minorminer Documentation

Release 0.2.3

D-Wave Systems

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Contents

minorminer is a heuristic tool for minor embedding: given a minor and target graph, it tries to find a mapping that embeds the minor into the target.

The primary utility function, `` `find_embedding()` ``, is an implementation of the heuristic algorithm described in [1]. It accepts various optional parameters used to tune the algorithm's execution or constrain the given problem.

This implementation performs on par with tuned, non-configurable implementations while providing users with hooks to easily use the code as a basic building block in research.

[1] https://arxiv.org/abs/1406.2741

CHAPTER 1

Documentation

Note: This documentation is for the latest version of minorminer. Documentation for the version currently installed by dwave-ocean-sdk is here: minorminer.

1.1 Introduction

1.1.1 Examples

This example minor embeds a triangular source K4 graph onto a square target graph.

```
from minorminer import find_embedding

# A triangle is a minor of a square.
triangle = [(0, 1), (1, 2), (2, 0)]
square = [(0, 1), (1, 2), (2, 3), (3, 0)]

# Find an assignment of sets of square variables to the triangle variables
embedding = find_embedding(triangle, square, random_seed=10)
print(len(embedding))  # 3, one set for each variable in the triangle
print(embedding)
# We don't know which variables will be assigned where, here are a
# couple possible outputs:
# [[0, 1], [2], [3]]
# [[3], [1, 0], [2]]
```

This minorminer execution of the example requires that source variable 0 always be assigned to target node 2.

```
embedding = find_embedding(triangle, square, fixed_chains={0: [2]})
print(embedding)
# [[2], [3, 0], [1]]
```

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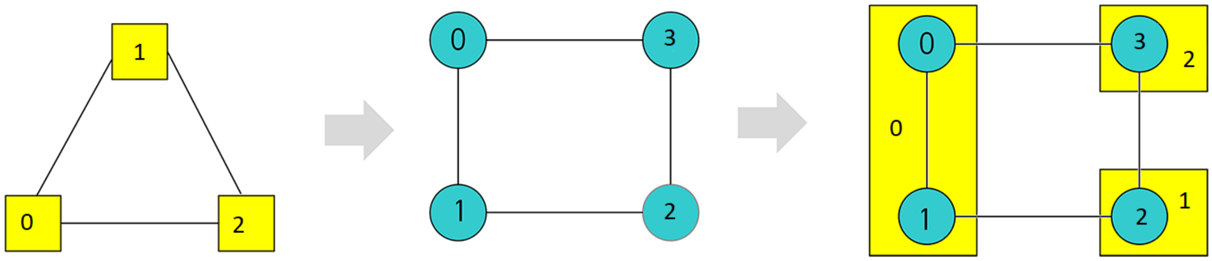

Fig. 1: Embedding a K_3 source graph into a square target graph by chaining two target nodes to represent one source node.

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```
# [[2], [1], [0, 3]]
# And more, but all of them start with [2]
```

This minorminer execution of the example suggests that source variable 0 be assigned to target node 2 as a starting point for finding an embedding.

```
embedding = find_embedding(triangle, square, initial_chains={0: [2]})
print(embedding)
# [[2], [0, 3], [1]]
# [[0], [3], [1, 2]]
# Output where source variable 0 has switched to a different target node is possible.
```

This example minor embeds a fully connected K6 graph into a 30-node random regular graph of degree 3.

```
import networkx as nx

clique = nx.complete_graph(6).edges()
target_graph = nx.random_regular_graph(d=3, n=30).edges()

embedding = find_embedding(clique, target_graph)

print(embedding)
# There are many possible outputs, and sometimes it might fail
# and return an empty list
# One run returned the following embedding:
{0: [10, 9, 19, 8],
 1: [18, 7, 0, 12, 27],
 2: [1, 17, 22],
 3: [16, 28, 4, 21, 15, 23, 25],
 4: [11, 24, 13],
 5: [2, 14, 26, 5, 3]}
```

1.2 Reference Documentation

1.2.1 Python Interface

General Embedding

minorminer.**find_embedding**(*S*, *T*, ***params*)

Heuristically attempt to find a minor-embedding of a graph representing an Ising/QUBO into a target graph.

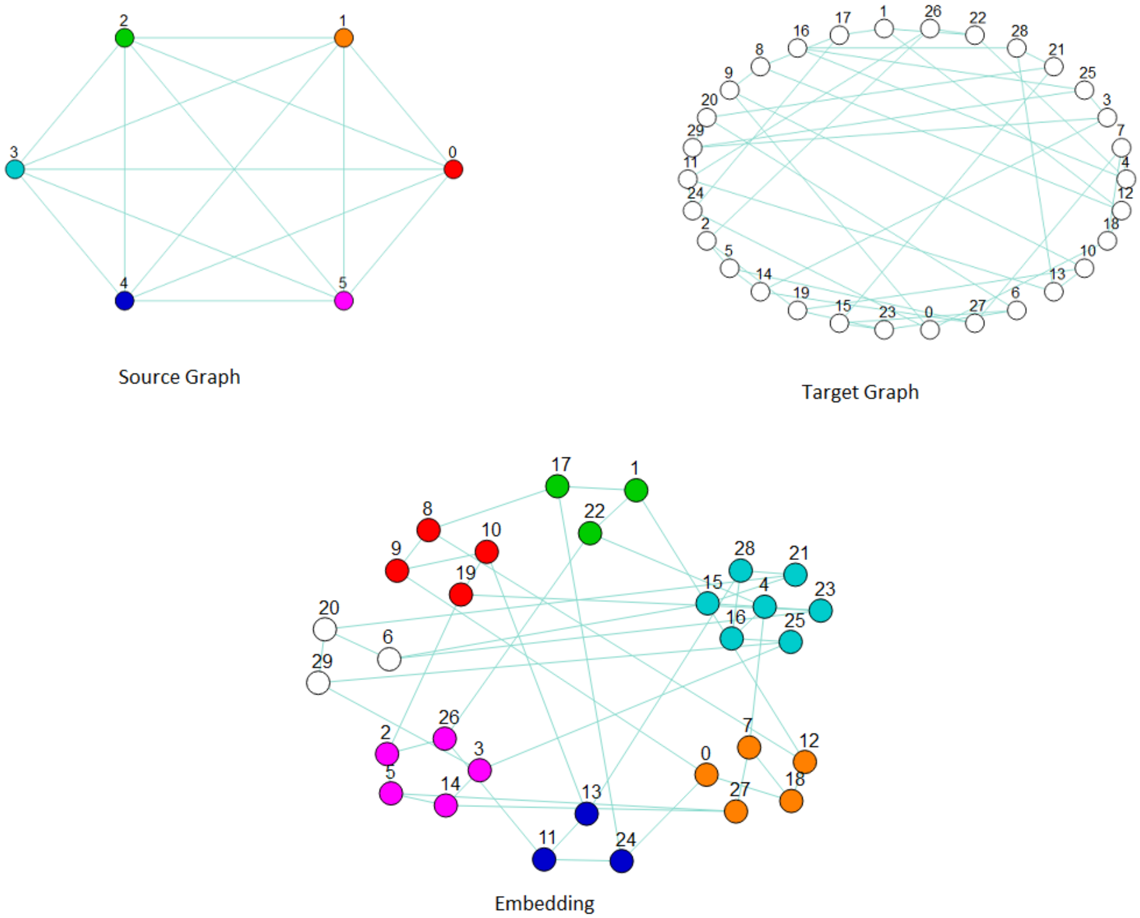

Fig. 2: Embedding a K_6 source graph (upper left) into a 30-node random target graph of degree 3 (upper right) by chaining several target nodes to represent one source node (bottom). The graphic of the embedding clusters chains representing nodes in the source graph: the cluster of red nodes is a chain of target nodes that represent source node 0, the orange nodes represent source node 1, and so on.

Args:

```
S: an iterable of label pairs representing the edges in the source graph, or a␣
↪NetworkX Graph

T: an iterable of label pairs representing the edges in the target graph, or a␣
↪NetworkX Graph

**params (optional): see below
```

Returns:

```
When return_overlap = False (the default), returns a dict that maps labels in S␣
↪to lists of labels in T.
    If the heuristic fails to find an embedding, an empty dictionary is returned

When return_overlap = True, returns a tuple consisting of a dict that maps labels␣
↪in S to lists of
    labels in T and a bool indicating whether or not a valid embedding was found

When interrupted by Ctrl-C, returns the best embedding found so far

Note that failure to return an embedding does not prove that no embedding exists
```

Optional parameters:

```
max_no_improvement: Maximum number of failed iterations to improve the
    current solution, where each iteration attempts to find an embedding
    for each variable of S such that it is adjacent to all its
    neighbours. Integer >= 0 (default = 10)

random_seed: Seed for the random number generator that find_embedding
    uses. Integer >=0 (default is randomly set)

timeout: Algorithm gives up after timeout seconds. Number >= 0 (default
    is approximately 1000 seconds, stored as a double)

max_beta: Qubits are assigned weight according to a formula (beta^n)
    where n is the number of chains containint that qubit.  This value
    should never be less than or equal to 1. (default is effectively
    infinite, stored as a double)

tries: Number of restart attempts before the algorithm stops. On
    D-WAVE 2000Q, a typical restart takes between 1 and 60 seconds.
    Integer >= 0 (default = 10)

inner_rounds: the algorithm takes at most this many iterations between
    restart attempts; restart attempts are typically terminated due to
    max_no_improvement. Integer >= 0 (default = effectively infinite)

chainlength_patience: Maximum number of failed iterations to improve
    chainlengths in the current solution, where each iteration attempts
    to find an embedding for each variable of S such that it is adjacent
    to all its neighbours. Integer >= 0 (default = 10)

max_fill: Restricts the number of chains that can simultaneously
    incorporate the same qubit during the search. Integer >= 0, values
    above 63 are treated as 63 (default = effectively infinite)
```

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```
threads: Maximum number of threads to use. Note that the
    parallelization is only advantageous where the expected degree of
    variables is significantly greater than the number of threads.
    Integer >= 1 (default = 1)

return_overlap: This function returns an embedding whether or not qubits
    are used by multiple variables. Set this value to 1 to capture both
    return values to determine whether or not the returned embedding is
    valid. Logical 0/1 integer (default = 0)

skip_initialization: Skip the initialization pass. Note that this only
    works if the chains passed in through initial_chains and
    fixed_chains are semi-valid. A semi-valid embedding is a collection
    of chains such that every adjacent pair of variables (u,v) has a
    coupler (p,q) in the hardware graph where p is in chain(u) and q is
    in chain(v). This can be used on a valid embedding to immediately
    skip to the chainlength improvement phase. Another good source of
    semi-valid embeddings is the output of this function with the
    return_overlap parameter enabled. Logical 0/1 integer (default = 0)

verbose: Level of output verbosity. Integer < 4 (default = 0).
    When set to 0, the output is quiet until the final result.
    When set to 1, output looks like this:

        initialized
        max qubit fill 3; num maxfull qubits=3
        embedding trial 1
        max qubit fill 2; num maxfull qubits=21
        embedding trial 2
        embedding trial 3
        embedding trial 4
        embedding trial 5
        embedding found.
        max chain length 4; num max chains=1
        reducing chain lengths
        max chain length 3; num max chains=5

    When set to 2, outputs the information for lower levels and also
        reports progress on minor statistics (when searching for an
        embedding, this is when the number of maxfull qubits decreases;
        when improving, this is when the number of max chains decreases)
    When set to 3, report before each before each pass. Look here when
        tweaking `tries`, `inner_rounds`, and `chainlength_patience`
    When set to 4, report additional debugging information. By default,
        this package is built without this functionality. In the c++
        headers, this is controlled by the CPPDEBUG flag
    Detailed explanation of the output information:
        max qubit fill: largest number of variables represented in a qubit
        num maxfull: the number of qubits that has max overfill
        max chain length: largest number of qubits representing a single variable
        num max chains: the number of variables that has max chain size

interactive: If `logging` is None or False, the verbose output will be printed
    to stdout/stderr as appropriate, and keyboard interrupts will stop the␣
↪embedding
    process and the current state will be returned to the user.  Otherwise, output
```

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```
    will be directed to the logger `logging.getLogger(minorminer.__name__)` and
    keyboard interrupts will be propagated back to the user.  Errors will use
    `logger.error()`, verbosity levels 1 through 3 will use `logger.info()` and␣
↪level
    4 will use `logger.debug()`.  bool, default False

initial_chains: Initial chains inserted into an embedding before
    fixed_chains are placed, which occurs before the initialization
    pass. These can be used to restart the algorithm in a similar state
    to a previous embedding; for example, to improve chainlength of a
    valid embedding or to reduce overlap in a semi-valid embedding (see
    skip_initialization) previously returned by the algorithm. Missing
    or empty entries are ignored. A dictionary, where initial_chains[i]
    is a list of qubit labels.

fixed_chains: Fixed chains inserted into an embedding before the
    initialization pass. As the algorithm proceeds, these chains are not
    allowed to change, and the qubits used by these chains are not used by
    other chains. Missing or empty entries are ignored. A dictionary, where
    fixed_chains[i] is a list of qubit labels.

restrict_chains: Throughout the algorithm, we maintain the condition
    that chain[i] is a subset of restrict_chains[i] for each i, except
    those with missing or empty entries. A dictionary, where
    restrict_chains[i] is a list of qubit labels.

