

Random Graph Coloring Evaluation

Entwurfsdokument

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1 Anmerkungen zum Pflichtenheft

1.1 Klarstellungen

1.2 Änderungen

2 Übersicht

3 Model

Package graph

This package contains the interfaces for the interaction with graphs. In the subpackages concrete graph-types are implemented.

TODO graph.png UML einfügen

Class Graph

Description

This class describes the abstract structure of a graph. Each graph has (independent of its concrete type) a finite amount of vertices and edges, which define a relation of vertices. The type **E** of this edges defines the concrete graph type. The class has methods for retrieving the relations given by the edges. Vertices are identified with their unique index and thus are not saved explicitly.

Documentation

- + **Graph(edges: List<E>, numVertices: int)**
the constructor of this class
@param edges the edges belonging to this graph **@numVertices** the number of vertices this graph has
- + **getNumVertices(): int**
@return returns the number of vertices which the graph contains
- + **getVertices(): int**
convenience method for retrieving the list of vertex indices
@return returns the list [0 ... numVertices-1]
- + **getEdges(): List<E>**
@return returns the edges giving the graph its structure
- + **areIncident(vertex: int, edge: E): bool**
@param vertex the index of a vertex of the graph ie. in [0 ... numVertices-1]
@param edge an edge of the graph
@return returns **true** iff the vertex is incident to the given edge
@throws **GraphInconsistencyException** if **vertex** is an invalid vertex index or **edge** is not an edge of the graph
- + **areAdjacent(vertex1: int, vertex2: int): bool**
@param vertex1 the index of a vertex of the graph ie. in [0 ... numVertices-1]
@param vertex2 see **vertex1**
@return returns **true** iff there is an edge which is incident to both vertices
@throws **GraphInconsistencyException** if **vertex1** or **vertex2** is not a valid vertex index
- + **areAdjacent(edge1: E, edge2: E): bool**
@param edge1 an edge of the graph
@param edge2 another edge of the graph
@return returns **true** iff there is a vertex which is incident to both edges
@throws **GraphInconsistencyException** if **edge1** or **edge2** is not an edge of the graph
- + **getAdjacentVertices(vertex: int): List<int>**
@param vertex the index of a vertex of the graph ie. in [0 ... numVertices-1]
@return returns the list of all vertices which are adjacent to **vertex**
@throws **GraphInconsistencyException** if **vertex** is not a valid vertex index

- + **getAdjacentEdges(edge: E): bool**
 @param **edge** an edge of the graph
 @return returns the list of all edges which are adjacent to **edge**
 @throws **GraphInconsistencyException** if **edge** is not an edge of the graph
- + **getIncidentEdges(vertex: int): List<E>**
 @param **vertex** the index of a vertex of the graph ie. in [0 ... numVertices-1]
 @return returns the list of all edges incident to **vertex**
 @throws **GraphInconsistencyException** if **vertex** is an invalid vertex index
- + **getIncidentVertices(edges: List<E>): List<int>**
 @param **edges** a list of edges of the graph
 @return returns the list of all vertices which are incident to any of the edges in the list
 @throws **GraphInconsistencyException** if there is an edge in **edges**, which is not an edge of the graph
- + **toRAGE(): List<String>**
 @return returns the line-by-line representation of the graph as specified in the RAGE-data format

Class Edge

Description

An edge always defines an adjacency-relation of the vertices incident to it. Moreover this class provides methods to compare edges.

Documentation

- + **getVertices(): List<int>**
 @return returns the list of all indices of vertices incident to this edge
- + **equals(edge: E): bool**
 @return returns **true** iff **edge** equals the edge this method is invoked upon. Note that the notion of equality depends on the concrete implementation.
- + **compareTo(edge: E): int**
 @return returns **-1/0/1** if **edge** is greater/equal/smaller than the edge this method is invoked upon. Note that the notions of order and equality depend on the concrete implementation.

Class GraphProperties

Description

This class is required for exchanging data between controller and model, especially to signal the settings required to generate graphs. It assures that the following graph-properties can be retrieved and set at all times:

- "graphTypes" – a const list of strings, initialised with ["simpleUndirectedGraph", "simpleHyperGraph"]
- "type" – a string
- "numVertices" – a nonnegative integer

Class GraphBuilder

Description This class is a factory class to generate graphs of type **G** by given GraphProperties **G** as well as to modify graphs of this type.

