::size_type local_size_o = 0

> *The size of the local subdomain matrix + the overlap.*

- gko::size_type overlap_size = 0

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

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

  The rank of the subdomain.
- int my_local_rank

  The local rank of the subdomain.
- int local_num_procs

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

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

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

  The iteration count of the solver.
- ValueType tolerance

  The tolerance of the complete solver.
- ValueType local_solver_tolerance

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

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

  The maximum iteration count of the local iterative solver.
- IndexType updated_max_iters

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

  Local preconditioner.
- unsigned int precond_max_block_size

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

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

  The minimum residual norm of the subdomain.
- std::vector$<$ std::tuple$<$ int, int, int, std::string, std::vector$<$ ValueType $>$ $>$ $>$ time_struct

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

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

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

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

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

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

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

  The inverse permutation used for the re-ordering.

7.10.1 Detailed Description

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

The solver metadata struct.

Template Parameters

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 (e9d2b7d)

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 (e9d2b7d)

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

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

```
#include <schwarz_base.hpp>
```

Public Member Functions

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

  The constructor that takes in the user settings and a metadata struct containing the solver metadata.
- void initialize ()

  Initialize the matrix and vectors.
- void run (std::shared_ptr< gko::matrix::Dense< ValueType >> &solution)

  The function that runs the actual solver and obtains the final solution.
- void print_vector (const std::shared_ptr< gko::matrix::Dense< ValueType >> &vector, int subd, std::string name)

  The auxiliary function that prints a passed in vector.
- void print_matrix (const std::shared_ptr< gko::matrix::Csr< ValueType, IndexType >> &matrix, int rank, std::string name)

  The auxiliary function that prints a passed in CSR matrix.

Public Attributes

- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > local_matrix

  The local subdomain matrix.
- std::shared_ptr< gko::matrix::Permutation< IndexType > > local_perm

  The local subdomain permutation matrix/array.
- std::shared_ptr< gko::matrix::Permutation< IndexType > > local_inv_perm

  The local subdomain inverse permutation matrix/array.
- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > triangular_factor_l

  The local lower triangular factor used for the triangular solves.
- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > triangular_factor_u

  The local upper triangular factor used for the triangular solves.
- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > interface_matrix

  The local interface matrix.

- std::shared_ptr< gko::matrix::Csr< ValueType, IndexType > > global_matrix
    The global matrix.
- std::shared_ptr< gko::matrix::Dense< ValueType > > local_rhs
    The local right hand side.
- std::shared_ptr< gko::matrix::Dense< ValueType > > global_rhs
    The global right hand side.
- std::shared_ptr< gko::matrix::Dense< ValueType > > local_solution
    The local solution vector.
- std::shared_ptr< gko::matrix::Dense< ValueType > > global_solution
    The global solution vector.
- std::vector< ValueType > local_residual_vector_out
    The global residual vector.
- std::vector< std::vector< ValueType > > global_residual_vector_out
    The local residual vector.

Additional Inherited Members

7.13.1 Detailed Description

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

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

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

Template Parameters

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

7.13.2 Constructor & Destructor Documentation

7.13.2.1 SchwarzBase()

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

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

Parameters

settings	The settings struct.
metadata	The metadata struct.

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

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

7.13.3 Member Function Documentation

7.13.3.1 print_matrix()

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

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

The auxiliary function that prints a passed in CSR matrix.

Parameters

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

7.13.3.2   print_vector()

```
template<typename ValueType = gko::default_precision, typename IndexType = gko::int32, typename
MixedValueType = gko::default_precision>
void schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::print_vector (
            const std::shared_ptr< gko::matrix::Dense< ValueType >> & vector,
            int subd,
            std::string name )
```

The auxiliary function that prints a passed in vector.

Parameters

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

7.13.3.3   run()

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

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

Parameters

solution	The solution vector.

References schwz::Communicate< ValueType, IndexType, MixedValueType >::exchange_boundary(), schwz::←
Settings::executor, schwz::Settings::executor_string, schwz::SchwarzBase< ValueType, IndexType, MixedValue←
Type >::global_matrix, schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_rhs, schwz←
::SchwarzBase< ValueType, IndexType, MixedValueType >::global_solution, schwz::SchwarzBase< ValueType,