suspend_chains: This is a metafeature that is only implemented in the Python
    interface.  suspend_chains[i] is an iterable of iterables; for example
        suspend_chains[i] = [blob_1, blob_2],
    with each blob_j an iterable of target node labels.
    this enforces the following:
        for each suspended variable i,
            for each blob_j in the suspension of i,
                at least one qubit from blob_j will be contained in the
                chain for i

    we accomplish this trhough the following problem transformation
    for each iterable blob_j in suspend_chains[i],
        * add an auxiliary node Zij to both source and target graphs
        * set fixed_chains[Zij] = [Zij]
        * add the edge (i,Zij) to the source graph
        * add the edges (q,Zij) to the target graph for each q in blob_j
```

Clique Embedding

class minorminer.busclique.**busgraph_cache**

minorminer.busclique.**find_clique_embedding**()

Finds a clique embedding in the graph g using a polynomial-time algorithm.

Inputs: g: either a dwave_networkx.chimera_graph or dwave_networkx.pegasus_graph nodes: a number (indicating the size of the desired clique) or an

iterable (specifying the node labels of the desired clique)

use_cache: bool, default True – whether or not to compute / restore a cache of clique embeddings for

g. Note that this function only uses the filesystem cache, and does not maintain the cache in memory. If many (or even several) embeddings are desired in a single session, it is recommended to use *busgraph_cache*

Returns

dict mapping node labels (either nodes, or range(nodes)) to chains of a clique embedding

Return type emb

Note: due to internal optimizations, not all chimera graphs are supported by this code. Specifically, the graphs

dwave_networkx.chimera_graph(m, n, t)

are only supported for t <= 8. Thus, we support current D-Wave products (which have t = 4) but not all graphs. For graphs with t > 8, use the legacy chimera-embedding package.

Note: when the cache is used, clique embeddings of all sizes are computed and cached. This takes somewhat longer than a single embedding, but tends to pay off after a fairly small number of calls. An exceptional use case is when there are a large number of missing internal couplers, where the result is nondeterministic – avoiding the cache in this case may be preferable.

Layout & Placement Embedding

class `minorminer.layout.layout.`**`Layout`**(*G*, *layout=None*, *dim=None*, *center=None*, *scale=None*, *pack_components=True*, ***kwargs*)

`minorminer.layout.layout.`**`p_norm`**(*G*, *p=2*, *starting_layout=None*, *G_distances=None*, *dim=None*, *center=None*, *scale=None*, ***kwargs*)

Embeds a graph in R^d with the p-norm and minimizes a Kamada-Kawai-esque objective function to achieve an embedding with low distortion. This computes a layout where the graph distance and the p-distance are very close to each other.

Parameters

- **G** (*NetworkX graph*) – The graph you want to compute the layout for.
- **p** (*int (default 2)*) – The order of the p-norm to use as a metric.
- **starting_layout** (*dict (default None)*) – A mapping from the vertices of G to points in R^d. If None, nx.spectral_layout is used if possible, otherwise nx.random_layout is used.
- **G_distances** (*dict (default None)*) – A dictionary of dictionaries representing distances from every vertex in G to every other vertex in G. If None, it is computed.
- **dim** (*int (default None)*) – The desired dimension of the layout, R^dim. If None, check the dimension of center, if center is None, set dim to 2.
- **center** (*tuple (default None)*) – The desired center point of the layout. If None, it is set as the origin in R^dim space.
- **scale** (*float (default None)*) – The desired scale of the layout; i.e. the layout is in [center - scale, center + scale]^d space. If None, do not set a scale.

Returns **layout** – A mapping from vertices of G (keys) to points in R^d (values).

Return type dict

`minorminer.layout.layout.`**`dnx_layout`**(*G*, *dim=None*, *center=None*, *scale=None*, ***kwargs*)

The Chimera or Pegasus layout from dwave_networkx centerd at the origin with scale a function of the number of rows or columns. Note: As per the implementation of dnx.*_layout, if dim > 2, coordinates beyond the second are 0.

Parameters

- **G** (*NetworkX graph*) – The graph you want to compute the layout for.
- **dim** (*int (default None)*) – The desired dimension of the layout, R^dim. If None, check the dimension of center, if center is None, set dim to 2.
- **center** (*tuple (default None)*) – The desired center point of the layout. If None, it is set as the origin in R^dim space.
- **scale** (*float (default None)*) – The desired scale of the layout; i.e. the layout is in [center - scale, center + scale]^d space. If None, it is set as max(n, m)/2, where n, m are the number of columns, rows respectively in G.

Returns **layout** – A mapping from vertices of G (keys) to points in R^d (values).

Return type dict

class minorminer.layout.placement.**Placement**(*S_layout*, *T_layout*, *placement=None*, *scale_ratio=None*, ***kwargs*)

minorminer.layout.placement.**intersection**(*S_layout*, *T_layout*, ***kwargs*)

Map each vertex of S to its nearest row/column intersection qubit in T (T must be a D-Wave hardware graph). Note: This will modifiy S_layout.

Parameters

- **S_layout** (layout.Layout) – A layout for S; i.e. a map from S to R^d.
- **T_layout** (layout.Layout) – A layout for T; i.e. a map from T to R^d.
- **scale_ratio** (*float (default None)*) – If None, S_layout is not scaled. Otherwise, S_layout is scaled to scale_ratio*T_layout.scale.

Returns **placement** – A mapping from vertices of S (keys) to vertices of T (values).

Return type dict

minorminer.layout.placement.**closest**(*S_layout*, *T_layout*, *subset_size=(1, 1)*, *num_neighbors=1*, ***kwargs*)

Maps vertices of S to the closest vertices of T as given by S_layout and T_layout. i.e. For each vertex u in S_layout and each vertex v in T_layout, map u to the v with minimum Euclidean distance (||u - v||_2).

Parameters

- **S_layout** (layout.Layout) – A layout for S; i.e. a map from S to R^d.
- **T_layout** (layout.Layout) – A layout for T; i.e. a map from T to R^d.
- **subset_size** (*tuple (default (1, 1))*) – A lower (subset_size[0]) and upper (subset_size[1]) bound on the size of subets of T that will be considered when mapping vertices of S.
- **num_neighbors** (*int (default 1)*) – The number of closest neighbors to query from the KDTree–the neighbor with minimium overlap is chosen. Increasing this reduces overlap, but increases runtime.

Returns **placement** – A mapping from vertices of S (keys) to subsets of vertices of T (values).

Return type dict

1.2.2 C++ Library

Namespace list

Namespace busclique

namespace busclique

Typedefs

using biclique_result_cache = std::unordered_map<pair<size_t, size_t>, value_t, *craphash*>

using chimera_spec = *topo_spec_cellmask*<*chimera_spec_base*>

using pegasus_spec = *topo_spec_cellmask*<*pegasus_spec_base*>

Enums

enum corner

Values:

NW = 1

NE = 2

SW = 4

SE = 8

NWskip = 16

NEskip = 32

SWskip = 64

SEskip = 128

skipmask = 255 - 15

shift = 8

mask = 255

none = 0

Functions

template<typename **topo_spec**>
void **best_bicliques** (**const** *topo_spec* &*topo*, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*, vector<pair<pair<size_t, size_t>, vector<vector<size_t>>>> &*embs*)

template<typename **topo_spec**>
void **best_bicliques** (*topo_cache*<*topo_spec*> &*topology*, vector<pair<pair<size_t, size_t>, vector<vector<size_t>>>> &*embs*)

template<typename **T**>
size_t **get_maxlen** (vector<*T*> &*emb*, size_t *size*)

template<typename **topo_spec**>
bool **find_clique_nice** (**const** *cell_cache*<*topo_spec*>&, size_t *size*, vector<vector<size_t>> &*emb*, size_t &*min_width*, size_t &*max_width*, size_t &*max_length*)

template<>
bool **find_clique_nice** (**const** *cell_cache*<*chimera_spec*> &*cells*, size_t *size*, vector<vector<size_t>> &*emb*, size_t&, size_t&, size_t &*max_length*)

template<>
bool **find_clique_nice** (**const** *cell_cache*<*pegasus_spec*> &*cells*, size_t *size*, vector<vector<size_t>> &*emb*, size_t&, size_t&, size_t &*max_length*)

template<typename **topo_spec**>
bool **find_clique** (**const** *topo_spec* &*topo*, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*, size_t *size*, vector<vector<size_t>> &*emb*)

template<typename **topo_spec**>
bool **find_clique** (*topo_cache*<*topo_spec*> &*topology*, size_t *size*, vector<vector<size_t>> &*emb*)

template<typename **topo_spec**>
bool **find_clique_nice** (**const** *topo_spec* &*topo*, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*, size_t *size*, vector<vector<size_t>> &*emb*)

template<typename **topo_spec**>
void **short_clique** (**const** *topo_spec*&, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*, vector<vector<size_t>> &*emb*)

template<typename **topo_spec**>
void **best_cliques** (*topo_cache*<*topo_spec*> &*topology*, vector<vector<vector<size_t>>> &*embs*, vector<vector<size_t>> &*emb_1*)

bool **find_generic_1** (**const** vector<size_t> &*nodes*, vector<vector<size_t>> &*emb*)

bool **find_generic_2** (**const** vector<pair<size_t, size_t>> &*edges*, vector<vector<size_t>> &*emb*)

bool **find_generic_3** (**const** vector<pair<size_t, size_t>> &*edges*, vector<vector<size_t>> &*emb*)

bool **find_generic_4** (**const** vector<pair<size_t, size_t>> &*edges*, vector<vector<size_t>> &*emb*)

size_t **binom** (size_t *x*)

Variables

const vector<vector<size_t>> **empty_emb**

const uint8_t **popcount**[256] = {0, 1, 1, 2, 1, 2, 2, 3, 1, 2, 2, 3, 2, 3, 3, 4, 1, 2, 2, 3, 2, 3, 3, 4, 2, 3, 3, 4, 3, 4, 4, 5, 1, 2, 2, 3, 2,

const uint8_t **first_bit**[256] = {0, 0, 1, 0, 2, 0, 1, 0, 3, 0, 1, 0, 2, 0, 1, 0, 4, 0, 1, 0, 2, 0, 1, 0, 3, 0, 1, 0, 2, 0, 1, 0, 5, 0, 1, 0,

const uint8_t **mask_bit**[8] = {1, 2, 4, 8, 16, 32, 64, 128}

const uint16_t **mask_subsets**[8] = {1, 2, 4, 8, 16, 32, 64, 128}

const std::set<size_t> **_emptyset**

class topo_spec_base
#include <util.hpp> Subclassed by *busclique::chimera_spec_base*, *busclique::pegasus_spec_base*

Namespace find_embedding

namespace find_embedding

Typedefs

using distance_t = long long int

using RANDOM = *fastrng*

using clock = std::chrono::high_resolution_clock

using min_queue = std::priority_queue<*priority_node*<P, *min_heap_tag*>>

using max_queue = std::priority_queue<*priority_node*<P, *max_heap_tag*>>

using distance_queue = *pairing_queue*<*priority_node*<*distance_t*, *min_heap_tag*>>

typedef shared_ptr<*LocalInteraction*> **LocalInteractionPtr**

Enums

enum VARORDER

Values:

VARORDER_SHUFFLE

VARORDER_DFS

VARORDER_BFS

VARORDER_PFS

VARORDER_RPFS

VARORDER_KEEP

Functions

int **findEmbedding**(*graph*::*input_graph* &*var_g*, *graph*::*input_graph* &*qubit_g*, *optional_parameters* &*params*, vector<vector<int>> &*chains*)

The main entry function of this library.

This method primarily dispatches the proper implementation of the algorithm where some parameters/behaviours have been fixed at compile time.

In terms of dispatch, there are three dynamically-selected classes which are combined, each according to a specific optional parameter.

- a domain_handler, described in embedding_problem.hpp, manages constraints of the form "variable a's chain must be a subset of…"
- a fixed_handler, described in embedding_problem.hpp, manages contstraints of the form "variable a's chain must be exactly…"
- a pathfinder, described in pathfinder.hpp, which come in two flavors, serial and parallel The optional parameters themselves can be found in util.hpp. Respectively, the controlling options for the above are restrict_chains, fixed_chains, and threads.

template<typename **T**>

void **collectMinima** (**const** vector<*T*> &*input*, vector<int> &*output*)
Fill output with the index of all of the minimum and equal values in input.

Variables

constexpr *distance_t* **max_distance** = numeric_limits<*distance_t*>::max()

class chain
#include <chain.hpp>

Public Functions

chain (vector<int> &*w*, int *l*)
construct this chain, linking it to the qubit_weight vector `w` (common to all chains in an embedding, typically) and setting its variable label `l`

chain &**operator=** (**const** vector<int> &*c*)
assign this to a vector of ints.

each incoming qubit will have itself as a parent.

chain &**operator=** (**const** *chain* &*c*)
assign this to another chain

size_t **size** () **const**
number of qubits in chain

size_t **count** (**const** int *q*) **const**
returns 0 if `q` is not contained in `this`, 1 otherwise

int **get_link** (**const** int *x*) **const**
get the qubit, in `this`, which links `this` to the chain of x (if x==label, interpret the linking qubit as the chain's root)

void **set_link** (**const** int *x*, **const** int *q*)
set the qubit, in `this`, which links `this` to the chain of x (if x==label, interpret the linking qubit as the chain's root)

int **drop_link** (**const** int *x*)
discard and return the linking qubit for `x`, or -1 if that link is not set

void **set_root** (**const** int *q*)
insert the qubit `q` into `this`, and set `q` to be the root (represented as the linking qubit for `label`)

void **clear** ()
empty this data structure

void **add_leaf** (**const** int *q*, **const** int *parent*)
add the qubit `q` as a leaf, with `parent` as its parent

int **trim_branch** (int *q*)
try to delete the qubit `q` from this chain, and keep deleting until no more qubits are free to be deleted.

return the first ancestor which cannot be deleted

int **trim_leaf** (int *q*)
try to delete the qubit `q` from this chain.

if `q` cannot be deleted, return it; otherwise return its parent

int **parent** (**const** int *q*) **const**
the parent of `q` in this chain which might be `q` but otherwise cycles should be impossible

void **adopt** (**const** int *p*, **const** int *q*)
assign `p` to be the parent of `q`, on condition that both `p` and `q` are contained in `this`, `q` is its own parent, and `q` is not the root

int **refcount** (**const** int *q*) **const**
return the number of references that `this` makes to the qubit `q` where a "reference" is an occurrence of `q` as a parent or an occurrence of `q` as a linking qubit / root

size_t **freeze** (vector<*chain*> &*others*, *frozen_chain* &*keep*)
store this chain into a `frozen_chain`, unlink all chains from this, and *clear()*

void **thaw** (vector<*chain*> &*others*, *frozen_chain* &*keep*)
restore a `frozen_chain` into this, re-establishing links from other chains.

precondition: this is empty.

template<typename **embedding_problem_t**>
void **steal** (*chain* &*other*, *embedding_problem_t* &*ep*, int *chainsize* = 0)
assumes `this` and `other` have links for eachother's labels steals all qubits from `other` which are available to be taken by `this`; starting with the qubit links and updating qubit links after all

void **link_path** (*chain* &*other*, int *q*, **const** vector<int> &*parents*)
link this chain to another, following the path `q, parent[q], parent[parent[q]], ...`

from `this` to `other` and intermediate nodes (all but the last) into `this` (preconditions: `this` and `other` are not linked, `q` is contained in `this`, and the parent-path is eventually contained in `other`)

iterator **begin** () **const**
iterator pointing to the first qubit in this chain

iterator **end** () **const**
iterator pointing to the end of this chain

void **diagnostic** ()
run the diagnostic, and if it fails, report the failure to the user and throw a *CorruptEmbeddingException*.

the `last_op` argument is used in the error message

int **run_diagnostic** () **const**
run the diagnostic and return a nonzero status `r` in case of failure if(`r`&1), then the parent of a qubit is not contained in this chain if(`r`&2), then there is a refcounting error in this chain

class domain_handler_masked
#include <embedding_problem.hpp> this domain handler stores masks for each variable so that prepare_visited and prepare_distances are barely more expensive than a memcopy

class domain_handler_universe
#include <embedding_problem.hpp> this is the trivial domain handler, where every variable is allowed to use every qubit

template<typename **embedding_problem_t**>

class embedding

#include <embedding.hpp> This class is how we represent and manipulate embedding objects, using as much encapsulation as possible.

We provide methods to view and modify chains.

Public Functions

embedding(embedding_problem_t &*e_p*)

constructor for an empty embedding

embedding(embedding_problem_t &*e_p*, map<int, vector<int>> &*fixed_chains*, map<int, vector<int>> &*initial_chains*)