Documentation

- + *generateGraph(properties: P): G*
@param **properties** the properties which the generated graphs will have
@return returns a randomly generated graph satisfying the specified **properties**
- + *deleteVertex(graph: G, vertex: int): G*
@param **graph** the graph which is going to be modified
@param **vertex** the index of a vertex of **graph**, which will be deleted
@return returns a modified copy of **graph** in which the vertex with index **vertex** and all edges incident to it are deleted
@throws **GraphInconsistencyException** if **graph** has no vertex with index **vertex**
- + *addVertex(graph: G): G*
@param **graph** the graph which is going to be modified
@return returns a modified copy of **graph** which has precisely one isolated vertex more
- + *swapVertices(graph: G, vertex1: int, vertex2: int): G*
@param **graph** the graph which is going to be modified
@param **vertex1** the index of a vertex of **graph**
@param **vertex2** the index of another vertex of **graph**
@return returns a modified copy of **graph** in which the vertices having index **vertex1** and **vertex2** swap indices. Note this results in a different but isomorphic graph to **graph**
@throws **GraphInconsistencyException** if **graph** has no vertex with index **vertex1** or **vertex2**
- + *deleteEdge(graph: G, edge: E): G*
@param **graph** the graph which is going to be modified
@param **edge** the edge which is going to be deleted
@return returns a modified copy of **graph** in which **edge** is deleted, if it was an edge in **graph**. Otherwise it just returns **graph**

- + ***addEdge(graph: G, edge: E): G***
 - @param graph** the graph which is going to be modified
 - @param edge** the edge which is going to be inserted
 - @return** returns a modified copy of **graph** in which **edge** is inserted if it wasn't already an edge in **graph** otherwise it returns just **graph**. Note that the edge may contain vertices which are not in **graph**, since missing vertices will automatically be added
- + ***deleteIsolatedVertices(graph: G): G***
 - @param graph** the graph which is going to be modified
 - @return** returns a modified copy of **graph** in which all isolated vertices are deleted

Class GraphInconsistencyException

Description

This class extends the usual Java Exception to an exception specifically thrown when graphs are treated wrong.

Package graph.simpleUndirectedGraph

In this package **simple undirected graphs** (ie. graphs where edges always connect two distinct vertices x and y , where there is no distinction between edges xy and yx and where there is at most one edge xy) are implemented. It offers methods to generate, modify and distinct them by some (for simple undirected graphs well defined) criterions.

Class SimpleUndirectedGraph

Description

This class concretizes the abstract Graph class in the sense of simple undirected graphs. As mentioned such a graph does not contain any loops or multiedges. Besides incidence relations, this class offers methods to identify properties of simple undirected graphs.

Documentation

- + **SimpleUndirectedGraph(edges: List<SimpleUndirectedEdge>, numVertices: int)**
a constructor for this class
@param edges the edges contained in this graph
@param numVertices the amount of vertices this graph being strictly greater than zero
@throws **GraphInconsistencyException** if numVertices ≤ 0 or if there is an edge with a vertex \geq numVertices or of there exists an edge more than once
- + **SimpleUndirectedGraph(rageFormat: List<String>)**
another constructor for this class
@param rageFormat the lines of the line by line representation as specified in the RAGE data-format.
@throws **GraphInconsistencyException** if rageFormat is not a valid representation of SimpleUndirectedGraph
- + **getVerticesBFS(): List<int>**
@return returns the list of vertices of the graph in the order of a breadth first search
- + **areIncident(vertex: int, edge: SimpleUndirectedEdge): bool**
@param vertex the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@param edge an edge of the graph
@return returns **true** iff the vertex is incident to the given edge
@throws **GraphInconsistencyException** if vertex is an invalid vertex index or edge is not an edge of the graph
- + **areAdjacent(vertex1: int, vertex2: int): bool**
@param vertex1 the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@param vertex2 see vertex1
@return returns **true** iff there is an edge which is incident to both vertices
@throws **GraphInconsistencyException** if vertex1 or vertex2 is not a valid vertex index
- + **areAdjacent(edge1: SimpleUndirectedEdge, edge2: SimpleUndirectedEdge): bool**
@param edge1 an edge of the graph
@param edge2 another edge of the graph
@return returns **true** iff there is a vertex which is incident to both edges
@throws **GraphInconsistencyException** if edge1 or edge2 is not an edge of the graph
- + **getAdjacentVertices(vertex: int): List<int>**
@param vertex the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@return returns the list of all vertices which are adjacent to vertex
@throws **GraphInconsistencyException** if vertex is not a valid vertex index

- + **getAdjacentEdges(edge: SimpleUndirectedEdge): bool**
@param **edge** an edge of the graph
@return returns the list of all edges which are adjacent to **edge**
@throws **GraphInconsistencyException** if **edge** is not an edge of the graph
- + **getIncidentEdges(vertex: int): List<SimpleUndirectedEdge>**
@param **vertex** the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@return returns the list of all edges incident to **vertex**
@throws **GraphInconsistencyException** if **vertex** is an invalid vertex index
- + **getIncidentVertices(edges: List<SimpleUndirectedEdge>): List<int>**
@param **edges** a list of edges of the graph
@return returns the list of all vertices which are incident to any of the edges in the list
@throws **GraphInconsistencyException** if there is an edge in **edges**, which is not an edge of the graph
- + **isConnected(): bool**
@return returns **true** iff the graph is connected ie. iff for any two vertices there is a sequence of edges where any two consecutive edges are adjacent
- + **isForest(): bool**
@return returns **true** iff the graph is a forest ie. acyclic
- + **isBipartite(): bool**
@return returns **true** iff the vertex set can be partitioned into two parts such that no two vertices from the same partition are adjacent
- + **isPlanar(): bool**
@return returns **true** iff the graph has an embedding into the plane such that no two edges intersect
- + **toRage(): List<String>**
@return returns the line-by-line representation of the graph as specified in the RAGE-data format

Class SimpleUndirectedEdge

Description

This class concretizes the class Edge in the sense of a simple undirected edge. It always relates two distinct vertices.

