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1.1 C++ Constrained Delaunay Triangulation Fade2D

• Very fast multithreaded Delaunay triangulation library (benchmark)
• Well documented and with easy to use example source codes
• 2D Delaunay with Polygon support and Constraint Edges
• 2.5D Delaunay for Surfaces and Digital Elevation Models
• Earthwork Volume Computations: Cut And Fill
• Segment Intersection Test Software
• Grid Mesher and Delaunay Mesh Generator
• Supports Windows, MacOS, Linux on PC and Raspberry PI
• Student license. Evaluation license. Commercial licenses and support available
• Fade is actively developed and maintained. If you miss a feature please get in contact

1.1.1 Delaunay triangulation: Getting started

Download. Unzip. Start to play with the included examples. The example source code is described here. It works without installation.

Fade comes as two separate libraries, Fade2D and Fade2.5D. Fade2.5D can do everything that Fade2D can do. But Fade2.5D offers a z-coordinate and additional functionality for Digital Elevation Models (DEM) and surfaces. A collection of 2D and 2.5D example source codes is contained in the download. The examples go step by step over the concepts of Fade. New Fade2.5D users are advised to start with the 2D examples because the basics are described there and these apply also to Fade2.5D.

1.1.2 For Windows users:


2. Compile the example source code. The executable is written to the Win32 or x64 folder.

When you link Fade with your own software you can use the settings from the example solutions or use the table below:

<table>
<thead>
<tr>
<th>Visual Studio</th>
<th>IDE version</th>
<th>Platform Toolset</th>
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</thead>
<tbody>
<tr>
<td>VS2010</td>
<td>version 10</td>
<td>toolset v100 or Windows7.1SDK</td>
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<tr>
<td>VS2012</td>
<td>version 11</td>
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<td>VS2013</td>
<td>version 12</td>
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<tr>
<td>VS2015</td>
<td>version 14</td>
<td>toolset v140</td>
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<tr>
<td>VS2017</td>
<td>version 15</td>
<td>toolset v141</td>
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Generated by Doxygen
1.1.3 For Linux and Apple users:

1. Edit the Makefile (choose Apple, your Linux distro or Raspberry PI) and type make to compile the example source code.

2. Make sure GMP is installed:
   $ sudo apt-get install libgmp10 (works on Ubuntu/Debian/Mint/Raspbian, on other systems search for libgmp or gmp)

Work through the provided examples. They are small, well documented and they visualize the results.

1.1.4 Directory Contents

- **include_fade2d** and **include_fade25d**
  Header files of the two libraries.

- **Win32** and **x64**
  This directory contains the DLL's for Windows 32-bit and 64-bit and it is the target directory for the executables of example code compiled with Visual Studio.

- **lib_${DISTRO}_${ARCHITECTURE}**
  The shared libs (*.so) for Linux/Apple developers.

- **examples_2D**
  Example source code and Visual Studio projects using Fade2D

- **examples_25D**
  Example source code and Visual Studio projects using Fade2.5D

- **doc**
  PDF Documentation

1.1.5 Troubleshooting

- Mixing multiple Visual Studio versions won't work. Use the right dll.

- Compare your settings with the ones from the example projects.

- In rare cases you might need to increase Properties->ConfigurationProperties->Linker->System->Stack->ReserveSize in your Visual Studio project settings.

- If your problem persists, don't hesitate to send a minimal example that reproduces it and it will be fixed asap.
1.1.6  Release notes / History

Version 1.74, March 19th, 2019:

- Cleanup: The (until now experimental) surface reconstruction module has been moved into the separate WOF Point Cloud Meshing library (https://www.geom.at/products/wof-point-cloud-mesher/). This makes the Fade binaries smaller and it improves the maintainability of the code.

- Cleanup: Support for VS2008 has been dropped (if you are a commercial user and still need VS2008 then contact the author please!).

- The build system has been migrated to CMake to reduce the manual work and to guarantee uniform flags for all builds.

- The HoleFiller class that has been developed for the removed surface reconstruction module is retained in Fade because it has already users. Its code has been revised in order to provide repeatable results for identical inputs.

- According to a user request the MeshGenParams class (used for advanced Delaunay Meshing) offers now a method to lock certain constraint segments such that they are not splitted while all others can be splitted if required.

Version 1.73, January 14th, 2019:

While all below mentioned versions after v1.63 were development versions the present v1.73 is again an official release version for all. The work of the below internal versions is included as well as a bugfix in the getProfile() method of the IsoContours class (this method was new and experimental in v1.63)

Version 1.71 and 1.72, October 24th, 2018:
(internal) Hole-Filling (Polygon-Triangulation) improved.

Version 1.70, October 17th, 2018:
(internal) Hole-Filling (Polygon-Triangulation) improved.

Version 1.69, October 15th, 2018:
(internal) Hole-Filling (Polygon-Triangulation) improved.

Version 1.68, September 14th, 2018:
(internal) Hole-Filling (Polygon-Triangulation) improved.

Version 1.67, September 4th, 2018:
(internal) Hole-Filling (Polygon-Triangulation) is now offered via. an API call. Intermediate beta release.

Version 1.66, August 25th, 2018:
(internal) Bugfix in Cut&Fill: An intersection point could be slightly off its expected range. Solved. Unofficial intermediate version.

Version 1.65, July 29th, 2018:
(internal) Another bugfix in Cut&Fill. Unofficial intermediate version.

Version 1.64, July 21st, 2018:
(internal) Bugfix in the Cut&Fill module: In rare cases Cut&Fill crashed due to unexpected numeric deviation (fixed). The importTriangles() function has been reimplemented and is considerably faster now. And there is a change that affects only 32-bit users: Binary files written with the writePointsBIN() and writeSegmentsBIN() functions on 32-bit machines were not readable on 64-bit machines. The format on 32-bit machines (read/write) has been adapted to match exactly the one of 64-bit machines. But note that old 32-bit files are not readable anymore. This should affect next to nobody, thus this solution has been chosen.
Version 1.63, June 10th, 2018:
Cookie-Cutter operation added. 3D Point Cloud Reconstruction added to the API (but is still under development, pls. take it as a preview). Raspberry PI support added again.

Version 1.62, June 3rd, 2018:
3D Point Cloud Reconstruction considerably improved. Unofficial demo.

Version 1.61, May 1st, 2018:
3D Point Cloud Reconstruction: Unofficial demo.

Version 1.60, February 26th, 2018:
Accurate computation of glancing segment intersections. Additional parameter for Advanced Meshing: bool bKeepExistingSteinerPoints=true in MeshGenParams makes all Steiner points from previous refinement calls static, i.e. unremovable during subsequent refinement calls. This way Advanced Meshing can be carried out for several zones of a triangulation such that it does not destroy what has been meshed so far.

Version 1.59, January 14th, 2018:
Performance upgrade: Multithreading is available now. Large point sets reach a speedup of 4.4 on a hexacore CPU (i7 6800K)

Version 1.58, October 23th, 2017:
Mesh Generator refactored. Delaunay Meshing is +10x faster now. A function to create polygons from boundary edges has been added.

Version 1.57, October 9th, 2017:
Nonpublic test version.