constructor for an initial embedding: accepts fixed and initial chains, populates the embedding based on them, and attempts to link adjacent chains together.

embedding<embedding_problem_t> &**operator=**(**const** embedding<embedding_problem_t> &*other*)

copy the data from `other.var_embedding` into `this.var_embedding`

const *chain* &**get_chain**(int *v*) **const**

Get the variables in a chain.

int **chainsize**(int *v*) **const**

Get the size of a chain.

int **weight**(int *q*) **const**

Get the weight of a qubit.

int **max_weight**() **const**

Get the maximum of all qubit weights.

int **max_weight**(**const** int *start*, **const** int *stop*) **const**

Get the maximum of all qubit weights in a range.

bool **has_qubit**(**const** int *v*, **const** int *q*) **const**

Check if variable v is includes qubit q in its chain.

void **set_chain**(**const** int *u*, **const** vector<int> &*incoming*)

Assign a chain for variable u.

void **fix_chain**(**const** int *u*, **const** vector<int> &*incoming*)

Permanently assign a chain for variable u.

NOTE: This must be done before any chain is assigned to u.

bool **operator==**(**const** embedding &*other*) **const**

check if `this` and `other` have the same chains (up to qubit containment per chain; linking and parent information is not checked)

void **construct_chain**(**const** int *u*, **const** int *q*, **const** vector<vector<int>> &*parents*)

construct the chain for `u`, rooted at `q`, with a vector of parent info, where for each neibor `v` of `u`, following `q` -> `parents[v][q]` -> `parents[v][parents[v][q]]` ...

terminates in the chain for `v`

void **construct_chain_steiner**(**const** int *u*, **const** int *q*, **const** vector<vector<int>> &*parents*, **const** vector<vector<*distance_t*>> &*distances*, vector<vector<int>> &*visited_list*)

construct the chain for `u`, rooted at `q`.

for the first neighbor `v` of `u`, we follow the parents until we terminate in the chain for `v` `q` -> `parents[v][q]` -> .... adding all but the last node to the chain of `u`. for each subsequent neighbor `w`, we pick a nearest Steiner node, `qw`, from the current chain of `u`, and add the path starting at `qw`, similar to the above… `qw` -> `parents[w][qw]` -> … this has an opportunity to make shorter chains than `construct_chain`

void **flip_back**(int *u*, **const** int *target_chainsize*)

distribute path segments to the neighboring chains path segments are the qubits that are ONLY used to join link_qubit[u][v] to link_qubit[u][u] and aren't used for any other variable

- if the target chainsize is zero, dump the entire segment into the neighbor
- if the target chainsize is k, stop when the neighbor's size reaches k

void **tear_out**(int *u*)

short tearout procedure blank out the chain, its linking qubits, and account for the qubits being freed

int **freeze_out**(int *u*)

undo-able tearout procedure.

similar to `tear_out(u)`, but can be undone with `thaw_back(u)`. note that this embedding type has a space for a single frozen chain, and `freeze_out(u)` overwrites the previously-frozen chain consequently, `freeze_out(u)` can be called an arbitrary (nonzero) number of times before `thaw_back(u)`, but `thaw_back(u)` MUST be preceeded by at least one `freeze_out(u)`. returns the size of the chain being frozen

void **thaw_back**(int *u*)

undo for the freeze_out procedure: replaces the chain previously frozen, and destroys the data in the frozen chain `thaw_back(u)` must be preceeded by at least one `freeze_out(u)` and the chain for `u` must currently be empty (accomplished either by `tear_out(u)` or `freeze_out(u)`)

void **steal_all**(int *u*)

grow the chain for `u`, stealing all available qubits from neighboring variables

int **statistics**(vector<int> &*stats*) **const**

compute statistics for this embedding and return `1` if no chains are overlapping when no chains are overlapping, populate `stats` with a chainlength histogram chains do overlap, populate `stats` with a qubit overfill histogram a histogram, in this case, is a vector of size (maximum attained value+1) where `stats[i]` is either the number of qubits contained in `i+2` chains or the number of chains with size `i`

bool **linked**() **const**

check if the embedding is fully linked that is, if each pair of adjacent variables is known to correspond to a pair of adjacent qubits

bool **linked**(int *u*) **const**

check if a single variable is linked with all adjacent variables.

void **print**() **const**

print out this embedding to a level of detail that is useful for debugging purposes TODO describe the output format.

void **long_diagnostic**(char **current_state*)

run a long diagnostic, and if debugging is enabled, record `current_state` so that the error message has a little more context.

if an error is found, throw a *CorruptEmbeddingException*

void **run_long_diagnostic**(char **current_state*) **const**
run a long diagnostic to verify the integrity of this datastructure.

the guts of this function are its documentation, because this function only exists for debugging purposes

template<class **fixed_handler**, class **domain_handler**, class **output_handler**>
class embedding_problem : **public** *find_embedding*::*embedding_problem_base*, **public** *fixed_handler*, **public** *dom*
#include <embedding_problem.hpp> A template to construct a complete embedding problem by combining `embedding_problem_base` with fixed/domain handlers.

class embedding_problem_base
#include <embedding_problem.hpp> Common form for all embedding problems.

Needs to be extended with a fixed handler and domain handler to be complete.

Subclassed by *find_embedding::embedding_problem< fixed_handler, domain_handler, output_handler >*

Public Functions

void **reset_mood**()
resets some internal, ephemeral, variables to a default state

void **populate_weight_table**(int *max_weight*)
precomputes a table of weights corresponding to various overlap values `c`, for `c` from 0 to `max_weight`, inclusive.

distance_t **weight**(unsigned int *c*) **const**
returns the precomputed weight associated with an overlap value of `c`

const vector<int> &**var_neighbors**(int *u*) **const**
a vector of neighbors for the variable `u`

const vector<int> &**var_neighbors**(int *u*, *shuffle_first*)
a vector of neighbors for the variable `u`, pre-shuffling them

const vector<int> &**var_neighbors**(int *u*, *rndswap_first*)
a vector of neighbors for the variable `u`, applying a random transposition before returning the reference

const vector<int> &**qubit_neighbors**(int *q*) **const**
a vector of neighbors for the qubit `q`

int **num_vars**() **const**
number of variables which are not fixed

int **num_qubits**() **const**
number of qubits which are not reserved

int **num_fixed**() **const**
number of fixed variables

int **num_reserved**() **const**
number of reserved qubits

int **randint**(int *a*, int *b*)
make a random integer between 0 and `m-1`

template<typename **A**, typename **B**>
void **shuffle** (*A a*, *B b*)
shuffle the data bracketed by iterators `a` and `b`

void **qubit_component** (int *q0*, vector<int> &*component*, vector<int> &*visited*)
compute the connected component of the subset `component` of qubits, containing `q0`, and usingvisited as an indicator for which qubits have been explored

const vector<int> &**var_order** (*VARORDER order* = *VARORDER_SHUFFLE*)
compute a variable ordering according to the `order` strategy

void **dfs_component** (int *x*, **const** vector<vector<int>> &*neighbors*, vector<int> &*component*, vector<int> &*visited*)
Perform a depth first search.

Public Members

optional_parameters &**params**
A mutable reference to the user specified parameters.

class fixed_handler_hival
#include <embedding_problem.hpp> This fixed handler is used when the fixed variables are processed before instantiation and relabeled such that variables v >= num_v are fixed and qubits q >= num_q are reserved.

class fixed_handler_none
#include <embedding_problem.hpp> This fixed handler is used when there are no fixed variables.

struct frozen_chain
#include <chain.hpp> This class stores chains for embeddings, and performs qubit-use accounting.

The `label` is the index number for the variable represented by this chain. The `links` member of a chain is an unordered map storing the linking information for this chain. The `data` member of a chain stores the connectivity information for the chain.

Links: If `u` and `v` are variables which are connected by an edge, the following must be true: either chain_u or chain_v is empty,

or

chain_u.links[v] is a key in chain_u.data, chain_v.links[u] is a key in chain_v.data, and (chain_u.links[v], chain_v.links[u]) are adjacent in the qubit graph

Moreover, (chain_u.links[u]) must exist if chain_u is not empty, and this is considered the root of the chain.

Data: The `data` member stores the connectivity information. More precisely, `data` is a mapping `qubit->(parent, refs)` where: `parent` is also contained in the chain `refs` is the total number of references to `qubit`, counting both parents and links the chain root is its own parent.

class LocalInteraction
#include <util.hpp> Interface for communication between the library and various bindings.

Any bindings of this library need to provide a concrete subclass.

Public Functions

void **displayOutput** (int *loglevel*, **const** string &*msg*) **const**
Print a message through the local output method.

void **displayError** (int *loglevel*, **const** string &*msg*) **const**
Print an error through the local output method.

int **cancelled** (**const** *clock*::time_point *stoptime*) **const**
Check if someone is trying to cancel the embedding process.

class MinorMinerException : **public** runtime_error
#include <util.hpp> Subclassed by *find_embedding::BadInitializationException*, *find_embedding::CorruptEmbeddingException*, *find_embedding::CorruptParametersException*, *find_embedding::ProblemCancelledException*, *find_embedding::TimeoutException*

class optional_parameters
#include <util.hpp> Set of parameters used to control the embedding process.

Public Functions

optional_parameters (*optional_parameters* &*p*, map<int, vector<int>> *fixed_chains*, map<int, vector<int>> *initial_chains*, map<int, vector<int>> *restrict_chains*)
duplicate all parameters but chain hints, and seed a new rng.

this vaguely peculiar behavior is utilized to spawn parameters for component subproblems

Public Members

LocalInteractionPtr **localInteractionPtr**
actually not controlled by user, not initialized here, but initialized in Python, MATLAB, C wrappers level

double **timeout** = 1000
Number of seconds before the process unconditionally stops.

template<bool **verbose**>
class output_handler
#include <embedding_problem.hpp> Output handlers are used to control output.

We provide two handlers one which only reports all errors (and optimizes away all other output) and another which provides full output. When verbose is zero, we recommend the errors-only handler and otherwise, the full handler Here's the full output handler

Subclassed by *find_embedding::embedding_problem< fixed_handler, domain_handler, output_handler >*

Public Functions

template<typename ...**Args**>
void **error** (**const** char **format*, *Args*... *args*) **const**
printf regardless of the verbosity level

template<typename ...**Args**>
void **major_info** (**const** char **format*, *Args*... *args*) **const**
printf at the major_info verbosity level

template<typename ...**Args**>
void **minor_info** (**const** char **format*, *Args*... *args*) **const**
print at the minor_info verbosity level

template<typename ...**Args**>
void **extra_info** (**const** char **format*, *Args*... *args*) **const**
print at the extra_info verbosity level

template<typename ...**Args**>
void **debug** (**const** char *, *Args*...) **const**
print at the debug verbosity level (only works when `CPPDEBUG` is set)

template<typename **N**>
class pairing_node : **public** *N*
#include <pairing_queue.hpp>

Public Functions

pairing_node<N> ***merge_roots** (pairing_node<N> **other*)
the basic operation of the pairing queue put `this` and `other` into heap-order

template<typename **embedding_problem_t**>
class pathfinder_base : **public** *find_embedding*::*pathfinder_public_interface*
#include <pathfinder.hpp> Subclassed by *find_embedding::pathfinder_parallel< embedding_problem_t >*, *find_embedding::pathfinder_serial< embedding_problem_t >*

Public Functions

virtual void **set_initial_chains** (map<int, vector<int>> *chains*)
setter for the initial_chains parameter

bool **check_improvement** (**const** embedding_t &*emb*)
nonzero return if this is an improvement on our previous best embedding

virtual const *chain* &**get_chain** (int *u*) **const**
chain accessor

virtual int **heuristicEmbedding** ()
perform the heuristic embedding, returning 1 if an embedding was found and 0 otherwise

template<typename **embedding_problem_t**>
class pathfinder_parallel : **public** *find_embedding*::pathfinder_base<*embedding_problem_t*>
#include <pathfinder.hpp> A pathfinder where the Dijkstra-from-neighboring-chain passes are done serially.

Public Functions

virtual void **prepare_root_distances** (**const** embedding_t &*emb*, **const** int *u*)
compute the distances from all neighbors of `u` to all qubits

class pathfinder_public_interface
#include <pathfinder.hpp> Subclassed by *find_embedding::pathfinder_base< embedding_problem_t >*

template<typename **embedding_problem_t**>
class pathfinder_serial : **public** *find_embedding*::pathfinder_base<*embedding_problem_t*>
#include <pathfinder.hpp> A pathfinder where the Dijkstra-from-neighboring-chain passes are done serially.

Public Functions

virtual void **prepare_root_distances**(**const** embedding_t &*emb*, **const** int *u*)
compute the distances from all neighbors of `u` to all qubits

Namespace graph

namespace graph

class components
#include <graph.hpp> Represents a graph as a series of connected components.

The input graph may consist of many components, they will be separated in the construction.

Public Functions

const std::vector<int> &**nodes**(int *c*) **const**
Get the set of nodes in a component.

size_t **size**() **const**
Get the number of connected components in the graph.

size_t **num_reserved**(int *c*) **const**
returns the number of reserved nodes in a component

size_t **size**(int *c*) **const**
Get the size (in nodes) of a component.

const *input_graph* &**component_graph**(int *c*) **const**
Get a const reference to the graph object of a component.

std::vector<std::vector<int>> **component_neighbors**(int *c*) **const**
Construct a neighborhood list for component c, with reserved nodes as sources.

template<typename **T**>
bool **into_component**(**const** int *c*, *T* &*nodes_in*, std::vector<int> &*nodes_out*) **const**
translate nodes from the input graph, to their labels in component c

template<typename **T**>
void **from_component**(**const** int *c*, *T* &*nodes_in*, std::vector<int> &*nodes_out*) **const**
translate nodes from labels in component c, back to their original input labels

class input_graph
#include <graph.hpp> Represents an undirected graph as a list of edges.

Provides methods to extract those edges into neighbor lists (with options to relabel and produce directed graphs).

As an input to the library this may be a disconnected graph, but when returned from components it is a connected sub graph.

Public Functions

input_graph()
Constructs an empty graph.

input_graph(int *n_v*, **const** std::vector<int> &*aside*, **const** std::vector<int> &*bside*)
Constructs a graph from the provided edges.

The ends of edge ii are aside[ii] and bside[ii].

Parameters
- `n_v`: Number of nodes in the graph.
- `aside`: List of nodes describing edges.
- `bside`: List of nodes describing edges.

void **clear**()
Remove all edges and nodes from a graph.

int **a**(**const** int *i*) **const**
Return the nodes on either end of edge `i`

int **b**(**const** int *i*) **const**
Return the nodes on either end of edge `i`

size_t **num_nodes**() **const**
Return the size of the graph in nodes.

size_t **num_edges**() **const**
Return the size of the graph in edges.

void **push_back**(int *ai*, int *bi*)
Add an edge to the graph.

template<typename **T1**, typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors_sources**(**const** *T1* &*sources*, *Args*... *args*) **const**