Documentation

- + **SimpleUndirectedEdge(vertex1: int, vertex2: int)**
a constructor for this class
@param **vertex1** the index of the index of the first vertex this edge is incident to
@param **vertex2** the index of the index of the second this edge is incident to
@throws **GraphInconsistencyException** if **vertex1** equals **vertex2**
- + **getVertices(): List<int>**
@return returns the list of all indices of vertices incident to this edge
- + **equals(edge: E): bool**
@return returns **true** iff both edges are adjacent to the same two vertices

- + **compareTo(edge: E): int**
 The notion of order between edges (x, y) and (u, v) with $x \leq y$ and $u \leq v$ is defined by $(x, y) < (u, v)$ iff $x < u$ or $(x = u \text{ and } y < v)$
@return returns **-1/0/1** if **edge** is greater/equal/smaller than the edge this method is invoked upon

Class SimpleUndirectedGraphProperties

Description

This class is an extension of the GraphProperties class and serves as collection of data for exchange between controller and model, especially to signal the settings required for generating simple undirected graphs. It assures that the following properties can be retrieved and set at all times:

- "minDegree" – a nonnegative integer
- "maxDegree" – a nonnegative integer
- "connected" – a boolean
- "forest" – a boolean
- "bipartite" – a boolean
- "planar" – a boolean

Class SimpleUndirectedGraphBuilder

Description

This class concretizes the GraphBuilder class by offering methods for randomly generating simple undirected graphs after given SimpleUndirectedGraphProperties as well as modifying them.

Documentation

- + **generate(properties: SimpleUndirectedGraphProperties): SimpleUndirectedGraph**
@param properties the properties which the generated graphs will have
@return returns a randomly generated graph satisfying the specified **properties**
- + **deleteVertex(graph: SimpleUndirectedGraph, vertex: int): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@param vertex the index of a vertex of **graph**, which will be deleted
@return returns a modified copy of **graph** in which the vertex with index **vertex** and all edges incident to it are deleted
@throws GraphInconsistencyException if **graph** has no vertex with index **vertex**
- + **addVertex(graph: SimpleUndirectedGraph): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@return returns a modified copy of **graph** which has precisely one isolated vertex more

- + **copyVertex(graph: SimpleUndirectedGraph, vertex: int): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@param vertex the index of a vertex of **graph**, which will be copied
@return returns a modified copy of **graph** in which the vertex with index **vertex** is duplicated i.e. there is a new vertex which has precisely the same neighborhood
@throws GraphInconsistencyException if **graph** has no vertex with index **vertex**
- + **swapVertices(graph: SimpleUndirectedGraph, vertex1: int, vertex2: int): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@param vertex1 the index of a vertex of **graph**
@param vertex2 the index of another vertex of **graph**
@return returns a modified copy of **graph** in which the vertices having index **vertex1** and **vertex2** swap indices. Note this results in a different but isomorphic graph to **graph**
@throws GraphInconsistencyException if **graph** has no vertex with index **vertex1** or **vertex2**
- + **contractVertices(graph: SimpleUndirectedGraph, vertex1: int, vertex2: int): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@param vertex1 the index of a vertex of **graph**
@param vertex2 the index of another vertex of **graph**
@return returns a modified copy of **graph** in which the vertices having index **vertex1** and **vertex2** are contracted to a single vertex. Resulting loops will be deleted and multiedges will be reduced to one edge
@throws GraphInconsistencyException if **graph** has no vertex with index **vertex1** or **vertex2**
- + **deleteEdge(graph: SimpleUndirectedGraph, edge: SimpleUndirectedEdge): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@param edge the edge which is going to be deleted
@return returns a modified copy of **graph** in which **edge** is deleted, if it was an edge in **graph**. Otherwise it just returns **graph**
- + **addEdge(graph: SimpleUndirectedGraph, edge: SimpleUndirectedEdge): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@param edge the edge which is going to be inserted
@return returns a modified copy of **graph** in which **edge** is inserted if it wasn't already an edge in **graph** otherwise it returns just **graph**. Note that the edge being added may contain vertices which are not in **graph**, since missing vertices will automatically be added
- + **deleteIsolatedVertices(graph: SimpleUndirectedGraph): SimpleUndirectedGraph**
@param graph the graph which is going to be modified
@return returns a modified copy of **graph** in which all isolated vertices are deleted

Package graph.simpleHyperGraph

In this package simple hypergraphs (i.e. graphs whose edges are sets of at least two distinct vertices and whose edges don't overlap in more than one vertex) are implemented. It offers the functionality to generate, modify and distinct them by some for simple hypergraph welldefined criterions.