Version 1.56, September 24th, 2017:
Bugfix: createConstraint() crashed in a rare case. Solved. Functions for binary file I/O added.

Version 1.55, August 12th, 2017:

Version 1.54beta, August 8th, 2017:
Access to internal Cut&Fill datastructures. This is a pre-released beta version, code quality is good but final tests and documentation updates required.

Version 1.53, July 15th, 2017:
Error corrections and performance upgrades in the still quite new Cut&Fill library module.

Version 1.53 beta, June 2nd, 2017:
The new Cut&Fill library module has been added. Cut&Fill computes the volume between two surfaces.

Version 1.51 beta, May 27th, 2017:
Non-public test version

Version 1.50, April 5th, 2017:
After three internal test versions (that concetrated on refactoring and rare bugs) this is again a stable public release version: The constraint insertion subsystem has been rewritten and is faster now. Visualization improved. Exact orientation tests provided through the API. Improved progress bar support. Mesh generator improved.

Users who upgrade from earlier Fade versions: The Zone2::getArea() and Triangle2::getArea() methods have been replaced by getArea2D() in Fade2D and by getArea2D() AND getArea25D() in Fade2.5D. The reason is that the old getArea() method was easily misunderstood in Fade2.5D (it returned the same result as getArea25D() now). We have decided to remove the old method to avoid confusion and a potential source of error. If necessary, please adapt your code.

Version 1.49, March 2nd, 2017:
Constraint insertion subsystem improved. Mesh generator revised.
Version 1.48, February 15th, 2017:
Corrections of yesterday's v1.47 version.

Version 1.47, February 14th, 2017:
The focus of this (for now) non-public version is stability: Intersecting constraint segments must be subdivided although their exact intersection is not always representable with double precision coordinates. Thus tiny rounding errors are unavoidable and these caused trouble in very unlikely cases. The constraint insertion subsystem has now been re-implemented to behave robust also in such cases.

Version 1.46a, January 14th, 2017:
+++ Raspberry PI is supported now +++ // Appart from RPI support version 1.46a is equal to v1.46. Raspberry PI users: Please give feedback, do you have everything you need for RPI development now?

Version 1.46, January 8th, 2017:
+++ MacOS is supported now +++ // A new class EfficientModel takes oversampled 2.5D point clouds and returns a subset that represents the model efficiently. The automatic pruning process runs in a controlled fashion such that a user specified maximum error is kept. // The Delaunay Mesh Generator is now supported by a Grid Mesher, thus it creates more regular meshes. // The Delaunay triangulation of specific point sets is not unique, for example when grid points are triangulated (4 points on a common circumcircle). To improve the repeatability and for reasons of visual appearance the new method Zone2::unifyGrid() has been implemented. // A problem in the point location method Fade_2D::locate() when the query point was exactly on the convex hull of the triangulation has been solved.

Version 1.43, November 20th, 2016:
Better example source code for the new SegmentChecker class. And the SegmentChecker of v1.42 returned false positives, this problem is solved now.

Version 1.42, October 19th, 2016:
The new tool SegmentChecker takes a bunch of segments and fully automatically identifies intersecting segments. The underlying data structure makes the tool incredibly fast. Intersecting segments can be visualized. Intersections can be computed in 2D and 2.5D (with heights). A new module named TestDataGenerators creates random polygons, random segments, points, random numbers and polylines for automated software stress tests. Progress bar support added.

Version 1.41, July 24th, 2016:

Version 1.40 beta, June 14th, 2016:
Non public intermediate test version. Bounded zones introduced: Mesh generation algorithms require that zones are bounded by constraint segments. This is certainly the case for the most usual zones with zoneLocation=ZL_INSIDE. But other types of zones may be unbounded and in this case remeshing won't work well, so it was necessary to change the behavior: From now on calling refine() and refineAdvanced() is only allowed with zones whose zoneLocation is ZL_INSIDE or ZL_BOUNDED. A bounded zone can easily be gained from any other zone using Zone2::convertToBoundedZone(). Also new: Fade_2D::createConstraintGraph(..) has now a third parameter 'bool bOrientedSegments=false'. By default it is false to provide backwards compatibility. This parameter allows you to specify that the provided segments are CCW oriented. This way more complex inside- and outside-zones can be formed. Performance of Fade_2D::createConstraint(...) drastically improved.

Version 1.39, May 31st, 2016:
Non public intermediate test version.

Version 1.37, March 15th, 2016:
Small upgrade: The performance of the remove method has been improved.

Version 1.37, March 10th, 2016:
Interface change in the MeshGenParams class. The class has been introduced two weeks before, so chances are good that the change does not affect you. Previously the class had the methods getMaxTriangleArea(double x,double y) and getMaxEdgeLength(double x,double y) where x and y where the barycenter of a triangle for which the algorithm determines if it must be refined. The change is that x and y have been replaced by the triangle itself to give client code even more control (x and y can still be computed from the triangle).
Version 1.36, February 29th, 2016:
Experimental method refineExtended(..) replaced by the (now permanent) method refineAdvanced(MeshGen← Params∗ pParams). This method allows much more control over the mesh density.

Version 1.34, February 14th, 2016:
Vertex management subsystem revised (sometimes Vertex removement did not work as expected). Performance improvement.

Version 1.33 PreRelease, January 17th, 2016:
The previous official Fade version is Fade 1.24. It was released 6 months ago. Since then major developments have been made and now a big upgrade follows with version 1.33.14: Constraint segments may intersect now and they are automatically subdivided at their intersection points. Import of existing triangles is supported and one can cut through static triangulations. This version is well tested. It also runs at two customers sites with no known problems. But due to the large amount of new code we call this version a pre-release. Please report if you find any problems and note that it is also helpful if you report that the library works well in your setting. The DLL names have been adapted to the safer and more convenient pattern

fade[2D][25D]_${(Platform)}_${(PlatformToolset)}_${(Configuration)}.dll

If you upgrade from an earlier version it is recommended that you remove any previous Fade DLL's to avoid unintended linking to an old version.

Version 1.31 and 1.32, December 1st, 2015:
Non public intermediate release, improves the CDT.

Version 1.30, November 18th, 2015:
Non public intermediate release, improves the refineExtended method.

Version 1.29, October 17th, 2015:
Non public intermediate release. The method importTriangles() detects invalid input data now and returns NULL to avoid an assertion or even an infinite loop when the input data is not clean. The possibly invalid input elements are written to stdout and a postscript file visualizes where the problem occurs.

Version 1.28, October 10th, 2015:
Non public intermediate release. Customer specific code revised. Stress tests with random polygons and segments have been made. Heap checking to ensure proper memory handling.

Version 1.27, October 5th, 2015:
Non public release, improvements of the recently implemented functions, especially of customer specific code Fade_2D::importTriangles() and Fade2D::cutTriangles().

Version 1.26, September 8th, 2015:
New functions of the last inofficial version 1.25 have been revised. Constraint segments may intersect now.

Version 1.25, August 18th, 2015:
Intermediate pre-release with new features: importTriangles() imports arbitrary triangles into a triangulation, cut−− Triangles() allows to insert a constraint segment as if it where a knife, getOrientation() provides an exact orientation test. Zone2 objects can now also be made from a set of triangles. Constraint segments can intersect now. These features correspond to a large amount of new code: Please test v1.25 carefully before deploying it in a production environment.