produce a std::vector<std::vector<int>> of neigborhoods, with certain nodes marked as sources (inbound edges are omitted) sources is either a std::vector<int> (where non-sources x have sources[x] = 0), or another type for which we have a unaryint specialization optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking sources / mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

template<typename **T2**, typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors_sinks**(**const** *T2* &*sinks*, *Args*... *args*) **const**
produce a std::vector<std::vector<int>> of neigborhoods, with certain nodes marked as sinks (outbound edges are omitted) sinks is either a std::vector<int> (where non-sinks x have sinks[x] = 0), or another type for which we have a unaryint specialization optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking sinks / mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

template<typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors**(*Args*... *args*) **const**
produce a std::vector<std::vector<int>> of neigborhoods optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

template<>
class unaryint<void *>
#include <graph.hpp> this one is a little weird construct a unaryint(nullptr) and get back the identity function f(x) -> x

File list

File biclique_cache.hpp

namespace busclique

template<typename **topo_spec**>
class biclique_cache
#include <biclique_cache.hpp>

Public Functions

biclique_cache(**const** *biclique_cache*&)

biclique_cache(*biclique_cache*&&)

yieldcache **get**(size_t *h*, size_t *w*) **const**

biclique_cache(**const** *cell_cache*<topo_spec> &*c*, **const** bundle_cache<topo_spec> &*b*)

~biclique_cache()

std::pair<size_t, size_t> **score**(size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*) **const**

Public Members

const *cell_cache*<topo_spec> &**cells**

Private Functions

size_t **memrows**(size_t *h*) **const**

size_t **memcols**(size_t *w*) **const**

size_t **memsize**(size_t *h*, size_t *w*) **const**

size_t **memsize**() **const**

size_t **mem_addr**(size_t *h*, size_t *w*) **const**

void **make_access_table**()

void **compute_cache**(**const** bundle_cache<topo_spec> &*bundles*)

Private Members

size_t ***mem**

template<typename **topo_spec**>
class biclique_yield_cache
#include <biclique_cache.hpp>

Public Functions

biclique_yield_cache(**const** *biclique_yield_cache*&)

biclique_yield_cache(*biclique_yield_cache*&&)

biclique_yield_cache(**const** *cell_cache*<topo_spec> &*c*, **const** bundle_cache<topo_spec> &*b*, **const** *biclique_cache*<topo_spec> &*bicliques*)

iterator **begin**() **const**

iterator **end**() **const**

Public Members

const *cell_cache*<topo_spec> &**cells**

const bundle_cache<topo_spec> &**bundles**

Private Types

template<>
using bound_t = std::tuple<size_t, size_t, size_t, size_t>

Private Functions

void **compute_cache**(**const** *biclique_cache*<topo_spec> &*bicliques*)

Private Members

const size_t **rows**

const size_t **cols**

vector<vector<size_t>> **chainlength**

vector<vector<bound_t>> **biclique_bounds**

class iterator
#include <biclique_cache.hpp>

Public Functions

template<>
iterator(size_t *_s0*, size_t *_s1*, **const** size_t &*r*, **const** size_t &*c*, **const** vector<vector<size_t>> &*cl*, **const** vector<vector<*bound_t*>> &*_bounds*, **const** bundle_cache<topo_spec> &*_bundles*)

template<>
iterator **operator++**()

template<>
iterator **operator++**(int)

template<>
std::tuple<size_t, size_t, size_t, vector<vector<size_t>>> **operator***()

template<>
bool **operator==**(**const** iterator &*rhs*)

template<>
bool **operator!=**(**const** iterator &*rhs*)

Private Functions

template<>
void **adv**()

template<>
bool **inc**()

Private Members

template<>
size_t **s0**

template<>
size_t **s1**

template<>
const size_t &**rows**

template<>
const size_t &**cols**

template<>
const vector<vector<size_t>> &**chainlength**

template<>
const vector<vector<*bound_t*>> &**bounds**

template<>
const bundle_cache<topo_spec> &**bundles**

class yieldcache
#include <biclique_cache.hpp>

Public Functions

yieldcache (size_t *r*, size_t *c*, size_t **m*)

size_t **get** (size_t *y*, size_t *x*, size_t *u*) **const**

void **set** (size_t *y*, size_t *x*, size_t *u*, size_t *score*)

Public Members

const size_t **rows**

const size_t **cols**

Private Members

size_t ***mem**

File bundle_cache.hpp

namespace busclique

template<typename **topo_spec**>
class bundle_cache
#include <bundle_cache.hpp>

Public Functions

~bundle_cache ()

bundle_cache (**const** *cell_cache*<topo_spec> &*c*)

size_t **score** (size_t *yc*, size_t *xc*, size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*) **const**

void **inflate** (size_t *yc*, size_t *xc*, size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*, vector<vector<size_t>> &*emb*) **const**

void **inflate** (size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*, vector<vector<size_t>> &*emb*) **const**

void **inflate** (size_t *u*, size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*, vector<vector<size_t>> &*emb*) **const**

size_t **length** (size_t *yc*, size_t *xc*, size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*) **const**

uint8_t **get_line_score** (size_t *u*, size_t *w*, size_t *z0*, size_t *z1*) **const**

Private Functions

bundle_cache(**const** *bundle_cache*&)

bundle_cache(*bundle_cache*&&)

uint8_t **get_line_mask**(size_t *u*, size_t *w*, size_t *z0*, size_t *z1*) **const**

void **compute_line_masks**()

Private Members

const *cell_cache*<topo_spec> &**cells**

template<>
const size_t **linestride**[2]

const size_t **orthstride**

uint8_t ***line_mask**

File util.hpp

> **Warning:** doxygenfile: Found multiple matches for file "util.hpp

File cell_cache.hpp

namespace busclique

template<typename **topo_spec**>
class cell_cache
#include <cell_cache.hpp>

Public Functions

cell_cache(**const** *cell_cache*&)

cell_cache(*cell_cache*&&)

~cell_cache()

cell_cache(**const** topo_spec *p*, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*)

cell_cache(**const** topo_spec *p*, uint8_t **nm*, uint8_t **em*)

uint8_t **qmask**(size_t *u*, size_t *w*, size_t *z*) **const**

uint8_t **emask**(size_t *u*, size_t *w*, size_t *z*) **const**

Public Members

const topo_spec **topo**

Private Members

bool **borrow**

uint8_t ***nodemask**

uint8_t ***edgemask**

File chain.hpp

Defines

DIAGNOSE_CHAINS(other)

DIAGNOSE_CHAIN()

namespace find_embedding

class chain
#include <chain.hpp>

Public Functions

chain(vector<int> &*w*, int *l*)
construct this chain, linking it to the qubit_weight vector `w` (common to all chains in an embedding, typically) and setting its variable label `l`

chain &**operator=**(**const** vector<int> &*c*)
assign this to a vector of ints.

each incoming qubit will have itself as a parent.

chain &**operator=**(**const** *chain* &*c*)
assign this to another chain

size_t **size**() **const**
number of qubits in chain

size_t **count**(**const** int *q*) **const**
returns 0 if `q` is not contained in `this`, 1 otherwise

int **get_link**(**const** int *x*) **const**
get the qubit, in `this`, which links `this` to the chain of x (if x==label, interpret the linking qubit as the chain's root)

void **set_link**(**const** int *x*, **const** int *q*)
set the qubit, in `this`, which links `this` to the chain of x (if x==label, interpret the linking qubit as the chain's root)

int **drop_link**(**const** int *x*)
discard and return the linking qubit for `x`, or -1 if that link is not set

void **set_root** (**const** int *q*)
insert the qubit `q` into `this`, and set `q` to be the root (represented as the linking qubit for `label`)

void **clear** ()
empty this data structure

void **add_leaf** (**const** int *q*, **const** int *parent*)
add the qubit `q` as a leaf, with `parent` as its parent

int **trim_branch** (int *q*)
try to delete the qubit `q` from this chain, and keep deleting until no more qubits are free to be deleted.

return the first ancestor which cannot be deleted

int **trim_leaf** (int *q*)
try to delete the qubit `q` from this chain.

if `q` cannot be deleted, return it; otherwise return its parent

int **parent** (**const** int *q*) **const**
the parent of `q` in this chain which might be `q` but otherwise cycles should be impossible

void **adopt** (**const** int *p*, **const** int *q*)
assign `p` to be the parent of `q`, on condition that both `p` and `q` are contained in `this`, `q` is its own parent, and `q` is not the root

int **refcount** (**const** int *q*) **const**
return the number of references that `this` makes to the qubit `q` where a "reference" is an occurrence of `q` as a parent or an occurrence of `q` as a linking qubit / root

size_t **freeze** (vector<*chain*> &*others*, *frozen_chain* &*keep*)
store this chain into a `frozen_chain`, unlink all chains from this, and *clear()*

void **thaw** (vector<*chain*> &*others*, *frozen_chain* &*keep*)
restore a `frozen_chain` into this, re-establishing links from other chains.

precondition: this is empty.

template<typename **embedding_problem_t**>
void **steal** (*chain* &*other*, *embedding_problem_t* &*ep*, int *chainsize* = 0)
assumes `this` and `other` have links for eachother's labels steals all qubits from `other` which are available to be taken by `this`; starting with the qubit links and updating qubit links after all

void **link_path** (*chain* &*other*, int *q*, **const** vector<int> &*parents*)
link this chain to another, following the path `q, parent[q], parent[parent[q]], ...`

from `this` to `other` and intermediate nodes (all but the last) into `this` (preconditions: `this` and `other` are not linked, `q` is contained in `this`, and the parent-path is eventually contained in `other`)

iterator **begin** () **const**
iterator pointing to the first qubit in this chain

iterator **end** () **const**
iterator pointing to the end of this chain

void **diagnostic** ()
run the diagnostic, and if it fails, report the failure to the user and throw a *CorruptEmbeddingException*.

the `last_op` argument is used in the error message

int **run_diagnostic**() **const**
  run the diagnostic and return a nonzero status `r` in case of failure if(`r`&1), then the parent of a qubit is not contained in this chain if(`r`&2), then there is a refcounting error in this chain

Public Members

const int **label**

Private Functions

const pair<int, int> &**fetch**(int *q*) **const**
  const unsafe data accessor

pair<int, int> &**retrieve**(int *q*)
  non-const unsafe data accessor

Private Members

vector<int> &**qubit_weight**

unordered_map<int, pair<int, int>> **data**

unordered_map<int, int> **links**

class iterator
  #include <chain.hpp>

Public Functions

find_embedding::chain::iterator::iterator(typename decltype(data)::const_iterato

iterator **operator++**()

bool **operator!=**(**const** *iterator* &*other*)

decltype(data) const ::key_type& find_embedding::chain::iterator::operator*() co

Private Members

decltype(data) ::const_iterator find_embedding::chain::iterator::it

struct frozen_chain
  #include <chain.hpp> This class stores chains for embeddings, and performs qubit-use accounting.

The `label` is the index number for the variable represented by this chain. The `links` member of a chain is an unordered map storing the linking information for this chain. The `data` member of a chain stores the connectivity information for the chain.

Links: If `u` and `v` are variables which are connected by an edge, the following must be true: either chain_u or chain_v is empty,

or

chain_u.links[v] is a key in chain_u.data, chain_v.links[u] is a key in chain_v.data, and (chain_u.links[v], chain_v.links[u]) are adjacent in the qubit graph

Moreover, (chain_u.links[u]) must exist if chain_u is not empty, and this is considered the root of the chain.

Data: The `data` member stores the connectivity information. More precisely, `data` is a mapping `qubit->(parent, refs)` where: `parent` is also contained in the chain `refs` is the total number of references to `qubit`, counting both parents and links the chain root is its own parent.

Public Functions

void **clear**()

Public Members

unordered_map<int, pair<int, int>> **data**

unordered_map<int, int> **links**

File clique_cache.hpp

namespace busclique

Variables

const vector<vector<size_t>> **empty_emb**

template<typename **topo_spec**>
class clique_cache
#include <clique_cache.hpp>

Public Functions

clique_cache(**const** *clique_cache*&)

clique_cache(*clique_cache*&&)

clique_cache(**const** *cell_cache*<topo_spec> &*c*, **const** bundle_cache<topo_spec> &*b*, size_t *w*)

template<typename **C**>
clique_cache(**const** *cell_cache*<topo_spec> &*c*, **const** bundle_cache<topo_spec> &*b*, size_t *w*, *C* &*check*)

~clique_cache()

maxcache **get**(size_t *i*) **const**

void **print**()

bool **extract_solution**(vector<vector<size_t>> &*emb*) **const**

Private Functions

size_t **memrows** (size_t *i*) **const**

size_t **memcols** (size_t *i*) **const**

size_t **memsize** (size_t *i*) **const**

size_t **memsize** () **const**

template<typename **C**>
void **compute_cache** (*C* &*check*)

template<typename **T**, typename **C**, typename ...**Corners**>
void **extend_cache** (**const** *T* &*prev*, size_t *h*, size_t *w*, *C* &*check*, *Corners*... *corners*)

template<typename **T**, typename **C**, typename ...**Corners**>
void **extend_cache** (**const** *T* &*prev*, *maxcache* &*next*, size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*, *C* &*check*, *corner* *c*, *Corners*... *corners*)

template<typename **T**, typename **C**>
void **extend_cache** (**const** *T* &*prev*, *maxcache* &*next*, size_t *y0*, size_t *y1*, size_t *x0*, size_t *x1*, *C* &*check*, *corner* *c*)

corner **inflate_first_ell** (vector<vector<size_t>> &*emb*, size_t &*y*, size_t &*x*, size_t *h*, size_t *w*, *corner* *c*) **const**

Private Members

const *cell_cache*<topo_spec> &**cells**

const bundle_cache<topo_spec> &**bundles**

const size_t **width**

size_t ***mem**

Private Static Functions

static constexpr bool **nocheck** (size_t, size_t, size_t, size_t, size_t, size_t)

Friends

friend busclique::clique_iterator< topo_spec >

template<typename **topo_spec**>
class clique_iterator
#include <clique_cache.hpp>

Public Functions

clique_iterator (**const** *cell_cache*<topo_spec> &*c*, **const** *clique_cache*<topo_spec> &*q*)

bool **next** (vector<vector<size_t>> &*e*)

Private Functions

bool **advance**()

bool **grow_stack**()

Private Members

const *cell_cache*<topo_spec> &**cells**

const *clique_cache*<topo_spec> &**cliq**

size_t **width**

vector<std::tuple<size_t, size_t, *corner*>> **basepoints**

vector<std::tuple<size_t, size_t, size_t, *corner*>> **stack**

vector<vector<size_t>> **emb**

template<typename **topo_spec**>
class clique_yield_cache
#include <clique_cache.hpp>

Public Functions

clique_yield_cache(**const** *cell_cache*<*pegasus_spec*> &*cells*)

clique_yield_cache(**const** *cell_cache*<*chimera_spec*> &*cells*)

const vector<vector<vector<size_t>>> &**embeddings**()

Private Functions

size_t **emb_max_length**(**const** vector<vector<size_t>> &*emb*) **const**

void **process_cliques**(**const** *clique_cache*<topo_spec> &*cliques*)

void **compute_cache**(**const** *cell_cache*<topo_spec> &*cells*)

void **get_length_range**(**const** *bundle_cache*<*pegasus_spec*> &*bundles*, size_t *width*, size_t &*min_length*, size_t &*max_length*)

void **get_length_range**(**const** *bundle_cache*<*chimera_spec*>&, size_t *width*, size_t &*min_length*, size_t &*max_length*)

Private Members

const size_t **length_bound**

vector<size_t> **clique_yield**

vector<vector<vector<size_t>>> **best_embeddings**

class maxcache
#include <clique_cache.hpp>

Public Functions

maxcache (size_t *r*, size_t *c*, size_t **m*)

void **setmax** (size_t *y*, size_t *x*, size_t *s*, *corner* *c*)

size_t **score** (size_t *y*, size_t *x*) **const**

corner **corners** (size_t *y*, size_t *x*) **const**

Public Members

const size_t **rows**

const size_t **cols**

Private Members

size_t ***mem**

class zerocache
#include <clique_cache.hpp>

Public Functions

constexpr size_t **score** (size_t, size_t) **const**

File debug.hpp

Defines

minorminer_assert (X)

File embedding.hpp

Defines

DIAGNOSE_EMB (X)

namespace find_embedding

template<typename **embedding_problem_t**>
class embedding
#include <embedding.hpp> This class is how we represent and manipulate embedding objects, using as much encapsulation as possible.

We provide methods to view and modify chains.

Public Functions

embedding (embedding_problem_t &*e_p*)
constructor for an empty embedding

embedding (embedding_problem_t &*e_p*, map<int, vector<int>> &*fixed_chains*, map<int, vector<int>> &*initial_chains*)