Class SimpleHyperGraph

Description

This class concretizes the graph class in the sense of a simple hypergraphs. Besides incidence relations this class offers methods to identify some of their properties.

Documentation

- + **SimpleHyperGraph(edges: List<SimpleHyperEdge>, numVertices: int)**
A constructor for this class
@param edges the edges this graph contains
@param numVertices the amount of vertices this graph has
@throws GraphInconsistencyException if **numVertices** ≤ 0 , if there is a hyperedge with a vertex \geq **numVertices** or if the resulting hypergraph is not simple
- + **SimpleHyperGraph(rageFormat: List<String>)**
A constructor of this class, assuring that this graph type can be loaded from harddrive
@param rageFormat the line by line representation of the graph as specified in the RAGE data format
- + **getVerticesBFS(): List<int>**
@return returns the list of vertices of the graph in the order of a breadth first search
- + **areIncident(vertex: int, edge: SimpleHyperEdge): bool**
@param vertex the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@param edge an edge of the graph
@return returns **true** iff the vertex is incident to the given edge
@throws GraphInconstistencyException if **vertex** is an invalid vertex index or **edge** is not an edge of the graph
- + **areAdjacent(vertex1: int, vertex2: int): bool**
@param vertex1 the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@param vertex2 see **vertex1**
@return returns **true** iff there is an edge which is incident to both vertices
@throws GraphInconsistencyException if **vertex1** or **vertex2** is not a valid vertex index
- + **areAdjacent(edge1: SimpleHyperEdge, edge2: SimpleHyperEdge): bool**
@param edge1 an edge of the graph
@param edge2 another edge of the graph
@return returns **true** iff there is a vertex which is incident to both edges
@throws GraphInconsistencyException if **edge1** or **edge2** is not an edge of the graph
- + **getAdjacentVertices(vertex: int): List<int>**
@param vertex the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@return returns the list of all vertices which are adjacent to **vertex**
@throws GraphInconsistencyException if **vertex** is not a valid vertex index
- + **getAdjacentEdges(edge: SimpleHyperEdge): List<SimpleHyperEdge>**
@param edge an edge of the graph
@return returns the list of all edges which are adjacent to **edge**
@throws GraphInconsistencyException if **edge** is not an edge of the graph

- + **getIncidentEdges(vertex: int): List<SimpleHyperEdge>**
@param vertex the index of a vertex of the graph ie. in $[0 \dots \text{numVertices}-1]$
@return returns the list of all edges incident to **vertex**
@throws GraphInconsistencyException if **vertex** is an invalid vertex index
- + **getIncidentVertices(edges: List<SimpleHyperEdge>): List<int>**
@param edges a list of edges of the graph
@return returns the list of all vertices which are incident to any of the edges in the list
@throws GraphInconsistencyException if there is an edge in **edges**, which is not an edge of the graph
- + **isConnected(): bool**
@return returns **true** iff the graph is connected ie. iff for any two vertices there is a sequence of edges where any two consecutive edges are adjacent
- + **toRage(): List<String>**
@return returns the line-by-line representation of the graph as specified in the RAGE-data format

Class SimpleHyperEdge

Description

This class concretizes the class edge in the sense of a hyperedge. It always relates at least two distinct vertices.

Documentation

- + **SimpleHyperEdge(vertices: List<int>)**
A constructor for this class
@param vertices the vertices this edge sets in relation
@throws GraphInconsistencyException if the list is empty, contains just one vertex or any vertex twice
- + **getVertices(): List<int>**
@return returns the list of all indices of vertices incident to this edge
- + **equals(edge: E): bool**
@return returns **true** both edges are adjacent to the same vertices
- + **compareTo(edge: E): int**
The notion of order between edges (x_1, \dots, x_n) and (y_1, \dots, y_m) with $x_1 < \dots < x_n$, $y_1 < \dots < y_m$ and $n \leq m$ is defined by $(x_1, \dots, x_n) < (y_1, \dots, y_m)$ iff $x_1 < y_1$ or $(x_1 = y_1 \text{ and } x_2 < y_2)$ or ... or $(x_1 = y_1 \text{ and } \dots \text{ and } x_n = y_n \text{ and } n < m)$
@return returns **-1/0/1** if **edge** is greater/equal/smaller than the edge this method is invoked upon

Class SimpleHyperGraphProperties

Description

This class is an extension of the GraphProperties class and is likely meant for the exchange of data between controller and model, especially for transferring the settings required for generating simple hyper graphs. It assures that the following graph properties can be retrieved and set at all times:

- "uniform" – a nonnegative integer
- "minDegree" – a nonnegative integer
- "maxDegree" – a nonnegative integer
- "connected" – a boolean

Class SimpleHyperGraphBuilder

Description

This class concretizes the GraphBuilder class by offering methods for randomly generating simple hypergraphs after given SimpleHyperGraphProperties as well as modifying them.