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

```
319 {
320     using vec_vtype = gko::matrix::Dense<ValueType>;
321     if (!solution.get()) {
322         solution =
323             vec_vtype::create(settings.executor->get_master(),
324                               gko::dim<2>(this->metadata.global_size, 1));
325     }
326     MixedValueType dummy1 = 0.0;
327     ValueType dummy2 = 1.0;
328
329     if (metadata.my_rank == 0) {
330         std::cout << " MixedValueType: " << typeid(dummy1).name()
331                   << " ValueType: " << typeid(dummy2).name() << std::endl;
332     }
333     // The main solution vector
334     std::shared_ptr<vec_vtype> global_solution = vec_vtype::create(
335         this->settings.executor, gko::dim<2>(this->metadata.global_size, 1));
336     // The previous iteration solution vector
337     std::shared_ptr<vec_vtype> prev_global_solution = vec_vtype::create(
338         this->settings.executor, gko::dim<2>(this->metadata.global_size, 1));
339     // A work vector.
340     std::shared_ptr<vec_vtype> work_vector = vec_vtype::create(
341         settings.executor, gko::dim<2>(2 * this->metadata.local_size_x, 1));
342     // An initial guess.
343     std::shared_ptr<vec_vtype> init_guess = vec_vtype::create(
344         settings.executor, gko::dim<2>(this->metadata.local_size_x, 1));
345     // init_guess->copy_from(local_rhs.get());
346
347     if (settings.executor_string == "omp") {
348         ValueType sum_rhs = std::accumulate(
349             local_rhs->get_values(),
350             local_rhs->get_values() + local_rhs->get_size()[0], 0.0);
351         std::cout << " Rank " << this->metadata.my_rank << " sum local rhs "
352                   << sum_rhs << std::endl;
353     }
354
355     // std::vector<IndexType> local_converged_iter_count;
356
357     // Setup the windows for the onesided communication.
358     this->setup_windows(this->settings, this->metadata, global_solution);
359
360     const auto solver_settings =
361         (Settings::local_solver_settings::direct_solver_cholmod |
362          Settings::local_solver_settings::direct_solver_umfpack |
363          Settings::local_solver_settings::direct_solver_ginkgo |
364          Settings::local_solver_settings::iterative_solver_dealii |
365          Settings::local_solver_settings::iterative_solver_ginkgo) &
366         settings.local_solver;
367     prev_global_solution->copy_from(gko::lend(global_solution));
368
369     ValueType local_residual_norm = -1.0, local_residual_norm0 = -1.0,
370               global_residual_norm = 0.0, global_residual_norm0 = -1.0;
371     metadata.iter_count = 0;
372     auto start_time = std::chrono::steady_clock::now();
373     int num_converged_procs = 0;
374
375     for (; metadata.iter_count < metadata.max_iters; ++(metadata.iter_count)) {
376         // Exchange the boundary values. The communication part.
377         MEASURE_ELAPSED_FUNC_TIME(
378             this->exchange_boundary(settings, metadata, prev_global_solution,
379                                     global_solution),
380             0, metadata.my_rank, boundary_exchange, metadata.iter_count);
381         prev_global_solution->copy_from(gko::lend(global_solution));
382
383         // Update the boundary and interior values after the exchanging from
384         // other processes.
385         MEASURE_ELAPSED_FUNC_TIME(
386             this->update_boundary(settings, metadata, this->
387     local_solution,
388                                   this->local_rhs, global_solution,
389                                   this->interface_matrix),
390             1, metadata.my_rank, boundary_update, metadata.iter_count);
```

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

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

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

- schwarz_base.hpp (ca00a18)
- /home/runner/work/schwarz-lib/schwarz-lib/source/schwarz_base.cpp (7c9a9f7)

7.14 schwz::Settings Struct Reference

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

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

Classes

- struct comm_settings

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

  The various convergence settings available.

Public Types

- enum partition_settings

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

  The local solver algorithm for the local subdomain solves.

Public Attributes

- std::string executor_string

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

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

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

  The overlap between the subdomains.
- std::string matrix_filename = "null"

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

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

- bool use_mixed_precision = false

    Flag if mixed precision should be used.

- bool enable_random_rhs = false

    Flag to enable a random rhs.

- bool print_matrices = false

    Flag to enable printing of matrices.

- bool debug_print = false

    Flag to enable some debug printing.

- bool non_symmetric_matrix = false

    Is the matrix non-symmetric ? , Use GMRES for local solves.

- unsigned int restart_iter = 1u

    The restart iter for the GMRES solver.

- int reset_local_crit_iter = -1

    The global iter at which to reset the local solver criterion.

- bool naturally_ordered_factor = false

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

- std::string metis_objtype

    This setting defines the objective type for the metis partitioning.

- bool use_precond = false

    Enable the block jacobi local preconditioner for the local solver.

- bool write_debug_out = false

    Enable the writing of debug out to file.

- bool write_iters_and_residuals = false

    Enable writing the iters and residuals to a file.