constructor for an initial embedding: accepts fixed and initial chains, populates the embedding based on them, and attempts to link adjacent chains together.

embedding<embedding_problem_t> &**operator=** (**const** embedding<embedding_problem_t> &*other*)
copy the data from `other.var_embedding` into `this.var_embedding`

const *chain* &**get_chain** (int *v*) **const**
Get the variables in a chain.

int **chainsize** (int *v*) **const**
Get the size of a chain.

int **weight** (int *q*) **const**
Get the weight of a qubit.

int **max_weight** () **const**
Get the maximum of all qubit weights.

int **max_weight** (**const** int *start*, **const** int *stop*) **const**
Get the maximum of all qubit weights in a range.

bool **has_qubit** (**const** int *v*, **const** int *q*) **const**
Check if variable v is includes qubit q in its chain.

void **set_chain** (**const** int *u*, **const** vector<int> &*incoming*)
Assign a chain for variable u.

void **fix_chain** (**const** int *u*, **const** vector<int> &*incoming*)
Permanently assign a chain for variable u.

NOTE: This must be done before any chain is assigned to u.

bool **operator==** (**const** embedding &*other*) **const**
check if `this` and `other` have the same chains (up to qubit containment per chain; linking and parent information is not checked)

void **construct_chain** (**const** int *u*, **const** int *q*, **const** vector<vector<int>> &*parents*)
construct the chain for `u`, rooted at `q`, with a vector of parent info, where for each neibor `v` of `u`, following `q` -> `parents[v][q]` -> `parents[v][parents[v][q]]` …

terminates in the chain for `v`

void **construct_chain_steiner** (**const** int *u*, **const** int *q*, **const** vector<vector<int>> &*parents*, **const** vector<vector<*distance_t*>> &*distances*, vector<vector<int>> &*visited_list*)
construct the chain for `u`, rooted at `q`.

for the first neighbor `v` of `u`, we follow the parents until we terminate in the chain for `v` `q` -> `parents[v][q]` -> …. adding all but the last node to the chain of `u`. for each subsequent neighbor `w`, we pick a nearest Steiner node, `qw`, from the current chain of `u`, and add the path starting at `qw`, similar to the above… `qw` -> `parents[w][qw]` -> … this has an opportunity to make shorter chains than `construct_chain`

void **flip_back**(int *u*, **const** int *target_chainsize*)
distribute path segments to the neighboring chains path segments are the qubits that are ONLY used to join link_qubit[u][v] to link_qubit[u][u] and aren't used for any other variable

- if the target chainsize is zero, dump the entire segment into the neighbor
- if the target chainsize is k, stop when the neighbor's size reaches k

void **tear_out**(int *u*)
short tearout procedure blank out the chain, its linking qubits, and account for the qubits being freed

int **freeze_out**(int *u*)
undo-able tearout procedure.

similar to `tear_out(u)`, but can be undone with `thaw_back(u)`. note that this embedding type has a space for a single frozen chain, and `freeze_out(u)` overwrites the previously-frozen chain consequently, `freeze_out(u)` can be called an arbitrary (nonzero) number of times before `thaw_back(u)`, but `thaw_back(u)` MUST be preceeded by at least one `freeze_out(u)`. returns the size of the chain being frozen

void **thaw_back**(int *u*)
undo for the freeze_out procedure: replaces the chain previously frozen, and destroys the data in the frozen chain `thaw_back(u)` must be preceeded by at least one `freeze_out(u)` and the chain for `u` must currently be empty (accomplished either by `tear_out(u)` or `freeze_out(u)`)

void **steal_all**(int *u*)
grow the chain for `u`, stealing all available qubits from neighboring variables

int **statistics**(vector<int> &*stats*) **const**
compute statistics for this embedding and return `1` if no chains are overlapping when no chains are overlapping, populate `stats` with a chainlength histogram chains do overlap, populate `stats` with a qubit overfill histogram a histogram, in this case, is a vector of size (maximum attained value+1) where `stats[i]` is either the number of qubits contained in `i+2` chains or the number of chains with size `i`

bool **linked**() **const**
check if the embedding is fully linked that is, if each pair of adjacent variables is known to correspond to a pair of adjacent qubits

bool **linked**(int *u*) **const**
check if a single variable is linked with all adjacent variables.

void **print**() **const**
print out this embedding to a level of detail that is useful for debugging purposes TODO describe the output format.

void **long_diagnostic**(char **current_state*)
run a long diagnostic, and if debugging is enabled, record `current_state` so that the error message has a little more context.

if an error is found, throw a *CorruptEmbeddingException*

void **run_long_diagnostic**(char **current_state*) **const**
run a long diagnostic to verify the integrity of this datastructure.

the guts of this function are its documentation, because this function only exists for debugging purposes

Private Functions

bool **linkup**(int *u*, int *v*)
This method attempts to find the linking qubits for a pair of adjacent variables, and returns true/false on success/failure in finding that pair.

Private Members

embedding_problem_t &**ep**

int **num_qubits**

int **num_reserved**

int **num_vars**

int **num_fixed**

vector<int> **qub_weight**
weights, that is, the number of non-fixed chains that use each qubit this is used in pathfinder clases to determine non-overlapped, or or least-overlapped paths through the qubit graph

vector<*chain*> **var_embedding**
this is where we store chains see chain.hpp for how

frozen_chain **frozen**

File embedding_problem.hpp

namespace find_embedding

Enums

enum VARORDER
Values:

VARORDER_SHUFFLE

VARORDER_DFS

VARORDER_BFS

VARORDER_PFS

VARORDER_RPFS

VARORDER_KEEP

class domain_handler_masked
#include <embedding_problem.hpp> this domain handler stores masks for each variable so that prepare_visited and prepare_distances are barely more expensive than a memcopy

Public Functions

domain_handler_masked(*optional_parameters* &*p*, int *n_v*, int *n_f*, int *n_q*, int *n_r*)

virtual ~domain_handler_masked()

void **prepare_visited** (vector<int> &*visited*, **const** int *u*, **const** int *v*)

void **prepare_distances** (vector<*distance_t*> &*distance*, **const** int *u*, **const** *distance_t* &*mask_d*)

void **prepare_distances** (vector<*distance_t*> &*distance*, **const** int *u*, **const** *distance_t* &*mask_d*, **const** int *start*, **const** int *stop*)

bool **accepts_qubit** (**const** int *u*, **const** int *q*)

Private Members

optional_parameters &**params**

vector<vector<int>> **masks**

class domain_handler_universe

#include <embedding_problem.hpp> this is the trivial domain handler, where every variable is allowed to use every qubit

Public Functions

domain_handler_universe (*optional_parameters*&, int, int, int, int)

virtual ~domain_handler_universe ()

Public Static Functions

static void **prepare_visited** (vector<int> &*visited*, int, int)

static void **prepare_distances** (vector<*distance_t*> &*distance*, **const** int, **const** *distance_t*&)

static void **prepare_distances** (vector<*distance_t*> &*distance*, **const** int, **const** *distance_t*&, **const** int *start*, **const** int *stop*)

static bool **accepts_qubit** (int, int)

template<class **fixed_handler**, class **domain_handler**, class **output_handler**>

class embedding_problem : **public** *find_embedding*::*embedding_problem_base*, **public** *fixed_handler*, **public** *dom*

#include <embedding_problem.hpp> A template to construct a complete embedding problem by combining `embedding_problem_base` with fixed/domain handlers.

Public Functions

embedding_problem (*optional_parameters* &*p*, int *n_v*, int *n_f*, int *n_q*, int *n_r*, vector<vector<int>> &*v_n*, vector<vector<int>> &*q_n*)

virtual ~embedding_problem ()

Private Types

template<>
using ep_t = *embedding_problem_base*

template<>
using fh_t = fixed_handler

template<>
using dh_t = domain_handler

template<>
using oh_t = output_handler

class embedding_problem_base
#include <embedding_problem.hpp> Common form for all embedding problems.

Needs to be extended with a fixed handler and domain handler to be complete.

Subclassed by *find_embedding::embedding_problem< fixed_handler, domain_handler, output_handler >*

Public Functions

embedding_problem_base (*optional_parameters* &*p_*, int *n_v*, int *n_f*, int *n_q*, int *n_r*, vector<vector<int>> &*v_n*, vector<vector<int>> &*q_n*)

virtual ~embedding_problem_base ()

void **reset_mood** ()
resets some internal, ephemeral, variables to a default state

void **populate_weight_table** (int *max_weight*)
precomputes a table of weights corresponding to various overlap values `c`, for `c` from 0 to `max_weight`, inclusive.

distance_t **weight** (unsigned int *c*) **const**
returns the precomputed weight associated with an overlap value of `c`

const vector<int> &**var_neighbors** (int *u*) **const**
a vector of neighbors for the variable `u`

const vector<int> &**var_neighbors** (int *u*, *shuffle_first*)
a vector of neighbors for the variable `u`, pre-shuffling them

const vector<int> &**var_neighbors** (int *u*, *rndswap_first*)
a vector of neighbors for the variable `u`, applying a random transposition before returning the reference

const vector<int> &**qubit_neighbors** (int *q*) **const**
a vector of neighbors for the qubit `q`

int **num_vars** () **const**
number of variables which are not fixed

int **num_qubits** () **const**
number of qubits which are not reserved

int **num_fixed** () **const**
number of fixed variables

int **num_reserved**() **const**
number of reserved qubits

int **randint**(int *a*, int *b*)
make a random integer between 0 and `m-1`

template<typename **A**, typename **B**>
void **shuffle**(*A a*, *B b*)
shuffle the data bracketed by iterators `a` and `b`

void **qubit_component**(int *q0*, vector<int> &*component*, vector<int> &*visited*)
compute the connected component of the subset `component` of qubits, containing `q0`, and usingvisited as an indicator for which qubits have been explored

const vector<int> &**var_order**(*VARORDER order* = *VARORDER_SHUFFLE*)
compute a variable ordering according to the `order` strategy

void **dfs_component**(int *x*, **const** vector<vector<int>> &*neighbors*, vector<int> &*component*, vector<int> &*visited*)
Perform a depth first search.

Public Members

optional_parameters &**params**
A mutable reference to the user specified parameters.

double **max_beta**

double **round_beta**

double **bound_beta**

distance_t **weight_table**[64]

int **initialized**

int **embedded**

int **desperate**

int **target_chainsize**

int **improved**

int **weight_bound**

Protected Attributes

int **num_v**

int **num_f**

int **num_q**

int **num_r**

vector<vector<int>> &**qubit_nbrs**
Mutable references to qubit numbers and variable numbers.

vector<vector<int>> &**var_nbrs**

uniform_int_distribution **rand**
distribution over [0, 0xffffffff]

vector<int> **var_order_space**

vector<int> **var_order_visited**

vector<int> **var_order_shuffle**

unsigned int **exponent_margin**

Private Functions

size_t **compute_margin** ()
computes an upper bound on the distances computed during tearout & replace

template<typename **queue_t**>
void **pfs_component** (int *x*, **const** vector<vector<int>> &*neighbors*, vector<int> &*component*, vector<int> &*visited*, vector<int> *shuffled*)
Perform a priority first search (priority = #of visited neighbors)

void **bfs_component** (int *x*, **const** vector<vector<int>> &*neighbors*, vector<int> &*component*, vector<int> &*visited*, vector<int> &*shuffled*)
Perform a breadth first search, shuffling level sets.

class fixed_handler_hival
#include <embedding_problem.hpp> This fixed handler is used when the fixed variables are processed before instantiation and relabeled such that variables v >= num_v are fixed and qubits q >= num_q are reserved.

Public Functions

fixed_handler_hival (*optional_parameters*&, int *n_v*, int, int *n_q*, int)

virtual ~fixed_handler_hival ()

bool **fixed** (**const** int *u*)

bool **reserved** (**const** int *q*)

Private Members

int **num_v**

int **num_q**

class fixed_handler_none
#include <embedding_problem.hpp> This fixed handler is used when there are no fixed variables.

Public Functions

fixed_handler_none (*optional_parameters*&, int, int, int, int)

virtual ~fixed_handler_none ()

Public Static Functions

static bool **fixed** (int)

static bool **reserved** (int)

template<bool **verbose**>
class output_handler

#include <embedding_problem.hpp> Output handlers are used to control output.

We provide two handlers one which only reports all errors (and optimizes away all other output) and another which provides full output. When verbose is zero, we recommend the errors-only handler and otherwise, the full handler Here's the full output handler

Subclassed by *find_embedding::embedding_problem< fixed_handler, domain_handler, output_handler >*

Public Functions

output_handler (*optional_parameters* &*p*)

template<typename ...**Args**>
void **error** (**const** char **format*, *Args*... *args*) **const**

printf regardless of the verbosity level

template<typename ...**Args**>
void **major_info** (**const** char **format*, *Args*... *args*) **const**

printf at the major_info verbosity level

template<typename ...**Args**>
void **minor_info** (**const** char **format*, *Args*... *args*) **const**

print at the minor_info verbosity level

template<typename ...**Args**>
void **extra_info** (**const** char **format*, *Args*... *args*) **const**

print at the extra_info verbosity level

template<typename ...**Args**>
void **debug** (**const** char *, *Args*...) **const**

print at the debug verbosity level (only works when `CPPDEBUG` is set)

Private Members

optional_parameters &**params**

File fastrng.hpp

class fastrng

#include <fastrng.hpp>

Public Types

typedef uint64_t **result_type**

Public Functions

fastrng()

fastrng(uint64_t *x*)

void **seed**(uint32_t *x*)

void **seed**(uint64_t *x*)

uint64_t **operator()**()

void **discard**(int *n*)

Public Static Functions

static constexpr uint64_t **min**()

static constexpr uint64_t **max**()

Private Members

uint64_t **S0**

uint64_t **S1**

Private Static Functions

static uint64_t **splitmix64**(uint64_t &*x*)

static uint32_t **splitmix32**(uint32_t &*x*)

File find_biclique.hpp

namespace busclique

Typedefs

using biclique_result_cache = std::unordered_map<pair<size_t, size_t>, value_t, *craphash*>

Functions

template<typename **topo_spec**>
void **best_bicliques**(**const** *topo_spec* &*topo*, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*, vector<pair<pair<size_t, size_t>, vector<vector<size_t>>>> &*embs*)

template<typename **topo_spec**>
void **best_bicliques**(*topo_cache*<*topo_spec*> &*topology*, vector<pair<pair<size_t, size_t>, vector<vector<size_t>>>> &*embs*)

class craphash
#include <find_biclique.hpp>

Public Functions

size_t **operator()** (**const** pair<size_t, size_t> *x*) **const**

File find_clique.hpp

namespace busclique

Functions

template<typename **T**>
size_t **get_maxlen** (vector<*T*> *&emb*, size_t *size*)

template<typename **topo_spec**>
bool **find_clique_nice** (**const** *cell_cache*<*topo_spec*>&, size_t *size*, vector<vector<size_t>> *&emb*, size_t *&min_width*, size_t *&max_width*, size_t *&max_length*)

template<>
bool **find_clique_nice** (**const** *cell_cache*<*chimera_spec*> *&cells*, size_t *size*, vector<vector<size_t>> *&emb*, size_t&, size_t&, size_t *&max_length*)

template<>
bool **find_clique_nice** (**const** *cell_cache*<*pegasus_spec*> *&cells*, size_t *size*, vector<vector<size_t>> *&emb*, size_t&, size_t&, size_t *&max_length*)

template<typename **topo_spec**>
bool **find_clique** (**const** *topo_spec* *&topo*, **const** vector<size_t> *&nodes*, **const** vector<pair<size_t, size_t>> *&edges*, size_t *size*, vector<vector<size_t>> *&emb*)

template<typename **topo_spec**>
bool **find_clique** (*topo_cache*<*topo_spec*> *&topology*, size_t *size*, vector<vector<size_t>> *&emb*)

template<typename **topo_spec**>
bool **find_clique_nice** (**const** *topo_spec* *&topo*, **const** vector<size_t> *&nodes*, **const** vector<pair<size_t, size_t>> *&edges*, size_t *size*, vector<vector<size_t>> *&emb*)

template<typename **topo_spec**>
void **short_clique** (**const** *topo_spec*&, **const** vector<size_t> *&nodes*, **const** vector<pair<size_t, size_t>> *&edges*, vector<vector<size_t>> *&emb*)