Documentation

- + **generate(properties: SimpleHyperGraphProperties): SimpleHyperGraph**
@param **properties** the properties which the generated graphs will have
@return returns a randomly generated graph satisfying the specified **properties**
- + **deleteVertex(graph: SimpleHyperGraph, vertex: int): SimpleHyperGraph**
@param **graph** the graph which is going to be modified
@param **vertex** the index of a vertex of **graph**, which will be deleted
@return returns a modified copy of **graph** in which the vertex with index **vertex** and all edges incident to it are deleted
@throws **GraphInconsistencyException** if **graph** has no vertex with index **vertex**
- + **addVertex(graph: SimpleHyperGraph): SimpleHyperGraph**
@param **graph** the graph which is going to be modified
@return returns a modified copy of **graph** which has precisely one isolated vertex more
- + **swapVertices(graph: SimpleHyperGraph, vertex1: int, vertex2: int): SimpleHyperGraph**
@param **graph** the graph which is going to be modified
@param **vertex1** the index of a vertex of **graph**
@param **vertex2** the index of another vertex of **graph**
@return returns a modified copy of **graph** in which the vertices having index **vertex1** and **vertex2** swap indices. Note this results in a different but isomorphic graph to **graph**
@throws **GraphInconsistencyException** if **graph** has no vertex with index **vertex1** or **vertex2**
- + **deleteEdge(graph: SimpleHyperGraph, edge: SimpleHyperEdge): SimpleHyperGraph**
@param **graph** the graph which is going to be modified
@param **edge** the edge which is going to be deleted
@return returns a modified copy of **graph** in which **edge** is deleted, if it was an edge in **graph**. Otherwise it just returns **graph**

- + **addEdge(graph: SimpleHyperGraph, edge: SimpleHyperEdge): SimpleHyperGraph**
 - @param graph** the graph which is going to be modified
 - @param edge** the edge which is going to be inserted
 - @return** returns a modified copy of **graph** in which **edge** is inserted if it wasn't already an edge in **graph** otherwise it returns just **graph**. Note that the edge being added may contain vertices which are not in **graph**, since missing vertices will automatically be added
- + **deleteIsolatedVertices(graph: SimpleHyperGraph): SimpleHyperGraph**
 - @param graph** the graph which is going to be modified
 - @return** returns a modified copy of **graph** in which all isolated vertices are deleted

Package heuristic

The package contains the interface for implementing heuristics. In the subpackages some heuristics for the total coloring conjecture as well as for the Erdős-Faber-Lovasz conjecture are implemented.

TODO heuristic.png UML

Class Heuristic

Description

The class is the abstract interface of a heuristic which is applied to a graph of type **G** which has a result of type **R**.

Documentation

- + **Heuristic(properties: HeuristicProperties)**
A constructor for this class
@param properties the properties defining this heuristic
- + **getProperties(): HeuristicProperties**
@return returns the properties of this heuristic
- + **applyTo(graph: G): R**
@param graph the graph of type **G** on which the heuristic will be applied
@return returns the result of the heuristic application

Class HeuristicResult

Description

This class is the abstract interface of the result of a specific calculation of an heuristic **H** on a specific graph of type **G**.

Documentation

- + **HeuristicResult(graph: G, heuristic: H)**
The constructor of this class
@param graph the graph this heuristic was calculated upon
@param heuristic the heuristic by which the result was calculated
- + **getGraph(): G**
@return returns the graph this result was calculated upon
- + **getHeuristic(): H**
@return returns the heuristic by which this result was calculated
- + **toRAGE(): List<String>**
@return returns the line-by-line representation of this heuristic result as specified in the RAGE data format

Class **HeuristicProperties**

Description

This class serves as collection of data for exchange between controller and model, especially to transfer properties of heuristics. It assures that the following properties may be retrieved and set at any time:

- "name" – ein String
- "valid" – ein Boolean

Class **DataPool**

Description

The class manages the application of heuristics of type **H** on graphs of type **G** which results have type **R**. It assures that every heuristic stored in the pool is applied to every graph stored in the pool. Moreover it gathers statistics over this applications.

Documentation

- + **DataPool(rageFormat: List<String>)**
A constructor for this class, assuring that the datapool can be loaded from harddrive
@param rageFormat the line by line representation of a datapool as specified in the RAGE data format.
- + **getHeuristics(): List<H>**
@return returns the list of heuristics currently in this data pool
- + **addHeuristic(heuristic: H)**
@param heuristic the heuristic to be added to data pool, which then will be applied to every graph in the data pool
@throws DataInconsistencyException if heuristic may not be applied on graphs of type **G** or does not has results of type **R**
- + **getGraphs(): List<G>**
@return returns the list of graphs currently in this data pool
- + **addGraph(graph: G)**
@param graph the graph to be added to the data pool, on which then all heuristics in the data pool will be applied
@throws DataInconsistencyException if heuristics of type **H** may not be applied on this graph
- + **getResults(): List<R>**
@return returns the list of all results calculated on graphs by heuristics in this data pool
- + **getResults(heuristic: H): List<R>**
@param heuristic the heuristic the results were calculated by
@return returns all results calculated by **heuristic** on graphs in this data pool
- + **getResults(graph: G)**
@param graph the graph the results were calculated upon
@return returns all results calculated on **graph** by heuristics in this data pool