Version 1.24, July 22nd, 2015:
Public release of version 1.23's improvements. And I'm sorry but we had a bug in Fade_2D::getVertexPointers(..). The method may have missed to return a few pointers after a call to refine() or remove(). This bug is fixed now.

Version 1.23, July 9th, 2015:
Internal test release with the new refineExtended() method for the specific needs of a certain client software.
Version 1.22, May 25th, 2015:
Code refactored, build system refactored and as a result improved Linux support: CentOS 6.4, Ubuntu 14.04, Ubuntu 15.04 and similar systems. Removal of points has been implemented, Delaunay meshing has been reworked, sqDistance() has been replaced by sqDistance2D() and sqDistance25D() because both versions are useful in 2.5D. OpenMP has been removed, it was only used under Linux and currently I work on a better way to provide multithreading.

Version 1.21, May 17th, 2015:
Unofficial intermediate release. Testing new features.

Version 1.20, April 5th, 2015:
3D scene Visualization for (up to date) web browsers added. Misleading enumeration values CIS_KEEP_DELAUNAY and CIS_IGNORE_DELAUNAY have been replaced by CIS_CONFORMING_DELAUNAY and CIS_CONFORMED_STRAINED_DELAUNAY (the two deprecated names are kept for backward compatibility). Bug in the free function center(Point2&, Point2&) solved. Major revision of the documentation pages. The source codes of the examples have been reengineered and are included in the present documentation pages.

Version 1.19, October 26th, 2014:
Support for Visual Studio 2013 (VC12) has been added. Only minor code changes.

Version 1.18, June 9th, 2014:
Mesh generation (Delaunay Meshing) has been improved: Better quality, better performance. API improved. Small bug fixes.

Version 1.17, February 10th, 2014:
Small update: In rare cases it was possible that subdivided ConstraintSegments caused problems in combination with zone growing. This is fixed now.

Version 1.16, February 3rd, 2014:

Version 1.15, November 2013 and version 1.15, December 2013:
Non-public intermediate releases (test versions with experimental features).

Version 1.14, August 4th, 2013:
Mesh generation (Delaunay Meshing) has been improved and two bugfixes have been made in the new IsoContours class: A message can be suppressed now and a numeric problem has been fixed.

Version 1.13, June 30th, 2013:
Starting with version v1.12 the download consists of two separate libraries: The familiar full version of the 2D flavor as well as a 2.5D evaluation version. Two very fast new methods have been added to the 2.5D version: One computes iso-contours, the other computes the height of a point with arbitrary (x,y) coordinates. Delaunay mesh generation has been improved. Support for VS2008, 32-bit and 64-bit, has been added. The performance has been improved.

Version 1.11, June 14th, 2013:
Non-public intermediate release with VS2008 support and a first version of the iso-contour feature.

Version 1.10, March 30th, 2013:
Delaunay Refinement (already included as preview in the previous release) has been improved and is officially released now. Parts of the algorithm can use up to 8 CPUs under Linux if explicitly switched on using Fade2D::enableMultithreading(). There is a new insert method in the API which uses arrays.

Version 1.03, Nov. 4th, 2012:
A critical bug has been fixed, please switch to the current version. Performance upgrade: A first step towards multithreading has been made in the Linux version. In order to facilitate the installation for users without administrator privileges the installers have been replaced by a simple zipped directory that contains everything. Meshing through Delaunay Refinement is scheduled for the next release but it is pre-released as an experimental feature in the current version 1.03.
Version 1.02, 9/2012:
An additional debug library version for Windows has been added and the directory structure has been reorganized.

Version 1.01, 9/2012:
This is a stable public release. Since version 0.9 we have introduced insertion of constraint edges and the zone concept. Moreover the API is under a namespace now. Boost types have been removed from the API to avoid this additional dependency. New demo software has been written and the library is now also available for 64-bit Windows.

2 Module Index

2.1 Modules

Here is a list of all modules:

- Tools
- Version Information
- File I/O
- Test Data Generators

3 Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

- GEOM_FADE2D::Bbox2
  Bbox2 is an axis aligned bounding box

- GEOM_FADE2D::Circle2
  Circle

- GEOM_FADE2D::Color
  Color

- GEOM_FADE2D::ConstraintGraph2
  ConstraintGraph2 is a set of Constraint Edges to be enforced. These are ConstraintSegment2 objects

- GEOM_FADE2D::ConstraintSegment2
  A ConstraintSegment2 represents a Constraint Edge

- GEOM_FADE2D::Edge2
  Directed Edge

- GEOM_FADE2D::Fade_2D
  Delaunay triangulation - the main class

- GEOM_FADE2D::Func_gtEdge2D
  Functor to sort edges by 2d length (descending)
GEOM_FADE2D::Func_ltEdge2D
Functor to sort edges by 2d length (ascending) 67

GEOM_FADE2D::Func ltUndirected

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GEOM_FADE2D::MeshGenParams
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GEOM_FADE2D::MsgBase
MsgBase 73

GEOM_FADE2D::Point2
Point 74

GEOM_FADE2D::Segment2
Segment 80

GEOM_FADE2D::SegmentChecker
SegmentChecker identifies intersecting line segments 82

GEOM_FADE2D::Triangle2
Triangle 90

GEOM_FADE2D::TriangleAroundVertexIterator
Iterator for all triangles around a given vertex 97

GEOM_FADE2D::UserPredicateT
User defined predicate 100

GEOM_FADE2D::Vector2
Vector 101

GEOM_FADE2D::Visualizer2
Visualizer2 is a general Postscript writer. It draws the objects Point2, Segment2, Triangle2, Circle2 and Label 102

GEOM_FADE2D::Zone2
Zone2 is an exactly defined area of a triangulation 105

4 File Index

4.1 File List

Here is a list of all documented files with brief descriptions:

  Bbox2.h ??
  Circle2.h ??
  Color.h 111
  ConstraintGraph2.h ??
  ConstraintSegment2.h ??
5 Module Documentation

5.1 Tools

Functions

- bool GEOM_FADE2D::isSimplePolygon (std::vector< Segment2 > &vSegments)
  isSimplePolygon
- void GEOM_FADE2D::getDirectedEdges (std::vector< Triangle2 > * &vT, std::vector< Edge2 > &vDirectedEdgesOut)
  Get directed edge The directed edges of vT are returned vDirectedEdgesOut. Directed means that each edge (a,b) with two adjacent triangles in vT is returned twice, as edge(a,b) and edge(b,a).
- void GEOM_FADE2D::getUndirectedEdges (std::vector< Triangle2 > * &vT, std::vector< Edge2 > &vUndirectedEdgesOut)
  Get undirected edges.
- bool GEOM_FADE2D::fillHole (std::vector< std::pair< Segment2, Vector2 > > vPolygonSegments, bool bWithRefine, bool bVerbose, std::vector< Point2 > &vCornersOut)
  Fill a hole in a 3D mesh with triangles (deprecated)
- void GEOM_FADE2D::edgesToPolygons (std::vector< Edge2 > &vEdgesIn, std::vector< std::vector< Edge2 > > &vvPolygonsOut, std::vector< Edge2 > &vRemainingOut)
  Create polygons from a set of edges.
• void GEOM_FADE2D::getBorders (const std::vector<Triangle2 *> &vT, std::vector<Segment2> &vBorderSegmentsOut)
  Get Borders.