- bool enable_logging = false

    Flag to enable logging for local iterative solvers.

- bool write_perm_data = false

    Enable the local permutations from CHOLMOD to a file.

- int shifted_iter = 1

    Iteration shift for node local communication.

- std::string factorization = "cholmod"

    The factorization for the local direct solver.

- std::string reorder

    The reordering for the local solve.

7.14.1 Detailed Description

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

settings

7.14.2 Member Data Documentation

7.14.2.1 enable_logging

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

Flag to enable logging for local iterative solvers.

Note: Probably will have a significant performance hit.

7.14.2.2 explicit_laplacian

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

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

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

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

7.14.2.3 naturally_ordered_factor

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

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

Note

This is mainly to allow compatibility with GPU solution.

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

- settings.hpp (e9d2b7d)

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

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

An implementation of the solver interface using the RAS solver.

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

Public Member Functions

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

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

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

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

  Sets up the windows needed for the asynchronous communication.
- void [exchange_boundary](#) (const [Settings](#) &settings, const [Metadata](#)< ValueType, IndexType > &metadata, const std::shared_ptr< gko::matrix::Dense< ValueType >> &prev_global_solution, std::shared_ptr< gko ↩ ::matrix::Dense< ValueType >> &[global_solution](#)) override

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

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

Additional Inherited Members

7.16.1 Detailed Description

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

An implementation of the solver interface using the RAS solver.

Template Parameters

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.

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

7.16.3 Member Function Documentation

7.16.3.1 exchange_boundary()

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

Exchanges the elements of the solution vector.

Parameters

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, and schwz::SchwarzBase< ValueType, IndexType, MixedValueType >::global_solution.

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

7.16.3.2   setup_local_matrices()

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

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

Parameters

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.

```
62  {
63      using mtx = gko::matrix::Csr<ValueType, IndexType>;
64      using vec_itype = gko::Array<IndexType>;
65      using perm_type = gko::matrix::Permutation<IndexType>;
66      using arr = gko::Array<IndexType>;
67      auto my_rank = metadata.my_rank;
68      auto comm_size = metadata.comm_size;
69      auto num_subdomains = metadata.num_subdomains;
70      auto global_size = metadata.global_size;
71      auto mpi_itype = boost::mpi::get_mpi_datatype(*partition_indices.data());
72
73      MPI_Bcast(partition_indices.data(), global_size, mpi_itype, 0,
74                MPI_COMM_WORLD);
75
76      std::vector<IndexType> local_p_size(num_subdomains);
77      auto global_to_local = metadata.global_to_local->get_data();
78      auto local_to_global = metadata.local_to_global->get_data();
79
80      auto first_row = metadata.first_row->get_data();
81      auto permutation = metadata.permutation->get_data();
82      auto i_permutation = metadata.i_permutation->get_data();
83
84      auto nb = (global_size + num_subdomains - 1) /
    num_subdomains;
85      auto partition_settings =
86          (Settings::partition_settings::partition_zoltan |
87           Settings::partition_settings::partition_metis |
88           Settings::partition_settings::partition_regular |
89           Settings::partition_settings::partition_regular2d |
90           Settings::partition_settings::partition_custom) &
91          settings.partition;
92
93      IndexType *gmat_row_ptrs = global_matrix->get_row_ptrs();
94      IndexType *gmat_col_idxs = global_matrix->get_col_idxs();
95      ValueType *gmat_values = global_matrix->get_values();
96
97      // default local p size set for 1 subdomain.
98      first_row[0] = 0;
99      for (auto p = 0; p < num_subdomains; ++p) {
100         local_p_size[p] = std::min(global_size - first_row[p], nb);
101         first_row[p + 1] = first_row[p] + local_p_size[p];
102     }
103
104
105      if (partition_settings == Settings::partition_settings::partition_metis ||
106          partition_settings ==
107              Settings::partition_settings::partition_regular2d) {
108          if (num_subdomains > 1) {
109              for (auto p = 0; p < num_subdomains; p++) {
110                  local_p_size[p] = 0;
111              }
112              for (auto i = 0; i < global_size; i++) {
113                  local_p_size[partition_indices[i]]++;
114              }
115              first_row[0] = 0;
116              for (auto p = 0; p < num_subdomains; ++p) {
117                  first_row[p + 1] = first_row[p] + local_p_size[p];
118              }
119              // permutation
120              for (auto i = 0; i < global_size; i++) {
121                  permutation[first_row[partition_indices[i]]] = i;
122                  first_row[partition_indices[i]]++;
123              }
124              for (auto p = num_subdomains; p > 0; p--) {
125                  first_row[p] = first_row[p - 1];
126              }
127              first_row[0] = 0;
128
129              // iperm
130              for (auto i = 0; i < global_size; i++) {
131                  i_permutation[permutation[i]] = i;
132              }
133          }
134
135          auto gmat_temp = mtx::create(settings.executor->get_master(),
136                                       global_matrix->get_size(),
137                                       global_matrix->get_num_stored_elements());
138
139          auto nnz = 0;
140          gmat_temp->get_row_ptrs()[0] = 0;
141          for (auto row = 0; row < metadata.global_size; ++row) {
142              for (auto col = gmat_row_ptrs[permutation[row]];
143                   col < gmat_row_ptrs[permutation[row] + 1]; ++col) {
144                  gmat_temp->get_col_idxs()[nnz] =
145                      i_permutation[gmat_col_idxs[col]];
146                  gmat_temp->get_values()[nnz] = gmat_values[col];
147                  nnz++;
```