- + **getStatistics(heuristic: H): HeuristicStatistic**
@param heuristic the heuristic whose statistics are requested
@return returns the statistic gathered for **heuristic**
@throws DataInconsistencyException if **heuristic** is not a heuristic of this data pool
- + **toRAGE(): List<String>**
@return returns the line by line representation of this data pool as specified in the RAGE data format

Class HeuristicStatistic

This class collects some statistics over the applications of a specific heuristic within a data pool. It assures that the following properties may be retrieved at any time:

- "minRuntime" – a floating point number
- "avgRuntime" – a floating point number
- maxRuntime- a floating point number
- numApplications- a nonnegative integer
- numSuccesses- a nonnegative integer

Class DataInconsistencyException

Description

This class extends the usual Java Exception to an exception specifically thrown when data pools are treated wrong.

Package heuristic.totalColoring

In this package and its subpackages some heuristics for the **total coloring conjecture** (ie. any simple undirected graph with maximal degree Δ has a total coloring with $\Delta + 2$ colors) are implemented.

TODO tc.png UML

Class TCHuristic

Description

This abstract class is the abstract interface for a total coloring heuristic. It assures that any total coloring heuristic is calculated on SimpleUndirectedGraphs and returns a TCResult as result. It provides some methods, which any total coloring heuristic needs, such as coloring vertices and edges.

Documentation

```
# colorVertex(vertex: int, color: int, data: TCData, result: TCResult)
  @param vertex the vertex to be colored
  @param color the color which will be assigned to the vertex
  @param data the data required for the calculation of a total coloring
  @param result the resulting total coloring

# colorEdge(edge: SimpleUndirectedEdge, color: int, data: TCData, result: TCResult)
  @param edge the edge to be colored
  @param color the color which will be assigned to the edge
  @param data the data required for the calculation of a total coloring
  @param result the resulting total coloring

+ equals(heuristic: TCHuristic): bool
  @param heuristic another TCHuristic this will be compared to
  @return returns true iff the other TCHuristic is of the same type and has exactly the same properties
```

Class TCResult

Description

This class represents a total coloring of a simple undirected graph ie. a coloring of vertices and edges, such that no two adjacent or incident objects share the same color. Colors are represented as integers.

Documentation

```
+ TCResult(graph: SimpleUndirectedGraph, heuristic: TCHuristic)
  A constructor for this class @param graph the graph this result was calculated upon
  @param heuristic the heuristic this result was calculated by

+ getVertexColor(vertex: int): int
  @param vertex the vertex whose color is requested
  @return returns the color of vertex
  @throws DataInconsistencyException if vertex has no color

+ setVertexColor(vertex: int, color: int)
  @param vertex the vertex to be colored
  @param color the color to color vertex with
```

- + **getEdgeColor(edge: SimpleUndirectedEdge): int**
 @param **edge** the edge whose color is requested
 @return returns the color of **edge**
 @throws **DataInconsistencyException** if edge has no color
- + **setEdgeColor(edge: SimpleUndirectedEdge, color: int)**
 @param **edge** the edge to be colored
 @param **color** the color to color **edge** with

Class TCDData

Description

This abstract class encapsulates the data required temporarily to calculate a total coloring, such as the lists of **free colors** of uncolored vertices and edges (ie. the colors which are not used by other objects adjacent / incident to them). Moreover it stores the weighted (vertex vs. edges) sum of how often colors are used.

Documentation

- # **TCDData(graph: SimpleUndirectedGraph)**
 A constructor of this class
 @param **graph** the graph the heuristic is running at
- # **init()**
 May be implemented to (re-)initialize the data at any time within the running heuristic
- # **justColoredVertex(vertex: int)**
 May be implemented to update data anytime when a vertex was colored
 @param **vertex** the vertex which was just colored
- # **justColoredEdge(edge: SimpleUndirectedEdge)**
 May be implemented to update data anytime when an edge was colored
 @param **edge** the edge which was just colored
- # **removeFreeColor(vertex: int, color: int)**
 @param **vertex** the vertex which will have one free color less
 @param **color** the color which **vertex** mustnt use
- # **removeFreeColor(edge: SimpleUndirectedEdge, color: int)**
 @param **edge** the edge which will have one free color less
 @param **color** the color which **edge** mustnt use
- # **getFlex(vertices: List<int>): int**
 @param **vertices** the set of vertices whose flexibility should be calculated
 @return returns the flexibility of these vertices ie. # of colors free for all vertices – # of **vertices**
- # **getFlex(edges: List<SimpleUndirectedEdge>): int**
 @param **vertices** the set of vertices whose flexibility should be calculated
 @return returns the flexibility of these vertices ie. # of colors which are free for all edges – # of **edges**
- # **getFlex(vertices: List<int>, edges: List<SimpleUndirectedEdge>): int**
 @param **vertices** a set of vertices
 @param **edges** a set of edges
 @return returns the flexibility of these objects ie. # of colors which are free for all objects – # of **objects**

```

# getColorWeight(color: int): int
  @param color the color whose weight is requested
  @return returns the weight of this color ie. how often it was used weighted differently by vertices and
  edges

# setColorWeight(color: int, weight: int)
  @param color the color whose weight will be updated
  @param weight the new weight of color

# getFreeVertexColors(vertex: int): List<int>
  @param vertex the vertex whose free colors are requested
  @return returns the list of free colors of vertex

# getFreeVertexColors(edge: SimpleUndirectedEdge): List<int>
  @param edge the edge whose free colors are requested
  @return returns the list of free colors of edge