template<typename **topo_spec**>
void **best_cliques** (*topo_cache*<*topo_spec*> *&topology*, vector<vector<vector<size_t>>> *&embs*, vector<vector<size_t>> *&emb_1*)

File util.hpp

> **Warning:** doxygenfile: Found multiple matches for file "util.hpp

File find_embedding.hpp

namespace find_embedding

Functions

int **findEmbedding** (*graph*::*input_graph* &*var_g*, *graph*::*input_graph* &*qubit_g*, *optional_parameters* &*params*, vector<vector<int>> &*chains*)

The main entry function of this library.

This method primarily dispatches the proper implementation of the algorithm where some parameters/behaviours have been fixed at compile time.

In terms of dispatch, there are three dynamically-selected classes which are combined, each according to a specific optional parameter.

- a domain_handler, described in embedding_problem.hpp, manages constraints of the form "variable a's chain must be a subset of…"
- a fixed_handler, described in embedding_problem.hpp, manages contstraints of the form "variable a's chain must be exactly…"
- a pathfinder, described in pathfinder.hpp, which come in two flavors, serial and parallel The optional parameters themselves can be found in util.hpp. Respectively, the controlling options for the above are restrict_chains, fixed_chains, and threads.

class parameter_processor

#include <find_embedding.hpp>

Public Functions

parameter_processor (*graph*::*input_graph* &*var_g*, *graph*::*input_graph* &*qubit_g*, *optional_parameters* &*params_*)

map<int, vector<int>> **input_chains** (map<int, vector<int>> &*m*)

vector<int> **input_vars** (vector<int> &*V*)

Public Members

int **num_vars**

int **num_qubits**

vector<int> **qub_reserved_unscrewed**

vector<int> **var_fixed_unscrewed**

int **num_reserved**

graph::*components* **qub_components**

int **problem_qubits**

int **problem_reserved**

int **num_fixed**

vector<int> **unscrew_vars**

vector<int> **screw_vars**

optional_parameters **params**

vector<vector<int>> **var_nbrs**

vector<vector<int>> **qubit_nbrs**

Private Functions

int **_reserved**(*optional_parameters* &*params_*)

vector<int> **_filter_fixed_vars**()

vector<int> **_inverse_permutation**(vector<int> &*f*)

template<bool **parallel**, bool **fixed**, bool **restricted**, bool **verbose**>
class pathfinder_type
#include <find_embedding.hpp>

Public Types

typedef std::conditional<fixed, *fixed_handler_hival*, *fixed_handler_none*>::type **fixed_handler_t**

typedef std::conditional<restricted, *domain_handler_masked*, *domain_handler_universe*>::type **domain_handler_t**

typedef output_handler<verbose> **output_handler_t**

typedef *embedding_problem*<*fixed_handler_t*, *domain_handler_t*, *output_handler_t*> **embedding_problem_t**

typedef std::conditional<parallel, pathfinder_parallel<*embedding_problem_t*>, pathfinder_serial<*embedding_problem_t*

class pathfinder_wrapper
#include <find_embedding.hpp>

Public Functions

pathfinder_wrapper(*graph*::*input_graph* &*var_g*, *graph*::*input_graph* &*qubit_g*, *optional_parameters* &*params_*)

~pathfinder_wrapper()

void **get_chain**(int *u*, vector<int> &*output*) **const**

int **heuristicEmbedding**()

int **num_vars**()

void **set_initial_chains**(map<int, vector<int>> &*init*)

void **quickPass**(vector<int> &*varorder*, int *chainlength_bound*, int *overlap_bound*, bool *local_search*, bool *clear_first*, double *round_beta*)

void **quickPass**(*VARORDER* *varorder*, int *chainlength_bound*, int *overlap_bound*, bool *local_search*, bool *clear_first*, double *round_beta*)

Private Functions

template<bool **parallel**, bool **fixed**, bool **restricted**, bool **verbose**, typename ...**Args**>
std::unique_ptr<*pathfinder_public_interface*> **_pf_parse4** (*Args*&&... *args*)

template<bool **parallel**, bool **fixed**, bool **restricted**, typename ...**Args**>
std::unique_ptr<*pathfinder_public_interface*> **_pf_parse3** (*Args*&&... *args*)

template<bool **parallel**, bool **fixed**, typename ...**Args**>
std::unique_ptr<*pathfinder_public_interface*> **_pf_parse2** (*Args*&&... *args*)

template<bool **parallel**, typename ...**Args**>
std::unique_ptr<*pathfinder_public_interface*> **_pf_parse1** (*Args*&&... *args*)

template<typename ...**Args**>
std::unique_ptr<*pathfinder_public_interface*> **_pf_parse** (*Args*&&... *args*)

Private Members

parameter_processor **pp**

std::unique_ptr<*pathfinder_public_interface*> **pf**

File graph.hpp

template<>
class unaryint<std::vector<int>>
#include <graph.hpp>

Public Functions

unaryint (**const** std::vector<int> *m*)

int **operator()** (int *i*) **const**

Private Members

const std::vector<int> **b**

namespace graph

class components
#include <graph.hpp> Represents a graph as a series of connected components.

The input graph may consist of many components, they will be separated in the construction.

Public Functions

template<typename **T**>
components (**const** *input_graph* &*g*, **const** *unaryint*<*T*> &*reserve*)

components (**const** *input_graph* &*g*)

components (**const** *input_graph* &*g*, **const** std::vector<int> *reserve*)

const std::vector<int> &**nodes** (int *c*) **const**
Get the set of nodes in a component.

size_t **size** () **const**
Get the number of connected components in the graph.

size_t **num_reserved** (int *c*) **const**
returns the number of reserved nodes in a component

size_t **size** (int *c*) **const**
Get the size (in nodes) of a component.

const *input_graph* &**component_graph** (int *c*) **const**
Get a const reference to the graph object of a component.

std::vector<std::vector<int>> **component_neighbors** (int *c*) **const**
Construct a neighborhood list for component c, with reserved nodes as sources.

template<typename **T**>
bool **into_component** (**const** int *c*, *T* &*nodes_in*, std::vector<int> &*nodes_out*) **const**
translate nodes from the input graph, to their labels in component c

template<typename **T**>
void **from_component** (**const** int *c*, *T* &*nodes_in*, std::vector<int> &*nodes_out*) **const**
translate nodes from labels in component c, back to their original input labels

Private Functions

int **__init_find** (int *x*)

void **__init_union** (int *x*, int *y*)

Private Members

std::vector<int> **index**

std::vector<int> **label**

std::vector<int> **_num_reserved**

std::vector<std::vector<int>> **component**

std::vector<*input_graph*> **component_g**

class input_graph
#include <graph.hpp> Represents an undirected graph as a list of edges.

Provides methods to extract those edges into neighbor lists (with options to relabel and produce directed graphs).

As an input to the library this may be a disconnected graph, but when returned from components it is a connected sub graph.

Public Functions

input_graph()
Constructs an empty graph.

input_graph(int *n_v*, **const** std::vector<int> &*aside*, **const** std::vector<int> &*bside*)
Constructs a graph from the provided edges.

The ends of edge ii are aside[ii] and bside[ii].

Parameters
- `n_v`: Number of nodes in the graph.
- `aside`: List of nodes describing edges.
- `bside`: List of nodes describing edges.

void **clear**()
Remove all edges and nodes from a graph.

int **a**(**const** int *i*) **const**
Return the nodes on either end of edge `i`

int **b**(**const** int *i*) **const**
Return the nodes on either end of edge `i`

size_t **num_nodes**() **const**
Return the size of the graph in nodes.

size_t **num_edges**() **const**
Return the size of the graph in edges.

void **push_back**(int *ai*, int *bi*)
Add an edge to the graph.

template<typename **T1**, typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors_sources**(**const** *T1* &*sources*, *Args*... *args*) **const**
produce a std::vector<std::vector<int>> of neigborhoods, with certain nodes marked as sources (inbound edges are omitted) sources is either a std::vector<int> (where non-sources x have sources[x] = 0), or another type for which we have a unaryint specialization optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking sources / mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

template<typename **T2**, typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors_sinks**(**const** *T2* &*sinks*, *Args*... *args*) **const**
produce a std::vector<std::vector<int>> of neigborhoods, with certain nodes marked as sinks (outbound edges are omitted) sinks is either a std::vector<int> (where non-sinks x have sinks[x] = 0), or another type for which we have a unaryint specialization optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking sinks / mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

template<typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors**(*Args*... *args*) **const**
produce a std::vector<std::vector<int>> of neigborhoods optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

Private Functions

std::vector<std::vector<int>> **_to_vectorhoods** (std::vector<std::set<int>> &*_nbrs*) **const**

this method converts a std::vector of sets into a std::vector of sets, ensuring that element i is not contained in nbrs[i].

this method is called by methods which produce neighbor sets (killing parallel/overrepresented edges), in order to kill self-loops and also store each neighborhood in a contiguous memory segment.

template<typename **T1**, typename **T2**, typename **T3**, typename **T4**>
std::vector<std::vector<int>> **__get_neighbors** (**const** *unaryint*<*T1*> &*sources*, **const** *unaryint*<*T2*> &*sinks*, **const** *unaryint*<*T3*> &*relabel*, **const** *unaryint*<*T4*> &*mask*) **const**

produce the node->nodelist mapping for our graph, where certain nodes are marked as sources (no incoming edges), relabeling all nodes along the way, and filtering according to a mask.

note that the mask itself is assumed to be a union of components only one side of each edge is checked

template<typename **T1**, typename **T2**, typename **T3** = void *, typename **T4** = bool>
std::vector<std::vector<int>> **_get_neighbors** (**const** *T1* &*sources*, **const** *T2* &*sinks*, **const** *T3* &*relabel* = nullptr, **const** *T4* &*mask* = true) **const**

smash the types through unaryint

Private Members

std::vector<int> **edges_aside**

std::vector<int> **edges_bside**

size_t **_num_nodes**

template<>
class unaryint<bool>
#include <graph.hpp>

Public Functions

unaryint (**const** bool *x*)

int **operator()** (int) **const**

Private Members

const bool **b**

template<>
class unaryint<int>
#include <graph.hpp>

Public Functions

unaryint (int *m*)

int **operator()** (int *i*) **const**

Private Members

const int **b**

template<>
class unaryint<std::vector<int>>
#include <graph.hpp>

Public Functions

unaryint (**const** std::vector<int> *m*)

int **operator()** (int *i*) **const**

Private Members

const std::vector<int> **b**

template<>
class unaryint<void *>
#include <graph.hpp> this one is a little weird construct a unaryint(nullptr) and get back the identity function f(x) -> x

Public Functions

unaryint (void ***const** &)

int **operator()** (int *i*) **const**

File pairing_queue.hpp

namespace find_embedding

template<typename **N**>
class pairing_node : **public** *N*
#include <pairing_queue.hpp>

Public Functions

pairing_node ()

template<class ...**Args**>
pairing_node (*Args*... *args*)

pairing_node<N> ***merge_roots** (pairing_node<N> **other*)
the basic operation of the pairing queue put `this` and `other` into heap-order

template<class ...**Args**>
void **refresh** (*Args... args*)

pairing_node<N> ***next_root** ()

pairing_node<N> ***merge_pairs** ()

Private Functions

pairing_node<N> ***merge_roots_unsafe** (pairing_node<N> **other*)
the basic operation of the pairing queue put `this` and `other` into heap-order

pairing_node<N> ***merge_roots_unchecked** (pairing_node **other*)
merge_roots, assuming `other` is not null and that `val` < `other->val`.

may invalidate the internal data structure (see source for details)

Private Members

pairing_node ***next**

pairing_node ***desc**

template<typename **N**>
class pairing_queue
#include <pairing_queue.hpp>

Public Functions

pairing_queue (int *n*)

pairing_queue (*pairing_queue &&other*)

~pairing_queue ()

void **reset** ()

bool **empty** ()

template<class ...**Args**>
void **emplace** (*Args... args*)

N **top** ()

void **pop** ()

Private Members

int **count**

int **size**

pairing_node<N> ***root**

pairing_node<N> ***mem**

template<typename **P**, typename **heap_tag** = *min_heap_tag*>
class priority_node
#include <pairing_queue.hpp>

Public Functions

priority_node()

priority_node(int *n*, int *r*, P *d*)

bool **operator<**(**const** priority_node<P, heap_tag> &*b*) **const**

Public Members

int **node**

int **dirt**

P **dist**

File pathfinder.hpp

namespace find_embedding

template<typename **embedding_problem_t**>
class pathfinder_base : **public** *find_embedding*::*pathfinder_public_interface*
#include <pathfinder.hpp> Subclassed by *find_embedding::pathfinder_parallel< embedding_problem_t >*, *find_embedding::pathfinder_serial< embedding_problem_t >*

Public Types

template<>
using embedding_t = embedding<embedding_problem_t>

Public Functions

pathfinder_base(*optional_parameters* &*p_*, int &*n_v*, int &*n_f*, int &*n_q*, int &*n_r*, vector<vector<int>> &*v_n*, vector<vector<int>> &*q_n*)

virtual void **set_initial_chains**(map<int, vector<int>> *chains*)
setter for the initial_chains parameter

virtual ~pathfinder_base()

bool **check_improvement** (**const** embedding_t &*emb*)
nonzero return if this is an improvement on our previous best embedding

virtual const *chain* &**get_chain** (int *u*) **const**
chain accessor

virtual void **quickPass** (*VARORDER varorder*, int *chainlength_bound*, int *overlap_bound*, bool *local_search*, bool *clear_first*, double *round_beta*)

virtual void **quickPass** (**const** vector<int> &*varorder*, int *chainlength_bound*, int *overlap_bound*, bool *local_search*, bool *clear_first*, double *round_beta*)

virtual int **heuristicEmbedding** ()
perform the heuristic embedding, returning 1 if an embedding was found and 0 otherwise

Protected Functions

int **find_chain** (embedding_t &*emb*, **const** int *u*)
tear out and replace the chain in `emb` for variable `u`

int **check_stops** (**const** int &*return_value*)
internal function to check if we're supposed to stop for an external reason namely if we've timed out (which we catch immediately and return -2 to allow the heuristic to terminate gracefully), or received a keyboard interrupt (which we allow to propagate back to the user).

If neither stopping condition is encountered, return `return_value`.

int **initialization_pass** (embedding_t &*emb*)
sweep over all variables, either keeping them if they are pre-initialized and connected, and otherwise finding new chains for them (each, in turn, seeking connection only with neighbors that already have chains)

int **improve_overfill_pass** (embedding_t &*emb*)
tear up and replace each variable

int **pushdown_overfill_pass** (embedding_t &*emb*)
tear up and replace each chain, strictly improving or maintaining the maximum qubit fill seen by each chain

int **improve_chainlength_pass** (embedding_t &*emb*)
tear up and replace each chain, attempting to rebalance the chains and lower the maximum chainlength

void **accumulate_distance_at_chain** (**const** embedding_t &*emb*, **const** int *v*)
incorporate the qubit weights associated with the chain for `v` into `total_distance`

void **accumulate_distance** (**const** embedding_t &*emb*, **const** int *v*, vector<int> &*visited*, **const** int *start*, **const** int *stop*)
incorporate the distances associated with the chain for `v` into `total_distance`

void **accumulate_distance** (**const** embedding_t &*emb*, **const** int *v*, vector<int> &*visited*)
a wrapper for `accumulate_distance` and `accumulate_distance_at_chain`

void **compute_distances_from_chain** (**const** embedding_t &*emb*, **const** int &*v*, vector<int> &*visited*)
run dijkstra's algorithm, seeded at the chain for `v`, using the `visited` vector note: qubits are only visited if `visited[q] = 1`.

the value `-1` is used to prevent searching of overfull qubits

void **compute_qubit_weights** (**const** embedding_t &*emb*)
compute the weight of each qubit, first selecting `alpha`

void **compute_qubit_weights** (**const** embedding_t &*emb*, **const** int *start*, **const** int *stop*)
compute the weight of each qubit in the range from `start` to `stop`, where the weight is `2^(alpha*fill)` where `fill` is the number of chains which use that qubit

Protected Attributes

embedding_problem_t **ep**

optional_parameters &**params**