• bool GEOM_FADE2D::sortRing (std::vector<Segment2> &vRing)
  Sort a vector of Segments.

• bool GEOM_FADE2D::sortRingCCW (std::vector<Segment2> &vRing)
  Sort a vector of Segments.

• Orientation2 GEOM_FADE2D::getOrientation2 (const Point2 *p0, const Point2 *p1, const Point2 *p2)
  Get the orientation of three points.

• Orientation2 GEOM_FADE2D::getOrientation2_mt (const Point2 *p0, const Point2 *p1, const Point2 *p2)
  Get Orientation2 (MT)

5.1.1 Detailed Description

5.1.2 Function Documentation

5.1.2.1 edgesToPolygons()

void GEOM_FADE2D::edgesToPolygons {
  std::vector<Edge2> & vEdgesIn,
  std::vector<std::vector<Edge2> > & vvPolygonsOut,
  std::vector<Edge2> & vRemainingOut }

A number of methods in Fade returns an unorganized set of edges that delimit a certain area. But sometimes it is more beneficial to have these edges organized as a set of one or more polygons. This is the purpose of the present method.

Parameters

<table>
<thead>
<tr>
<th>in</th>
<th>vEdgesIn</th>
<th>is a vector of oriented edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>out</td>
<td>vvPolygonsOut</td>
<td>contains one vector&lt;Edge2&gt; for each polygon found in the input data.</td>
</tr>
<tr>
<td>out</td>
<td>vRemainingOut</td>
<td>is used to return unusable remaining edges</td>
</tr>
</tbody>
</table>

The present function adds one vector<Edge2> to vvPolygonsOut for each polygon found in vEdgesIn. Each such polygon starts with the leftmost vertex (and when two or more vertices share the smallest x-coordinate then the one of them with the smallest y-coordinate is chosen). Edges that do not form a closed polygon are returned in vRemainingOut.
Note

An Edge2 object represents an edge of a triangle. Triangle corners are always counterclockwise (CCW) oriented. Thus outer polygons are CCW-oriented while hole-polygons are CW-oriented, see the figure.

![Figure 1 Polygons created by edgesToPolygons](image)

5.1.2.2 fillHole()

bool GEOM_FADE2D::fillHole (  
    std::vector< std::pair< Segment2, Vector2 > > vPolygonSegments,  
    bool bWithRefine,  
    bool bVerbose,  
    std::vector< Point2 > & vCornersOut )

This function was experimental and is now deprecated because 3D point cloud meshing has been moved to the WOF library.
5.1 Tools

Parameters

| in  | vPolygonSegments | contains the segments of a closed, simple input polygon along with normal vectors. The segments are counterclockwise oriented and ordered with respect to the surface to be created. Check twice, the orientation is very important. The normal vectors point in the direction of the thought surface at the segment i.e., if a hole is filled, the normal vector of an adjacent triangle is taken but if a T-joint is filled the normal vector should be the average normal of the two triangles at the edge. |
|-----|------------------|
| in  | bWithRefine      | specifies if additional vertices shall be created. (bWithRefine=true is experimental, don’t use currently) |
| in  | bVerbose         | specifies if warnings shall be printed to stdout |
| out | vCornersOut      | contains the created fill triangles, 3 corners per triangle, counterclockwise oriented. |

5.1.2.3 getBorders()

```cpp
void GEOM_FADE2D::getBorders ( 
    const std::vector<Triangle2 *> & vT, 
    std::vector<Segment2> & vBorderSegmentsOut )
```

Computes the border of the triangles in vT. The border consists of all edges having only one adjacent triangle in vT.

Parameters

<table>
<thead>
<tr>
<th>in</th>
<th>vT</th>
<th>are the input triangles</th>
</tr>
</thead>
<tbody>
<tr>
<td>out</td>
<td>vBorderSegmentsOut</td>
<td>is used to return all border segments</td>
</tr>
</tbody>
</table>

5.1.2.4 getOrientation2()

```cpp
Orientation2 GEOM_FADE2D::getOrientation2 ( 
    const Point2 * p0, 
    const Point2 * p1, 
    const Point2 * p2 )
```

This function returns the exact orientation of the points p0, p1, p2. Possible values are ORIENTATION2_COLLINEAR if p0, p1, p2 are located on a line, ORIENTATION2_CCW if p0, p1, p2 are counterclockwise oriented ORIENTATION2_CW if p0, p1, p2 are clockwise oriented Not thread-safe but a bit faster than the thread-safe version

5.1.2.5 getOrientation2_mt()

```cpp
Orientation2 GEOM_FADE2D::getOrientation2_mt ( 
    const Point2 * p0, 
    const Point2 * p1, 
    const Point2 * p2 )
```

See also

getOrientation2(const Point2* p0,const Point2* p1,const Point2* p2)

This version is thread-safe.
5.1.2.6  getUndirectedEdges()

```cpp
void GEOM_FADE2D::getUndirectedEdges (
    std::vector< Triangle2 * > & vT,
    std::vector< Edge2 > & vUndirectedEdgesOut )
```

A unique set of edges of vT is returned.

5.1.2.7  isSimplePolygon()

```cpp
bool GEOM_FADE2D::isSimplePolygon ( 
    std::vector< Segment2 > & vSegments )
```

**Parameters**

| in | vSegments | specifies segments to be checked. Degenerate segments (0-length) are ignored. |

**Returns**

true when vSegments contains a closed polygon without selfintersections. False otherwise.

5.1.2.8  sortRing()

```cpp
bool GEOM_FADE2D::sortRing ( 
    std::vector< Segment2 > & vRing )
```

The segments in vRing are reoriented and sorted such that subsequent segments join at the endpoints.

5.1.2.9  sortRingCCW()

```cpp
bool GEOM_FADE2D::sortRingCCW ( 
    std::vector< Segment2 > & vRing )
```

The segments in vRing are reoriented and sorted such that the resulting polygon is counterclockwise oriented and subsequent segments join at the endpoints.
5.2 Version Information

Functions

- std::string GEOM_FADE2D::getFade2DVersion ()
  
  Get the Fade2D version string.

- int GEOM_FADE2D::getMajorVersionNumber ()
  
  Get the major version number.

- int GEOM_FADE2D::getMinorVersionNumber ()
  
  Get the minor version number.

- int GEOM_FADE2D::getRevisionNumber ()
  
  Get the revision version number.

- bool GEOM_FADE2D::isRelease ()
  
  Check if a RELEASE or a DEBUG version is used.