```

Class TCFlexSet

Description

This class represents a subset of vertices and edges of a graph with a given **flexibility value** (ie. # colors free for all objects – # objects) used heavily in some TCHeuristics.

Documentation

```

# TCFlexSet(vertices: List<int>, value: int)
  A constructor of this class
  @param vertices some vertices
  @param value the flexibility value of vertices

# TCFlexSet(edges: List<SimpleUndirectedEdge>, value: int)
  A constructor of this class
  @param edges some edges
  @param value the flexibility value of edges

# TCFlexSet(vertices: List<int>, edges: List<SimpleUndirectedEdge>, value: int)
  A constructor of this class
  @param vertices some vertices
  @param edges some edges
  @param value the flexibility value of the set of objects in vertices and edges

# getVertices(): List<int>
  @return returns the vertices in this flex set

# getEdges(): List<SimpleUndirectedEdge>
  @return returns the edges in this flex set

# getValue(): int
  @return returns the flexibility value of this set of objects

```

Package heuristic.totalColoring.greedy

In this package there are some greedy heuristics for the total coloring conjecture implemented. They all have in common, that the vertices are colored first and the edges are colored afterwards. The heuristics differ in the way the edges are colored.

Class TCGreedyData

Description

Since TCDData is abstract this class is required such that the TCGreedy heuristic has its own data class, even if with respect to TCDData no additional attributes or methods are added.

Class TCGreedy

Description

This class implements the TCGreedy heuristic which tries to calculate a total coloring.

Documentation

```
+ applyTo(graph: SimpleUndirectedGraph): TCRresult
  implements the following heuristic

  for every vertex v in order of a breadth first search
    if v cannot be colored
      return incomplete coloring
    get minimally used free color c of v with respect to the color weights
    color v with color c

  for every vertex v in order of a breadth first search
    for every uncolored edge e incident to v in the order defined on edges
      if e cannot be colored
        return incomplete coloring
      get minimally used free color c of e with respect to the color weights
      color e with color c

  return complete coloring

@param graph the graph this heuristic will be applied on
@return returns the calculated coloring
```

Class TCGreedyOneData

Description

This class stores all uncolored edges with exactly one free color temporarily.

Documentation

```
# init()  
    initializes the list of all uncolored edges with exactly one free color  
  
# justColoredEdge(edge: SimpleUndirectedEdge)  
    updates the list of edges with exactly one free color  
    @param edge the edge which was just colored  
  
- calcSingularEdges()  
    updates the list of edges with exactly one free color  
  
# getMinimalSingularEdge(): SimpleUndirectedEdge  
    @return returns the minimal edge with exactly one free color with respect to the order defined on  
    edges
```

Class TCGreedyOne

Description

This class implements the TCGreedyOne heuristic which tries to calculate a total coloring.

Documentation

```
+ applyTo(graph: SimpleUndirectedGraph): TCResult  
    implements the following heuristic  
  
    for every vertex v in the order of a breadth first search  
        if v cannot be colored  
            return incomplete coloring  
        get minimally used free color c of v with respect to the color weights  
        color v with color c  
  
    for every vertex v in the order of a breadth first search  
        for every uncolored edge e incident to v in the order defined on edges  
            while there are uncolored edges with exactly one free color  
                get minimal uncolored edge with exactly one free color f  
                get minimally used free color c of f with respect to the color weights  
                color f with color c  
            if e is colored already  
                continue  
            if e cannot be colored  
                return incomplete coloring  
            get minimally used free color c of e with respect to the color weights  
            color e with color c  
  
    return complete coloring  
  
@param graph the graph this heuristic will be calculated on  
@return returns the calculated coloring
```


Class TCGreedyFewData

Description

This class stores all uncolored edges sorted first by their amount of free colors and then by the order defined on edges.

Documentation

```
# init()  
    initializes the list of uncolored edges  
  
# justColoredEdge(edge: SimpleUndirectedEdge)  
    updates the list of uncolored edges  
  
# getMinimalUncoloredEdge(): SimpleUndirectedEdge  
    @return returns the minimal uncolored edge with respect to the number of free colors and the order  
    defined on edges
```

Class TCGreedyFew

Description

This class implements the TCGreedyFew heuristic, which tries to calculate a total coloring.