embedding_t **bestEmbedding**

embedding_t **lastEmbedding**

embedding_t **currEmbedding**

embedding_t **initEmbedding**

int **num_qubits**

int **num_reserved**

int **num_vars**

int **num_fixed**

vector<vector<int>> **parents**

vector<*distance_t*> **total_distance**

vector<int> **min_list**

vector<*distance_t*> **qubit_weight**

vector<int> **tmp_stats**

vector<int> **best_stats**

int **pushback**

clock::time_point **stoptime**

vector<vector<int>> **visited_list**

vector<vector<*distance_t*>> **distances**

vector<vector<int>> **qubit_permutations**

Private Functions

virtual void **prepare_root_distances** (**const** embedding_t &*emb*, **const** int *u*) = 0
compute the distances from all neighbors of `u` to all qubits

int **find_chain** (embedding_t &*emb*, **const** int *u*, int *target_chainsize*)
after `u` has been torn out, perform searches from each neighboring chain, select a minimum-distance root, and construct the chain

void **find_short_chain**(embedding_t &*emb*, **const** int *u*, **const** int *target_chainsize*)
after u has been torn out, perform searches from each neighboring chain, iterating over potential roots to find a root with a smallest-possible actual chainlength whereas other variants of find_chain simply pick a random root candidate with minimum estimated chainlength.

this procedure takes quite a long time and requires that emb is a valid embedding with no overlaps.

template<typename **pq_t**, typename **behavior_tag**>
void **dijkstra_initialize_chain**(**const** embedding_t &*emb*, **const** int &*v*, vector<int> &*parent*, vector<int> &*visited*, *pq_t* &*pq*, *behavior_tag*)
this function prepares the parent & distance-priority-queue before running dijkstra's algorithm

Friends

friend find_embedding::pathfinder_serial< embedding_problem_t >

friend find_embedding::pathfinder_parallel< embedding_problem_t >

template<typename **embedding_problem_t**>
class pathfinder_parallel : **public** *find_embedding*::pathfinder_base<*embedding_problem_t*>
#include <pathfinder.hpp> A pathfinder where the Dijkstra-from-neighboring-chain passes are done serially.

Public Types

template<>
using super = pathfinder_base<embedding_problem_t>

template<>
using embedding_t = embedding<embedding_problem_t>

Public Functions

pathfinder_parallel(*optional_parameters* &*p_*, int *n_v*, int *n_f*, int *n_q*, int *n_r*, vector<vector<int>> &*v_n*, vector<vector<int>> &*q_n*)

virtual ~pathfinder_parallel()

virtual void **prepare_root_distances**(**const** embedding_t &*emb*, **const** int *u*)
compute the distances from all neighbors of u to all qubits

Private Functions

void **run_in_thread**(**const** embedding_t &*emb*, **const** int *u*)

template<typename **C**>
void **exec_chunked**(*C e_chunk*)

template<typename **C**>
void **exec_indexed**(*C e_chunk*)

Private Members

int **num_threads**

vector<std::future<void>> **futures**

vector<int> **thread_weight**

mutex **get_job**

unsigned int **nbr_i**

int **neighbors_embedded**

class pathfinder_public_interface
#include <pathfinder.hpp> Subclassed by *find_embedding::pathfinder_base< embedding_problem_t >*

Public Functions

virtual int **heuristicEmbedding**() = 0

virtual const *chain* &**get_chain**(int) **const** = 0

virtual ~pathfinder_public_interface()

virtual void **set_initial_chains**(map<int, vector<int>>) = 0

virtual void **quickPass**(**const** vector<int>&, int, int, bool, bool, double) = 0

virtual void **quickPass**(*VARORDER*, int, int, bool, bool, double) = 0

template<typename **embedding_problem_t**>
class pathfinder_serial : **public** *find_embedding*::pathfinder_base<*embedding_problem_t*>
#include <pathfinder.hpp> A pathfinder where the Dijkstra-from-neighboring-chain passes are done serially.

Public Types

template<>
using super = pathfinder_base<embedding_problem_t>

template<>
using embedding_t = embedding<embedding_problem_t>

Public Functions

pathfinder_serial(*optional_parameters* &*p_*, int *n_v*, int *n_f*, int *n_q*, int *n_r*, vector<vector<int>> &*v_n*, vector<vector<int>> &*q_n*)

virtual ~pathfinder_serial()

virtual void **prepare_root_distances**(**const** embedding_t &*emb*, **const** int *u*)
compute the distances from all neighbors of `u` to all qubits

File small_cliques.hpp

namespace busclique

Functions

bool **find_generic_1** (**const** vector<size_t> &*nodes*, vector<vector<size_t>> &*emb*)

bool **find_generic_2** (**const** vector<pair<size_t, size_t>> &*edges*, vector<vector<size_t>> &*emb*)

bool **find_generic_3** (**const** vector<pair<size_t, size_t>> &*edges*, vector<vector<size_t>> &*emb*)

bool **find_generic_4** (**const** vector<pair<size_t, size_t>> &*edges*, vector<vector<size_t>> &*emb*)

File topo_cache.hpp

namespace busclique

template<typename **topo_spec**>
class topo_cache
#include <topo_cache.hpp>

Public Functions

topo_cache (**const** *topo_cache*&)

topo_cache (*topo_cache*&&)

~topo_cache ()

topo_cache (**const** *pegasus_spec t*, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*)

topo_cache (**const** *chimera_spec t*, **const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*)

void **reset** ()

bool **next** ()

Public Members

const topo_spec **topo**

const *cell_cache*<topo_spec> **cells**

Private Functions

_initializer_tag **_initialize** (**const** vector<size_t> &*nodes*, **const** vector<pair<size_t, size_t>> &*edges*)

void **compute_bad_edges** ()

Private Members

uint8_t ***nodemask**

uint8_t ***edgemask**

uint8_t ***badmask**

vector<pair<size_t, size_t>> **bad_edges**

uint8_t **mask_num**

_initializer_tag **_init**

uint8_t ***child_nodemask**

uint8_t ***child_edgemask**

Class list

Class busclique::biclique_cache

template<typename **topo_spec**>
class biclique_cache

Class busclique::biclique_yield_cache

template<typename **topo_spec**>
class biclique_yield_cache

Class busclique::biclique_yield_cache::iterator

class iterator

Class busclique::bundle_cache

template<typename **topo_spec**>
class bundle_cache

Class busclique::cell_cache

template<typename **topo_spec**>
class cell_cache

Class busclique::chimera_spec_base

class chimera_spec_base : **public** *busclique*::*topo_spec_base*

Class busclique::clique_cache

template<typename **topo_spec**>
class clique_cache

Class busclique::clique_iterator

template<typename **topo_spec**>
class clique_iterator

Class busclique::clique_yield_cache

template<typename **topo_spec**>
class clique_yield_cache

Class busclique::craphash

class craphash

Class busclique::ignore_badmask

class ignore_badmask

Class busclique::maxcache

class maxcache

Class busclique::pegasus_spec_base

class pegasus_spec_base : **public** *busclique*::*topo_spec_base*

Class busclique::populate_badmask

class populate_badmask

Class busclique::topo_cache

template<typename **topo_spec**>
class topo_cache

Class busclique::topo_cache::_initializer_tag

class _initializer_tag

Class busclique::topo_spec_base

class topo_spec_base
Subclassed by *busclique::chimera_spec_base*, *busclique::pegasus_spec_base*

Class busclique::topo_spec_cellmask

template<typename **topo_spec**>
class topo_spec_cellmask : **public** *topo_spec*

Class busclique::yieldcache

class yieldcache

Class busclique::zerocache

class zerocache

Class fastrng

class fastrng

Class find_embedding::BadInitializationException

class BadInitializationException : **public** *find_embedding*::*MinorMinerException*

Class find_embedding::CorruptEmbeddingException

class CorruptEmbeddingException : **public** *find_embedding*::*MinorMinerException*

Class find_embedding::CorruptParametersException

class CorruptParametersException : **public** *find_embedding*::*MinorMinerException*

Class find_embedding::LocalInteraction

class LocalInteraction
Interface for communication between the library and various bindings.

Any bindings of this library need to provide a concrete subclass.

Public Functions

void **displayOutput**(int *loglevel*, **const** string &*msg*) **const**
Print a message through the local output method.

void **displayError**(int *loglevel*, **const** string &*msg*) **const**
Print an error through the local output method.

int **cancelled**(**const** *clock*::time_point *stoptime*) **const**
Check if someone is trying to cancel the embedding process.

Class find_embedding::MinorMinerException

class MinorMinerException : **public** runtime_error
Subclassed by *find_embedding::BadInitializationException*, *find_embedding::CorruptEmbeddingException*, *find_embedding::CorruptParametersException*, *find_embedding::ProblemCancelledException*, *find_embedding::TimeoutException*

Class find_embedding::ProblemCancelledException

class ProblemCancelledException : **public** *find_embedding*::*MinorMinerException*

Class find_embedding::TimeoutException

class TimeoutException : **public** *find_embedding*::*MinorMinerException*

Class find_embedding::chain

class chain

Public Functions

chain(vector<int> &*w*, int *l*)
construct this chain, linking it to the qubit_weight vector `w` (common to all chains in an embedding, typically) and setting its variable label `l`

chain &**operator=**(**const** vector<int> &*c*)
assign this to a vector of ints.

each incoming qubit will have itself as a parent.

chain &**operator=**(**const** *chain* &*c*)
assign this to another chain

size_t **size**() **const**
number of qubits in chain

size_t **count**(**const** int *q*) **const**
returns 0 if `q` is not contained in `this`, 1 otherwise

int **get_link** (**const** int *x*) **const**
get the qubit, in `this`, which links `this` to the chain of x (if x==label, interpret the linking qubit as the chain's root)

void **set_link** (**const** int *x*, **const** int *q*)
set the qubit, in `this`, which links `this` to the chain of x (if x==label, interpret the linking qubit as the chain's root)

int **drop_link** (**const** int *x*)
discard and return the linking qubit for `x`, or -1 if that link is not set

void **set_root** (**const** int *q*)
insert the qubit `q` into `this`, and set `q` to be the root (represented as the linking qubit for `label`)

void **clear** ()
empty this data structure

void **add_leaf** (**const** int *q*, **const** int *parent*)
add the qubit `q` as a leaf, with `parent` as its parent

int **trim_branch** (int *q*)
try to delete the qubit `q` from this chain, and keep deleting until no more qubits are free to be deleted.

return the first ancestor which cannot be deleted

int **trim_leaf** (int *q*)
try to delete the qubit `q` from this chain.

if `q` cannot be deleted, return it; otherwise return its parent

int **parent** (**const** int *q*) **const**
the parent of `q` in this chain which might be `q` but otherwise cycles should be impossible

void **adopt** (**const** int *p*, **const** int *q*)
assign `p` to be the parent of `q`, on condition that both `p` and `q` are contained in `this`, `q` is its own parent, and `q` is not the root

int **refcount** (**const** int *q*) **const**
return the number of references that `this` makes to the qubit `q` where a "reference" is an occurrence of `q` as a parent or an occurrence of `q` as a linking qubit / root

size_t **freeze** (vector<*chain*> &*others*, *frozen_chain* &*keep*)
store this chain into a `frozen_chain`, unlink all chains from this, and *clear()*

void **thaw** (vector<*chain*> &*others*, *frozen_chain* &*keep*)
restore a `frozen_chain` into this, re-establishing links from other chains.

precondition: this is empty.

template<typename **embedding_problem_t**>
void **steal** (*chain* &*other*, *embedding_problem_t* &*ep*, int *chainsize* = 0)
assumes `this` and `other` have links for eachother's labels steals all qubits from `other` which are available to be taken by `this`; starting with the qubit links and updating qubit links after all

void **link_path** (*chain* &*other*, int *q*, **const** vector<int> &*parents*)
link this chain to another, following the path `q, parent[q], parent[parent[q]], ...`

from `this` to `other` and intermediate nodes (all but the last) into `this` (preconditions: `this` and `other` are not linked, `q` is contained in `this`, and the parent-path is eventually contained in `other`)

iterator **begin**() **const**
iterator pointing to the first qubit in this chain

iterator **end**() **const**
iterator pointing to the end of this chain

void **diagnostic**()
run the diagnostic, and if it fails, report the failure to the user and throw a *CorruptEmbeddingException*.

the `last_op` argument is used in the error message

int **run_diagnostic**() **const**
run the diagnostic and return a nonzero status `r` in case of failure if(`r`&1), then the parent of a qubit is not contained in this chain if(`r`&2), then there is a refcounting error in this chain

Class find_embedding::chain::iterator

class iterator

Class find_embedding::domain_handler_masked

class domain_handler_masked
this domain handler stores masks for each variable so that prepare_visited and prepare_distances are barely more expensive than a memcopy

Class find_embedding::domain_handler_universe

class domain_handler_universe
this is the trivial domain handler, where every variable is allowed to use every qubit

Class find_embedding::embedding

template<typename **embedding_problem_t**>
class embedding
This class is how we represent and manipulate embedding objects, using as much encapsulation as possible.

We provide methods to view and modify chains.

Public Functions

embedding(embedding_problem_t &*e_p*)
constructor for an empty embedding

embedding(embedding_problem_t &*e_p*, map<int, vector<int>> &*fixed_chains*, map<int, vector<int>> &*initial_chains*)
constructor for an initial embedding: accepts fixed and initial chains, populates the embedding based on them, and attempts to link adjacent chains together.

embedding<embedding_problem_t> &**operator=**(**const** embedding<embedding_problem_t> &*other*)
copy the data from `other.var_embedding` into `this.var_embedding`

const *chain* &**get_chain**(int *v*) **const**
Get the variables in a chain.

int **chainsize**(int *v*) **const**
Get the size of a chain.

int **weight**(int *q*) **const**
Get the weight of a qubit.

int **max_weight**() **const**
Get the maximum of all qubit weights.

int **max_weight**(**const** int *start*, **const** int *stop*) **const**
Get the maximum of all qubit weights in a range.

bool **has_qubit**(**const** int *v*, **const** int *q*) **const**
Check if variable v is includes qubit q in its chain.

void **set_chain**(**const** int *u*, **const** vector<int> &*incoming*)
Assign a chain for variable u.

void **fix_chain**(**const** int *u*, **const** vector<int> &*incoming*)
Permanently assign a chain for variable u.

NOTE: This must be done before any chain is assigned to u.

bool **operator==**(**const** embedding &*other*) **const**
check if `this` and `other` have the same chains (up to qubit containment per chain; linking and parent information is not checked)

void **construct_chain**(**const** int *u*, **const** int *q*, **const** vector<vector<int>> &*parents*)
construct the chain for `u`, rooted at `q`, with a vector of parent info, where for each neibor `v` of `u`, following `q` -> `parents[v][q]` -> `parents[v][parents[v][q]]` …

terminates in the chain for `v`

void **construct_chain_steiner**(**const** int *u*, **const** int *q*, **const** vector<vector<int>> &*parents*, **const** vector<vector<*distance_t*>> &*distances*, vector<vector<int>> &*visited_list*)
construct the chain for `u`, rooted at `q`.

for the first neighbor `v` of `u`, we follow the parents until we terminate in the chain for `v` `q` -> `parents[v][q]` -> …. adding all but the last node to the chain of `u`. for each subsequent neighbor `w`, we pick a nearest Steiner node, `qw`, from the current chain of `u`, and add the path starting at `qw`, similar to the above… `qw` -> `parents[w][qw]` -> … this has an opportunity to make shorter chains than `construct_chain`

void **flip_back**(int *u*, **const** int *target_chainsize*)
distribute path segments to the neighboring chains path segments are the qubits that are ONLY used to join link_qubit[u][v] to link_qubit[u][u] and aren't used for any other variable

- if the target chainsize is zero, dump the entire segment into the neighbor
- if the target chainsize is k, stop when the neighbor's size reaches k

void **tear_out**(int *u*)
short tearout procedure blank out the chain, its linking qubits, and account for the qubits being freed

int **freeze_out** (int *u*)
undo-able tearout procedure.