5.2.1 Detailed Description
5.3 File I/O

Functions

- bool GEOM_FADE2D::writePointsASCII (const char *filename, const std::vector<Point2 *> &vPointsIn)
  Write points to an ASCII file.
- bool GEOM_FADE2D::writePointsASCII (const char *filename, const std::vector<Point2> &vPointsIn)
  Write points to an ASCII file.
- bool GEOM_FADE2D::readXY (const char *filename, std::vector<Point2> &vPointsOut)
  Read (x, y) points.
- bool GEOM_FADE2D::writePointsBIN (const char *filename, std::vector<Point2> &vPointsIn)
  Write points to a binary file.
- bool GEOM_FADE2D::writePointsBIN (const char *filename, std::vector<Point2 *> &vPointsIn)
  Write points to a binary file.
- bool GEOM_FADE2D::readPointsBIN (const char *filename, std::vector<Point2> &vPointsIn)
  Read points from a binary file.
- bool GEOM_FADE2D::readPointsBIN (const char *filename, std::vector<Point2 *> &vPointsIn)
  Read points from a binary file.
- bool GEOM_FADE2D::writeSegmentsBIN (const char *filename, std::vector<Segment2> &vSegmentsIn)
  Write segments to a binary file.
- bool GEOM_FADE2D::writeSegmentsBIN (const char *filename, std::vector<Segment2 *> &vSegmentsIn)
  Write segments to a binary file.
- bool GEOM_FADE2D::readSegmentsBIN (const char *filename, std::vector<Segment2> &vSegmentsOut)
  Read segments from a binary file.
  Read segments from a binary file.

5.3.1 Detailed Description

5.3.2 Function Documentation

5.3.2.1 readPointsBIN()

bool GEOM_FADE2D::readPointsBIN (const char * filename, std::vector<Point2> & vPointsIn )

Reads points from a binary file.

See also
writePointsBIN()

5.3.2.2 readSegmentsBIN()

bool GEOM_FADE2D::readSegmentsBIN (const char * filename, std::vector<Segment2> & vSegmentsOut )

Reads segments from a binary file of type 21 or 31

See also
writeSegmentsBIN()
5.3.2.3 \texttt{readXY()}

\begin{verbatim}
bool GEOM_FADE2D::readXY (  
    const char * filename,  
    std::vector< Point2 > & vPointsOut )
\end{verbatim}

Reads points from an ASCII file. Expected file format: Two coordinates (x y) per line, whitespace separated.

5.3.2.4 \texttt{writePointsASCII() [1/2]}

\begin{verbatim}
bool GEOM_FADE2D::writePointsASCII (  
    const char * filename,  
    const std::vector< Point2 * > & vPointsIn )
\end{verbatim}

Writes points to an ASCII file, two coordinates (x y) per line, whitespace separated.

\textbf{Note}

Data exchange through ASCII files is easy and convenient but floating point coordinates are not necessarily exact when represented as decimal numbers. If the tiny rounding errors can’t be accepted in your setting you are advised to write binary files. (use \texttt{writePointsBIN()} )

5.3.2.5 \texttt{writePointsASCII() [2/2]}

\begin{verbatim}
bool GEOM_FADE2D::writePointsASCII (  
    const char * filename,  
    const std::vector< Point2 > & vPointsIn )
\end{verbatim}

Write points to an ASCII file

\textbf{See also}

\texttt{readPointsASCII()}

5.3.2.6 \texttt{writePointsBIN() [1/2]}

\begin{verbatim}
bool GEOM_FADE2D::writePointsBIN (  
    const char * filename,  
    std::vector< Point2 > & vPointsIn )
\end{verbatim}

File format:
\begin{verbatim}
int filetype (20)
size_t numPoints (vPointsIn.size())
double x0
double y0
double z0
...
double xn
double yn
double zn
\end{verbatim}

\textbf{Note}

Since version 1.64 the binary file format written by 32-bit machines is identical with the file format of x64 machines i.e., the numPoints value is always 8 bytes, not 4. This change affects only 32-bit programs.
5.3.2.7 writePointsBIN() [2/2]

```cpp
bool GEOM_FADE2D::writePointsBIN (  
    const char * filename,  
    std::vector< Point2 *> & vPointsIn )
```

Writes points to a binary file

See also

readPointsBIN()

5.3.2.8 writeSegmentsBIN()

```cpp
bool GEOM_FADE2D::writeSegmentsBIN (  
    const char * filename,  
    std::vector< Segment2 > & vSegmentsIn )
```

Binary file format:

- int filetype (21)
- size_t numSegments (vSegmentsIn.size())
- double x0_source
- double y0_source
- double x0_target
- double y0_target
- ...
- double xn_source
- double yn_source
- double xn_target
- double yn_target

Note

Since version 1.64 the binary file format written by 32-bit machines is identical with the file format of x64 machines i.e., the numSegments value is always 8 bytes, not 4. This change affects only 32-bit programs.

See also

readSegmentsBIN()
5.4 Test Data Generators

Functions

- void GEOM_FADE2D::generateRandomNumbers(size_t num, double min, double max, std::vector<double>& vRandomNumbersOut, unsigned int seed=0)
  
  Generate random numbers.

- void GEOM_FADE2D::generateRandomPoints(size_t numRandomPoints, double min, double max, std::vector<Point2>& vRandomPointsOut, unsigned int seed=0)
  
  Generate random points.

- void GEOM_FADE2D::generateRandomPolygon(size_t numSegments, double min, double max, std::vector<Segment2>& vPolygonOut, unsigned int seed=0)
  
  Generate a random simple polygon.

- void GEOM_FADE2D::generateRandomSegments(size_t numSegments, double min, double max, double maxLen, std::vector<Segment2>& vSegmentsOut, unsigned int seed)
  
  Generate random line segments.

- void GEOM_FADE2D::generateSineSegments(int numSegments, int numPeriods, double xOffset, double yOffset, double xFactor, double yFactor, bool bSwapXY, std::vector<Segment2>& vSineSegmentsOut)
  
  Generate segments from a sine function.

- void GEOM_FADE2D::generateCircle(int numPoints, double x, double y, double radiusX, double radiusY, std::vector<Point2>& vCirclePointsOut)
  
  Generate a circle.

- void GEOM_FADE2D::shear(std::vector<Point2>& vPointsInOut, double shearX, double shearY)

5.4.1 Detailed Description

Generate random polygons and other test objects

Theory, careful programming and automated software stress tests. Neither of them can replace the other one. Testing with random data helps to discover errors early. Fade provides random object generators for your automated software stress tests:

- Random simple polygons
- Random segments
- Random point clouds
- Random numbers.
- Polylines from sine functions

If you discover an error in your software you must be able to reproduce the input data that has triggered your bug. For this reason the random object generators take a seed value to initialize the internal random number generators. A certain seed value always leads to the same sequence of objects. Only when the special seed value 0 is used then the random number generators are initialized from the system time.

5.4.2 Function Documentation
5.4.2.1 generateCircle()

```cpp
void GEOM_FADE2D::generateCircle (  
    int numPoints,  
    double x,  
    double y,  
    double radiusX,  
    double radiusY,  
    std::vector<Point2> & vCirclePointsOut )
```

Returns points on a circle centered at the given coordinates

5.4.2.2 generateRandomNumbers()

```cpp
void GEOM_FADE2D::generateRandomNumbers {  
    size_t num,  
    double min,  
    double max,  
    std::vector<double> & vRandomNumbersOut,  
    unsigned int seed = 0 )
```

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>num</code></td>
<td>Number of random numbers to be generated</td>
</tr>
<tr>
<td><code>min</code></td>
<td>Lower bound</td>
</tr>
<tr>
<td><code>max</code></td>
<td>Upper bound</td>
</tr>
<tr>
<td><code>vRandomNumbersOut</code></td>
<td>is the output vector</td>
</tr>
</tbody>
</table>

**Note**

Reproducible random numbers are often desirable when software is tested with random geometric constructions. Thus each seed value different from 0 leads to its own, reproducible, output sequence. In contrast the seed value 0 is mapped to random initialization of the RNG. In this case the RNG will produce a different output sequence each time it is called.