Documentation

```
+ applyTo(graph: SimpleUndirectedGraph): TCResult  
    implements the following heuristic  
  
    for every vertex v in the order of a breadth first search  
        if v cannot be colored  
            return incomplete coloring  
        get minimally used free color c of v with respect to the color weights  
        color v with color c  
  
    for every vertex v in the order of a breadth first search  
        for every uncolored edge e incident to v in the order defined on edges  
            while there are uncolored edges with less free colors than e and lower order than e  
                get minimal uncolored edge f  
                if f cannot be colored  
                    return incomplete coloring  
                get minimally used free color c of f with respect to the color weights  
                color f with color c  
            if e is colored already  
                continue  
            if e cannot be colored  
                return incomplete coloring  
            get minimally used free color c of e with respect to the color weights  
            color e with color c  
  
    return complete coloring  
  
@param graph the graph this heuristic will be calculated on  
@return returns the calculated coloring
```

Class TCGreedySetData

Description

This class stores for any vertex v the subset of all uncolored edges incident to v which has the lowest flexibility value (ie. # of colors which are free for every edge in this set – # of edges in the set) and is the lowest with respect to lexicographic ordering using the order defined on edges. These sets are from now on referred to as minimal flex sets

Documentation

```
# init()
    initializes the minimal flex sets

# justColoredEdge(edge: SimpleUndirectedEdge)
    updates the minimal flex sets of the vertices incident to edge

- calcMinimalFlexSet(vertex: int)
    calculates the minimal flex set of vertex
    @param vertex the vertex whose minimal flex set is calculated

# getMinimalFlexSet(): TCFlexSet
    @return returns the minimal flex set belonging to the vertex with minimal index
```

Class TCGreedySet

Description

This class implements the TCGreedySet heuristic, which tries to calculate a total coloring.

Documentation

```
+ applyTo(graph: SimpleUndirectedGraph): TCResult
    implements the following heuristic

    for every vertex  $v$  in the order of a breadth first search
        if  $v$  cannot be colored
            return incomplete coloring
        get minimally used free color  $c$  of  $v$  with respect to the color weights
        color  $v$  with color  $c$ 

    while there is a set with minimal flexibility
        find the set  $X$  of minimal flexibility belonging to the vertex  $v$  with lowest index
        if  $X$  has negative flexibility
            return incomplete coloring
        for every edge  $e$  of  $X$  in the order defined on edges
            if  $e$  cannot be colored
                return incomplete coloring
            get minimally used free color  $c$  of  $e$  with respect to the color weights
            color  $e$  with color  $c$ 

    return complete coloring

    @param graph the graph this heuristic will be calculated on
    @return returns the calculated coloring
```

Class TCGreedyConData

Description

This class stores the list of uncolored edges temporarily to compute connected subsets of uncolored edges up to a specific size.

Documentation

```
# init()  
    initializes the list of uncolored edges  
  
# justColoredEdge(edge: SimpleUndirectedEdge)  
    updates the list of uncolored edges  
  
# getMinimalFlexSet(): TCFlexSet  
    @return returns the connected set of uncolored edges with minimal flexibility value (# of colors which  
    are free for all edges – # of edges) and minimal lexicographic order using the order defined on edges.
```

Class TCGreedyCon

This class implements the TCGreedyCon heuristic, which tries to calculate a total coloring.

Documentation

```
+ applyTo(graph: SimpleUndirectedGraph): TCResult  
    implements the following heuristic  
  
    for every vertex v in the order of a breadth first search  
        if v cannot be colored  
            return incomplete coloring  
        get minimally used free color c of v with respect to the color weights  
        color v with color c  
  
    while there is a set with minimal flexibility  
        find the set X of minimal flexibility which has the lowest lexicographic order  
        if X has negative flexibility  
            return incomplete coloring  
        for every edge e of X in the order defined on edges  
            if e cannot be colored  
                return incomplete coloring  
            get minimally used free color c of e with respect to the color weights  
            color e with color c  
  
    return complete coloring  
  
@param graph the graph this heuristic will be calculated on  
@return returns the calculated coloring
```

Package heuristic.totalColoring.mixedGreedy

Class TCMixedGreedyData

Class TCMixedGreedy

Class TCMixedGreedyOneData

Class TCMixedGreedyOne

Class TCMixedGreedyFewData

Class TCMixedGreedyFew

Class TCMixedGreedySetData

Class TCMixedGreedySet

Class TCMixedGreedyConData

Class TCMixedGreedyCon

Package heuristic.erdosFaberLovasz

Class EFLHeuristic

Class EFLResult

Package heuristic.erdosFaberLovasz.greedy

Class EFLGreedyData

Class EFLGreedy

Class EFLGreedyOneData

Class EFLGreedyOne

Class EFLGreedyFewData

Class EFLGreedyFew

Class EFLGreedySetData

Class EFLGreedySet

Class EFLGreedyConData

Class EFLGreedyCon

4 View

5 Controller

6 Input-Output