similar to `tear_out(u)`, but can be undone with `thaw_back(u)`. note that this embedding type has a space for a single frozen chain, and `freeze_out(u)` overwrites the previously-frozen chain consequently, `freeze_out(u)` can be called an arbitrary (nonzero) number of times before `thaw_back(u)`, but `thaw_back(u)` MUST be preceeded by at least one `freeze_out(u)`. returns the size of the chain being frozen

void **thaw_back** (int *u*)
undo for the freeze_out procedure: replaces the chain previously frozen, and destroys the data in the frozen chain `thaw_back(u)` must be preceeded by at least one `freeze_out(u)` and the chain for `u` must currently be empty (accomplished either by `tear_out(u)` or `freeze_out(u)`)

void **steal_all** (int *u*)
grow the chain for `u`, stealing all available qubits from neighboring variables

int **statistics** (vector<int> &*stats*) **const**
compute statistics for this embedding and return `1` if no chains are overlapping when no chains are overlapping, populate `stats` with a chainlength histogram chains do overlap, populate `stats` with a qubit overfill histogram a histogram, in this case, is a vector of size (maximum attained value+1) where `stats[i]` is either the number of qubits contained in `i+2` chains or the number of chains with size `i`

bool **linked** () **const**
check if the embedding is fully linked that is, if each pair of adjacent variables is known to correspond to a pair of adjacent qubits

bool **linked** (int *u*) **const**
check if a single variable is linked with all adjacent variables.

void **print** () **const**
print out this embedding to a level of detail that is useful for debugging purposes TODO describe the output format.

void **long_diagnostic** (char **current_state*)
run a long diagnostic, and if debugging is enabled, record `current_state` so that the error message has a little more context.

if an error is found, throw a *CorruptEmbeddingException*

void **run_long_diagnostic** (char **current_state*) **const**
run a long diagnostic to verify the integrity of this datastructure.

the guts of this function are its documentation, because this function only exists for debugging purposes

Class find_embedding::embedding_problem

template<class **fixed_handler**, class **domain_handler**, class **output_handler**>
class embedding_problem : **public** *find_embedding::embedding_problem_base*, **public** *fixed_handler*, **public** *domain_h*
A template to construct a complete embedding problem by combining *embedding_problem_base* with fixed/domain handlers.

Class find_embedding::embedding_problem_base

class embedding_problem_base
Common form for all embedding problems.

Needs to be extended with a fixed handler and domain handler to be complete.

Subclassed by *find_embedding::embedding_problem< fixed_handler, domain_handler, output_handler >*

Public Functions

void **reset_mood**()
: resets some internal, ephemeral, variables to a default state

void **populate_weight_table**(int *max_weight*)
: precomputes a table of weights corresponding to various overlap values `c`, for `c` from 0 to `max_weight`, inclusive.

distance_t **weight**(unsigned int *c*) **const**
: returns the precomputed weight associated with an overlap value of `c`

const vector<int> &**var_neighbors**(int *u*) **const**
: a vector of neighbors for the variable `u`

const vector<int> &**var_neighbors**(int *u*, *shuffle_first*)
: a vector of neighbors for the variable `u`, pre-shuffling them

const vector<int> &**var_neighbors**(int *u*, *rndswap_first*)
: a vector of neighbors for the variable `u`, applying a random transposition before returning the reference

const vector<int> &**qubit_neighbors**(int *q*) **const**
: a vector of neighbors for the qubit `q`

int **num_vars**() **const**
: number of variables which are not fixed

int **num_qubits**() **const**
: number of qubits which are not reserved

int **num_fixed**() **const**
: number of fixed variables

int **num_reserved**() **const**
: number of reserved qubits

int **randint**(int *a*, int *b*)
: make a random integer between 0 and `m-1`

template<typename **A**, typename **B**>
void **shuffle**(*A a*, *B b*)
: shuffle the data bracketed by iterators `a` and `b`

void **qubit_component**(int *q0*, vector<int> &*component*, vector<int> &*visited*)
: compute the connected component of the subset `component` of qubits, containing `q0`, and usingvisited as an indicator for which qubits have been explored

const vector<int> &**var_order**(*VARORDER order* = *VARORDER_SHUFFLE*)
: compute a variable ordering according to the `order` strategy

void **dfs_component**(int *x*, **const** vector<vector<int>> &*neighbors*, vector<int> &*component*, vector<int> &*visited*)
: Perform a depth first search.

Public Members

optional_parameters &**params**

A mutable reference to the user specified parameters.

Class find_embedding::fixed_handler_hival

class fixed_handler_hival

This fixed handler is used when the fixed variables are processed before instantiation and relabeled such that variables v >= num_v are fixed and qubits q >= num_q are reserved.

Class find_embedding::fixed_handler_none

class fixed_handler_none

This fixed handler is used when there are no fixed variables.

Class find_embedding::max_heap_tag

class max_heap_tag

Class find_embedding::min_heap_tag

class min_heap_tag

Class find_embedding::optional_parameters

class optional_parameters

Set of parameters used to control the embedding process.

Public Functions

optional_parameters(*optional_parameters* &*p*, map<int, vector<int>> *fixed_chains*, map<int, vector<int>> *initial_chains*, map<int, vector<int>> *restrict_chains*)

duplicate all parameters but chain hints, and seed a new rng.

this vaguely peculiar behavior is utilized to spawn parameters for component subproblems

Public Members

LocalInteractionPtr **localInteractionPtr**

actually not controlled by user, not initialized here, but initialized in Python, MATLAB, C wrappers level

double **timeout** = 1000

Number of seconds before the process unconditionally stops.

Class find_embedding::output_handler

template<bool **verbose**>
class output_handler

Output handlers are used to control output.

We provide two handlers one which only reports all errors (and optimizes away all other output) and another which provides full output. When verbose is zero, we recommend the errors-only handler and otherwise, the full handler Here's the full output handler

Subclassed by *find_embedding::embedding_problem< fixed_handler, domain_handler, output_handler >*

Public Functions

template<typename ...**Args**>
void **error**(**const** char **format*, *Args*... *args*) **const**

printf regardless of the verbosity level

template<typename ...**Args**>
void **major_info**(**const** char **format*, *Args*... *args*) **const**

printf at the major_info verbosity level

template<typename ...**Args**>
void **minor_info**(**const** char **format*, *Args*... *args*) **const**

print at the minor_info verbosity level

template<typename ...**Args**>
void **extra_info**(**const** char **format*, *Args*... *args*) **const**

print at the extra_info verbosity level

template<typename ...**Args**>
void **debug**(**const** char *, *Args*...) **const**

print at the debug verbosity level (only works when `CPPDEBUG` is set)

Class find_embedding::pairing_node

template<typename **N**>
class pairing_node : **public** *N*

Public Functions

pairing_node<N> ***merge_roots**(pairing_node<N> **other*)

the basic operation of the pairing queue put `this` and `other` into heap-order

Class find_embedding::pairing_queue

template<typename **N**>
class pairing_queue

Class find_embedding::parameter_processor

class parameter_processor

Class find_embedding::pathfinder_base

template<typename **embedding_problem_t**>
class pathfinder_base : **public** *find_embedding*::*pathfinder_public_interface*
Subclassed by *find_embedding::pathfinder_parallel< embedding_problem_t >*, *find_embedding::pathfinder_serial< embedding_problem_t >*

Public Functions

virtual void **set_initial_chains** (map<int, vector<int>> *chains*)
setter for the initial_chains parameter

bool **check_improvement** (**const** embedding_t &*emb*)
nonzero return if this is an improvement on our previous best embedding

virtual const *chain* &**get_chain** (int *u*) **const**
chain accessor

virtual int **heuristicEmbedding** ()
perform the heuristic embedding, returning 1 if an embedding was found and 0 otherwise

Class find_embedding::pathfinder_parallel

template<typename **embedding_problem_t**>
class pathfinder_parallel : **public** *find_embedding*::pathfinder_base<*embedding_problem_t*>
A pathfinder where the Dijkstra-from-neighboring-chain passes are done serially.

Public Functions

virtual void **prepare_root_distances** (**const** embedding_t &*emb*, **const** int *u*)
compute the distances from all neighbors of `u` to all qubits

Class find_embedding::pathfinder_public_interface

class pathfinder_public_interface
Subclassed by *find_embedding::pathfinder_base< embedding_problem_t >*

Class find_embedding::pathfinder_serial

template<typename **embedding_problem_t**>
class pathfinder_serial : **public** *find_embedding*::pathfinder_base<*embedding_problem_t*>
A pathfinder where the Dijkstra-from-neighboring-chain passes are done serially.

Public Functions

virtual void **prepare_root_distances**(**const** embedding_t &*emb*, **const** int *u*)
compute the distances from all neighbors of `u` to all qubits

Class find_embedding::pathfinder_type

template<bool **parallel**, bool **fixed**, bool **restricted**, bool **verbose**>
class pathfinder_type

Class find_embedding::pathfinder_wrapper

class pathfinder_wrapper

Class find_embedding::priority_node

template<typename **P**, typename **heap_tag** = *min_heap_tag*>
class priority_node

Class graph::components

class components
Represents a graph as a series of connected components.

The input graph may consist of many components, they will be separated in the construction.

Public Functions

const std::vector<int> &**nodes**(int *c*) **const**
Get the set of nodes in a component.

size_t **size**() **const**
Get the number of connected components in the graph.

size_t **num_reserved**(int *c*) **const**
returns the number of reserved nodes in a component

size_t **size**(int *c*) **const**
Get the size (in nodes) of a component.

const *input_graph* &**component_graph**(int *c*) **const**
Get a const reference to the graph object of a component.

std::vector<std::vector<int>> **component_neighbors**(int *c*) **const**
Construct a neighborhood list for component c, with reserved nodes as sources.

template<typename **T**>
bool **into_component**(**const** int *c*, *T* &*nodes_in*, std::vector<int> &*nodes_out*) **const**
translate nodes from the input graph, to their labels in component c

template<typename **T**>

void **from_component** (**const** int *c*, *T* &*nodes_in*, std::vector<int> &*nodes_out*) **const**
translate nodes from labels in component c, back to their original input labels

Class graph::input_graph

class input_graph
Represents an undirected graph as a list of edges.

Provides methods to extract those edges into neighbor lists (with options to relabel and produce directed graphs).

As an input to the library this may be a disconnected graph, but when returned from components it is a connected sub graph.

Public Functions

input_graph ()
Constructs an empty graph.

input_graph (int *n_v*, **const** std::vector<int> &*aside*, **const** std::vector<int> &*bside*)
Constructs a graph from the provided edges.

The ends of edge ii are aside[ii] and bside[ii].

Parameters

- `n_v`: Number of nodes in the graph.
- `aside`: List of nodes describing edges.
- `bside`: List of nodes describing edges.

void **clear** ()
Remove all edges and nodes from a graph.

int **a** (**const** int *i*) **const**
Return the nodes on either end of edge `i`

int **b** (**const** int *i*) **const**
Return the nodes on either end of edge `i`

size_t **num_nodes** () **const**
Return the size of the graph in nodes.

size_t **num_edges** () **const**
Return the size of the graph in edges.

void **push_back** (int *ai*, int *bi*)
Add an edge to the graph.

template<typename **T1**, typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors_sources** (**const** *T1* &*sources*, *Args*... *args*) **const**
produce a std::vector<std::vector<int>> of neigborhoods, with certain nodes marked as sources (inbound edges are omitted) sources is either a std::vector<int> (where non-sources x have sources[x] = 0), or another type for which we have a unaryint specialization optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking sources / mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

template<typename **T2**, typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors_sinks** (**const** *T2* &*sinks*, *Args*... *args*) **const**

produce a std::vector<std::vector<int>> of neigborhoods, with certain nodes marked as sinks (outbound edges are omitted) sinks is either a std::vector<int> (where non-sinks x have sinks[x] = 0), or another type for which we have a unaryint specialization optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking sinks / mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

template<typename ...**Args**>
std::vector<std::vector<int>> **get_neighbors** (*Args*... *args*) **const**

produce a std::vector<std::vector<int>> of neigborhoods optional arguments: relabel, mask (any type with a unaryint specialization) relabel is applied to the nodes as they are placed into the neighborhood list (and not used for checking mask) mask is used to filter down to the induced graph on nodes x with mask[x] = 1

Class graph::unaryint

template<typename **T**>
class unaryint

Class graph::unaryint< bool >

template<>
class unaryint<bool>

Class graph::unaryint< int >

template<>
class unaryint<int>

Class graph::unaryint< std::vector< int > >

template<>
class unaryint<std::vector<int>>

Class graph::unaryint< void * >

template<>
class unaryint<void *>

this one is a little weird construct a unaryint(nullptr) and get back the identity function f(x) -> x

Struct list

Struct find_embedding::frozen_chain

struct frozen_chain

This class stores chains for embeddings, and performs qubit-use accounting.

The `label` is the index number for the variable represented by this chain. The `links` member of a chain is an unordered map storing the linking information for this chain. The `data` member of a chain stores the connectivity information for the chain.

Links: If `u` and `v` are variables which are connected by an edge, the following must be true: either chain_u or chain_v is empty,

or

chain_u.links[v] is a key in chain_u.data, chain_v.links[u] is a key in chain_v.data, and (chain_u.links[v], chain_v.links[u]) are adjacent in the qubit graph

Moreover, (chain_u.links[u]) must exist if chain_u is not empty, and this is considered the root of the chain.

Data: The `data` member stores the connectivity information. More precisely, `data` is a mapping `qubit->(parent, refs)` where: `parent` is also contained in the chain `refs` is the total number of references to `qubit`, counting both parents and links the chain root is its own parent.

Struct find_embedding::pathfinder_base::default_tag

struct default_tag

Struct find_embedding::pathfinder_base::embedded_tag

struct embedded_tag

Struct find_embedding::rndswap_first

struct rndswap_first

Struct find_embedding::shuffle_first

struct shuffle_first

1.3 Installation

1.3.1 Python

pip installation is recommended for platforms with precompiled wheels posted to pypi. Source distributions are provided as well.

```
pip install minorminer
```

To install from this repository, run the *setuptools* script.

```
pip install cython==0.27
python setup.py install
# optionally, run the tests to check your build
pip install -r tests/requirements.txt
python -m nose . --exe
```

1.3.2 C++

The *CMakeLists.txt* in the root of this repo will build the library and optionally run a series of tests. On linux the commands would be something like this:

```
mkdir build; cd build
cmake ..
make
```

To build the tests turn the cmake option *MINORMINER_BUILD_TESTS* on. The command line option for cmake to do this would be *-DMINORMINER_BUILD_TESTS=ON*.

1.3.3 Library Usage

C++11 programs should be able to use this as a header-only library. If your project is using CMake this library can be used fairly simply; if you have checked out this repo as *externals/minorminer* in your project you would need to add the following lines to your *CMakeLists.txt*

```
add_subdirectory(externals/minorminer)

# After your target is defined
target_link_libraries(your_target minorminer pthread)
```

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