5.4.2.3 generateRandomPoints()

```cpp
void GEOM_FADE2D::generateRandomPoints (  
    size_t numRandomPoints,  
    double min,  
    double max,  
    std::vector<Point2> & vRandomPointsOut,  
    unsigned int seed = 0 )
```

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>numRandomPoints</code></td>
<td>Number of points to be generated</td>
</tr>
<tr>
<td><code>min</code></td>
<td>Lower bound (x,y)</td>
</tr>
<tr>
<td><code>max</code></td>
<td>Upper bound (x,y)</td>
</tr>
<tr>
<td><code>vRandomPointsOut</code></td>
<td>is the output vector</td>
</tr>
<tr>
<td><code>seed</code></td>
<td>Initializes the random number generator RNG (default: 0...mapped to a random seed, other values: constant initialization)</td>
</tr>
</tbody>
</table>
5.4 Test Data Generators

5.4.2.4 generateRandomPolygon()

```c
void GEOM_FADE2D::generateRandomPolygon (  
  size_t numSegments,  
  double min,  
  double max,  
  std::vector< Segment2 > & vPolygonOut,  
  unsigned int seed = 0  
)
```

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>numSegments</code></td>
<td>Number of segments to be generated</td>
</tr>
<tr>
<td><code>min</code></td>
<td>Lower bound (x,y)</td>
</tr>
<tr>
<td><code>max</code></td>
<td>Upper bound (x,y)</td>
</tr>
<tr>
<td><code>vPolygonOut</code></td>
<td>is the output vector</td>
</tr>
<tr>
<td><code>seed</code></td>
<td>initializes the random number generator RNG (default: 0...mapped to a random seed, other values: constant initialization)</td>
</tr>
</tbody>
</table>

Figure 2 Point generator
5.4.2.5 generateRandomSegments()

```cpp
void GEOM_FADE2D::generateRandomSegments (  
    size_t numSegments,  
    double min,  
    double max,  
    double maxLen,  
    std::vector< Segment2 > & vSegmentsOut,  
    unsigned int seed )
```

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>numSegments</code></td>
<td>Number of segments to be generated</td>
</tr>
<tr>
<td><code>min</code></td>
<td>Lower bound (x,y)</td>
</tr>
<tr>
<td><code>max</code></td>
<td>Upper bound (x,y)</td>
</tr>
<tr>
<td><code>maxLen</code></td>
<td>Maximal segment length</td>
</tr>
<tr>
<td><code>vSegmentsOut</code></td>
<td>is the output vector</td>
</tr>
<tr>
<td><code>seed</code></td>
<td>initializes the random number generator RNG</td>
</tr>
<tr>
<td></td>
<td>(default: 0...mapped to a random seed, other</td>
</tr>
<tr>
<td></td>
<td>values: constant initialization)</td>
</tr>
</tbody>
</table>
5.4 Test Data Generators

5.4.2.6 generateSineSegments()

```c
void GEOM_FADE2D::generateSineSegments (  
  int numSegments,  
  int numPeriods,  
  double xOffset,  
  double yOffset,  
  double xFactor,  
  double yFactor,  
  bool bSwapXY,  
  std::vector< Segment2 > & vSineSegmentsOut )
```

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>numSegments</code></td>
<td>Number of segments to be generated</td>
</tr>
<tr>
<td><code>numPeriods</code></td>
<td>Number of periods of the sine function</td>
</tr>
<tr>
<td><code>xOffset</code></td>
<td>Offset of the output x-coordinates</td>
</tr>
<tr>
<td><code>yOffset</code></td>
<td>Offset of the output y-coordinates</td>
</tr>
<tr>
<td><code>xFactor</code></td>
<td>Factor to scale the sine function in x direction</td>
</tr>
<tr>
<td><code>yFactor</code></td>
<td>Factor to scale the sine function in y direction</td>
</tr>
<tr>
<td><code>bSwapXY</code></td>
<td>Swap the x and y coordinate of the function</td>
</tr>
<tr>
<td><code>vSineSegmentsOut</code></td>
<td>is the output vector</td>
</tr>
</tbody>
</table>
Figure 5 Polyline generator: Polylines from sine functions
6 Class Documentation

6.1 GEOM_FADE2D::Bbox2 Class Reference

Bbox2 is an axis aligned bounding box.

#include <Bbox2.h>

Public Member Functions

- **Bbox2** (GeomTest ∗pGeomTest_=NULL)
  Constructor.
- **Bbox2** (std::vector< Point2 >::const_iterator start_it, std::vector< Point2 >::const_iterator end_it, GeomTest ∗pGeomTest_=NULL)
  Constructor.
- **bool isValid** () const
  Check if the bounds are valid.
- **void get_corners** (std::vector< Point2 >&vBoxCorners) const
  Get corners.
- **void get_offset_corners** (double offset, std::vector< Point2 >&vBoxCorners) const
  Get offset corners.
- **bool doIntersect** (const Bbox2 &other) const
  Check intersection.
- **bool add** (std::vector< Point2 >*:const_iterator start_it, std::vector< Point2 >*:const_iterator end_it)
  Add points.
- **bool add** (std::vector< Point2 >*:const_iterator start_it, std::vector< Point2 >*:const_iterator end_it)
  Add points.
- **bool add** (size_t numPoints, double ∗coordinates)
  Add points.
- **bool add** (const Point2 &p)
  Add a point.
- **bool isInBox** (const Point2 &p) const
  Point-in-Box Test.
- **Point2 computeCenter** () const
  Compute the midpoint.
- **Bbox2 operator+** (const Bbox2 &b)
  Add a bounding box.
- **Point2 getMinPoint** () const
  Get the min point.
- **Point2 getMaxPoint** () const
  Get the max point.
- **double getMinCoord** () const
  Get minimum coordinate.
- **double getMaxCoord** () const
  Get maximum coordinate.
- **double getRangeX** () const
  Get x-range.
- **double getRangeY** () const
  Get y-range.
- **double getMaxRange** () const

Generated by Doxygen
Get max range.

- double `get_minX()` const
  Get minX.
- double `get_minY()` const
  Get minY.
- double `get_maxX()` const
  Get maxX.
- double `get_maxY()` const
  Get maxY.
- void `getBounds(double &minX_, double &maxX_, double &minY_, double &maxY_)` const
  Get bounds.
- void `setMinX(double val)`
  Double the box.
- void `setMaxX(double val)`
  Set maxX.
- void `setMinY(double val)`
  Set minY.
- void `setMaxY(double val)`
  Set maxY.
- void `doubleTheBox()`
- void `enlargeRanges(double factor)`
- void `inflateIfDegenerate(double val)`
  Inflate if Degenerate.