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

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

7.16.3.3 setup_windows()

```
template<typename ValueType , typename IndexType , typename MixedValueType >
void schwz::SolverRAS< ValueType, IndexType, MixedValueType >::setup_windows (
            const Settings & settings,
```

```
            const Metadata< ValueType, IndexType > & metadata,
            std::shared_ptr< gko::matrix::Dense< ValueType >> & main_buffer ) [override],
[virtual]
```

Sets up the windows needed for the asynchronous communication.

Parameters

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::Settings::comm_settings::enable_get, schwz::Settings::comm_settings::enable_lock_←
all, schwz::Settings::comm_settings::enable_one_by_one, schwz::Settings::comm_settings::enable_onesided,
schwz::Settings::comm_settings::enable_overlap, schwz::Settings::comm_settings::enable_put, schwz::Settings←
::executor, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::get_displacements,
schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::get_request, schwz::←
Communicate< ValueType, IndexType, MixedValueType >::comm_struct::global_get, schwz::Communicate<
ValueType, IndexType, MixedValueType >::comm_struct::global_put, schwz::SchwarzBase< ValueType, Index←
Type, MixedValueType >::global_solution, schwz::Communicate< ValueType, IndexType, MixedValueType >←
::comm_struct::is_local_neighbor, schwz::Metadata< ValueType, IndexType >::iter_count, schwz::Communicate<
ValueType, IndexType, MixedValueType >::comm_struct::local_get, schwz::Communicate< ValueType, IndexType,
MixedValueType >::comm_struct::local_neighbors_in, schwz::Communicate< ValueType, IndexType, Mixed←
ValueType >::comm_struct::local_neighbors_out, schwz::Communicate< ValueType, IndexType, MixedValue←
Type >::comm_struct::local_num_neighbors_in, schwz::Communicate< ValueType, IndexType, MixedValue←
Type >::comm_struct::local_num_neighbors_out, schwz::Communicate< ValueType, IndexType, MixedValueType
>::comm_struct::local_put, schwz::Metadata< ValueType, IndexType >::local_size_o, schwz::Communicate<
ValueType, IndexType, MixedValueType >::comm_struct::mixedt_recv_buffer, schwz::Communicate< ValueType,
IndexType, MixedValueType >::comm_struct::mixedt_send_buffer, schwz::Communicate< ValueType, IndexType,
MixedValueType >::comm_struct::neighbors_in, schwz::Communicate< ValueType, IndexType, MixedValueType
>::comm_struct::neighbors_out, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_←
struct::num_neighbors_in, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct←
::num_neighbors_out, schwz::Metadata< ValueType, IndexType >::num_subdomains, schwz::Communicate<
ValueType, IndexType, MixedValueType >::comm_struct::put_displacements, schwz::Communicate< Value←
Type, IndexType, MixedValueType >::comm_struct::put_request, schwz::Communicate< ValueType, IndexType,
MixedValueType >::comm_struct::recv_buffer, schwz::Communicate< ValueType, IndexType, MixedValueType
>::comm_struct::remote_get, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_←
struct::remote_put, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_struct::send_←
buffer, schwz::Settings::use_mixed_precision, schwz::Communicate< ValueType, IndexType, MixedValueType
>::comm_struct::window_recv_buffer, schwz::Communicate< ValueType, IndexType, MixedValueType >::comm←
_struct::window_send_buffer, and schwz::Communicate< ValueType, IndexType, MixedValueType >::comm_←
struct::window_x.

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

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

7.16.3.4 update_boundary()

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

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

Parameters

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.

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

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

- restricted_schwarz.hpp (7c9a9f7)
- /home/runner/work/schwarz-lib/schwarz-lib/source/restricted_schwarz.cpp (7c9a9f7)

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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