Protected Member Functions

- void `treatPointForValidBox(const Point2 &p)`
- void `treatPointForInvalidBox(const Point2 &p)`

Protected Attributes

- double `minX`
- double `minY`
- double `maxX`
- double `maxY`
- bool `bValid`
- GeomTest * `pGeomTest`

Friends

- `std::ostream & operator<< (std::ostream &stream, Bbox2 &p)`

6.1.1 Detailed Description

6.1.2 Constructor & Destructor Documentation

Generated by Doxygen
6.1 GEOM_FADE2D::Bbox2 Class Reference

6.1.2.1 Bbox2() [1/2]

GEOM_FADE2D::Bbox2::Bbox2 (GeomTest * pGeomTest_ = NULL) [inline], [explicit]

Minimum bounds are initialized to DBL_MAX. Maximum bounds are initialized to -DBL_MAX. Box is not valid yet.

6.1.2.2 Bbox2() [2/2]

GEOM_FADE2D::Bbox2::Bbox2 (std::vector<Point2>::const_iterator start_it,
std::vector<Point2>::const_iterator end_it,
GeomTest * pGeomTest_ = NULL) [inline]

Bounds initialized to the minimal bounding box of the iterator range of points.

6.1.3 Member Function Documentation

6.1.3.1 add() [1/4]

bool GEOM_FADE2D::Bbox2::add (std::vector<Point2>::const_iterator start_it,
std::vector<Point2>::const_iterator end_it) [inline]

Extends the bounding box if required.

Returns

true if the bounding box changes, false otherwise

6.1.3.2 add() [2/4]

bool GEOM_FADE2D::Bbox2::add (std::vector<Point2>::const_iterator start_it,
std::vector<Point2>::const_iterator end_it) [inline]

Extends the bounding box if required.

Returns

true if the bounding box changes, false otherwise

Generated by Doxygen
6.1.3.3  add() [3/4]

```cpp
bool GEOM_FADE2D::Bbox2::add (  
    size_t numPoints,  
    double * coordinates ) [inline]
```

Extends the bounding box if required.

Returns

true if the bounding box changes, false otherwise

6.1.3.4  add() [4/4]

```cpp
bool GEOM_FADE2D::Bbox2::add (  
    const Point2 & p ) [inline]
```

Extends the bounding box if required.

Returns

true if the bounding box changes, false otherwise

6.1.3.5  computeCenter()

```cpp
Point2 GEOM_FADE2D::Bbox2::computeCenter ( ) const
```

6.1.3.6  doIntersect()

```cpp
bool GEOM_FADE2D::Bbox2::doIntersect (  
    const Bbox2 & other ) const
```

Two valid bounding boxes intersect if they share at least one point

6.1.3.7  get_maxX()

```cpp
double GEOM_FADE2D::Bbox2::get_maxX ( ) const [inline]
```

Returns

maxX
6.1.3.8 get\_maxY()

```c
double GEOM\_FADE2D::Bbox2::get\_maxY ( ) const [inline]
```

Returns

\texttt{maxY}

6.1.3.9 get\_minX()

```c
double GEOM\_FADE2D::Bbox2::get\_minX ( ) const [inline]
```

Returns

\texttt{minX}

6.1.3.10 get\_minY()

```c
double GEOM\_FADE2D::Bbox2::get\_minY ( ) const [inline]
```

Returns

\texttt{minY}

6.1.3.11 getBounds()

```c
void GEOM\_FADE2D::Bbox2::getBounds ( 
  double & minX_,
  double & maxX_,
  double & minY_,
  double & maxY_ ) const
```

6.1.3.12 get\_Corners()

```c
void GEOM\_FADE2D::Bbox2::get\_Corners ( 
  std::vector< Point2 > & vBoxCorners ) const
```

Convenience function: Returns the 4 corners of the bounding box

6.1.3.13 getMaxCoord()

```c
double GEOM\_FADE2D::Bbox2::get\_maxCoord ( ) const [inline]
```

Returns

the largest coordinate value, i.e. \( \max(\text{maxX},\text{maxY}) \)
6.1.3.14 getMaxPoint()

Point2 GEOM_FADE2D::bbox2::getMaxPoint ( ) const [inline]

Returns

the corner point with the maximum coordinates

6.1.3.15 getMaxRange()

double GEOM_FADE2D::bbox2::getMaxRange ( ) const [inline]

Returns

the largest range, i.e. max(getRangeX(),getRangeY())

6.1.3.16 getMinCoord()

double GEOM_FADE2D::bbox2::getMinCoord ( ) const [inline]

Returns

the smallest coordinate value, i.e. min(minX,minY)

6.1.3.17 getMinPoint()

Point2 GEOM_FADE2D::bbox2::getMinPoint ( ) const [inline]

Returns

the corner point with the minimum coordinates

6.1.3.18 getOffsetCorners()

void GEOM_FADE2D::bbox2::getOffsetCorners ( double offset,
                                          std::vector<Point2> & vBoxCorners ) const

Convenience function: Returns the 4 corners of an enlarged box. The box is enlarged by offset in each direction
6.1.3.19  getRangeX()

double GEOM_FADE2D::Bbox2::getRangeX ( ) const [inline]

Returns

maxX-minX

6.1.3.20  getRangeY()

double GEOM_FADE2D::Bbox2::getRangeY ( ) const [inline]

Returns

maxY-minY

6.1.3.21  inflateIfDegenerate()

void GEOM_FADE2D::Bbox2::inflateIfDegenerate ( 
  double val ) [inline]

When only one point has been added to Bbox2 or when all points have the same x- and/or y- coordinates then Bbox2 is degenerate. This is a valid state but sometimes undesirable. The present method inflates the Bbox2 by adding /p val to maxX and/or maxY.

6.1.3.22  isInBox()

bool GEOM_FADE2D::Bbox2::isInBox ( 
  const Point2 & p ) const

6.1.3.23  isValid()

bool GEOM_FADE2D::Bbox2::isValid ( ) const [inline]

The bounds are valid when at least one point has been added or when set-methods have been used to set minX<=maxX and minY<=maxY

6.1.3.24  operator+()

Bbox2 GEOM_FADE2D::Bbox2::operator+ ( 
  const Bbox2 & b )

Extends the bounding box if required.

Returns

the resulting bounding box
6.1.3.25 setMinX()

```cpp
void GEOM_FADE2D::Bbox2::setMinX ( double val ) [inline]
```

Changes the bounds such that the box grows in each direction by half the previous range. Set `minX`.

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

- Bbox2.h

### 6.2 GEOM_FADE2D::Circle2 Class Reference

Circle.

```cpp
#include <Circle2.h>
```

#### Public Member Functions

- **Circle2 (double x, double y, double sqRadius_)**
  Constructor.
- **Circle2 (const Point2 &center_, double sqRadius_)**
  Constructor.
- **double getRadius ()**
  Get the radius of the circle.
- **double getSqRadius ()**
  Get the squared radius of the circle.
- **Point2 getCenter ()**
  Get the center of the circle.

#### Protected Attributes

- **Point2 center**
- **double sqRadius**

#### Friends

- **std::ostream & operator<< (std::ostream &stream, Circle2 b)**

### 6.2.1 Detailed Description

### 6.2.2 Constructor & Destructor Documentation

#### 6.2.2.1 Circle2() [1/2]

```cpp
GEOM_FADE2D::Circle2::Circle2 ( double x,
                                double y,
                                double sqRadius_ )
```
Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( x )</td>
<td>is x-coordinate of the center</td>
</tr>
<tr>
<td>( y )</td>
<td>is y-coordinate of the center</td>
</tr>
<tr>
<td>( sq_{\text{Radius}} )</td>
<td>is the squared radius of the circle</td>
</tr>
</tbody>
</table>

Warning

The method expects the \textit{squared} radius

6.2.2.2 Circle2() [2/2]

`GEOM_FADE2D::Circle2::Circle2 ( const Point2 & center_, double sqRadius_ )`

Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>center_</td>
<td>center of the circle</td>
</tr>
<tr>
<td>( sq_{\text{Radius}} )</td>
<td>squared radius of the circle</td>
</tr>
</tbody>
</table>

Warning

The method expects the \textit{squared} radius

6.2.3 Member Function Documentation

6.2.3.1 getCenter()

`Point2 GEOM_FADE2D::Circle2::getCenter ()`

Returns

\( \text{a Point2} \) which represents the center

6.2.3.2 getRadius()

double GEOM_FADE2D::Circle2::getRadius ()

Returns

\( \text{the radius} \)
6.2.3.3  

```
double GEOM_FADE2D::Circle2::getSqRadius ( )
```

Returns

the squared radius

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

- Circle2.h

6.3  

GEOM_FADE2D::Color Class Reference

```
#include <Color.h>
```

Public Member Functions

- `Color (double r_, double g_, double b_, double width_, bool bFill_=false)`
- `Color (Colorname c, float width_=0.001, bool bFill_=false)`
- `bool operator< (const Color &other) const`
- `bool operator!= (const Color &other) const`
- `bool operator== (const Color &other) const`

Static Public Member Functions

- static `Colorname getNextColorName ()`

Public Attributes

- `float r`
  - _Red_.
- `float g`
  - _Green_.
- `float b`
  - _Blue_.
- `float width`
  - _Linewidth_.
- `bool bFill`
  - _Fill the shape or not_.

Static Public Attributes

- static `size_t currentColorName`
6.3 GEOM_FADE2D::Color Class Reference

Friends

- std::ostream & operator<< (std::ostream &stream, const Color &c)

6.3.1 Detailed Description

See also

Visualizer2

6.3.2 Constructor & Destructor Documentation

6.3.2.1 Color()[1/2]

GEOM_FADE2D::Color::Color (  
    double r_,  
    double g_,  
    double b_,  
    double width_,  
    bool bFill_ = false  
)

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>r_</td>
<td>red</td>
</tr>
<tr>
<td>g_</td>
<td>green</td>
</tr>
<tr>
<td>b_</td>
<td>blue</td>
</tr>
<tr>
<td>width_</td>
<td>linewidth</td>
</tr>
<tr>
<td>bFill_</td>
<td>fill (default: false)</td>
</tr>
</tbody>
</table>

Note

bFill_=true has two meanings: Objects that can be filled (Triangle2, Circle2) are filled with the rgb-color but line segments get x-marks at their endpoints.

6.3.2.2 Color()[2/2]

GEOM_FADE2D::Color::Color (  
    Colorname c,  
    float width_ = 0.001,  
    bool bFill_ = false  
)

For convenience predefined colors can be used.
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>c</code></td>
<td>is a predefined color name</td>
</tr>
<tr>
<td><code>width</code></td>
<td>linewidth (default: 0.001)</td>
</tr>
<tr>
<td><code>bFill</code></td>
<td>fill (default: false)</td>
</tr>
</tbody>
</table>

Note

`bFill_ = true` has two meanings: Objects that can be filled (Triangle2, Circle2) are filled with the rgb-color but line segments get x-marks at their endpoints.

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

- `Color.h`

6.4 GEOM_FADE2D::ConstraintGraph2 Class Reference

`ConstraintGraph2` is a set of Constraint Edges to be enforced. These are `ConstraintSegment2` objects.

```cpp
#include <ConstraintGraph2.h>
```

Public Member Functions

- `bool isPolygon () const`
  
  Does the constraint graph form a closed polygon?

- `bool isOriented () const`
  
  Are the segments of the constraint graph oriented?

- `void getPolygonVertices (std::vector<Point2 *> &vVertices_)`
  
  Get the vertices of the constraint segments.

- `ConstraintInsertionStrategy getInsertionStrategy () const`
  
  Get the constraint insertion strategy.

- `bool isConstraint (Point2 *p0, Point2 *p1) const`
  
  Check if an edge is a constraint.

- `bool isConstraint (ConstraintSegment2 *pCSeg) const`
  
  Check if a `ConstraintSegment2` is a member.

- `void show (const std::string &name)`
  
  Visualization.

- `void show (Visualizer2 *pVis, const Color &color)`
  
  Visualization.

- `void getOriginalConstraintSegments (std::vector<ConstraintSegment2 *> &vConstraintSegments_) const`
  
  Get the original `ConstraintSegment2` objects.

- `void getFirstChildConstraintSegments (std::vector<ConstraintSegment2 *> &vConstraintSegments_) const`
  
  Get child `ConstraintSegment2` objects.

- `Dt2 * getDt2 ()`

- `void getDirectChildren (ConstraintSegment2 *pParent, ConstraintSegment2 *pChild0, ConstraintSegment2 *pChild1)`
  
  Get direct children.

- `bool isReverse (ConstraintSegment2 *pCSeg) const`
6.4 GEOM_FADE2D::ConstraintGraph2 Class Reference

Protected Attributes

- Dt2 * pDt2
- GeomTest * pGeomPredicates
- ConstraintInsertionStrategy cis
- std::vector< ConstraintSegment2 * > vCSegParents
- bool blsPolygon
- std::map< ConstraintSegment2 *, bool, func_ltDerefPtr< ConstraintSegment2 * > > mCSegReverse
- std::map< Point2 *, size_t > mSplitPointNum
- bool bIsOriented

6.4.1 Detailed Description

See also

createConstraint in the Fade2D class

![Figure 6 Constraints in a triangulation](image)

6.4.2 Member Function Documentation

6.4.2.1 getChildConstraintSegments()

void GEOM_FADE2D::ConstraintGraph2::getChildConstraintSegments (  
std::vector< ConstraintSegment2 * > & vConstraintSegments_ ) const

Returns the current constraint segments, i.e., the original ones or, if splitted, their child segments.

6.4.2.2 getDirectChildren()

void GEOM_FADE2D::ConstraintGraph2::getDirectChildren (  
ConstraintSegment2 * pParent,  
ConstraintSegment2 * & pChild0,  
ConstraintSegment2 * & pChild1 )

Generated by Doxygen
### Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pParent</td>
<td>A ConstraintSegment that may have been split.</td>
</tr>
<tr>
<td>pChild0, pChild1</td>
<td>Direct child segments of pParent. They can be alive or dead (split).</td>
</tr>
</tbody>
</table>

The children are returned in the correct order of the present `ConstraintGraph2`.

#### 6.4.2.3 getDt2()

```cpp
Dt2* GEOM_FADE2D::ConstraintGraph2::getDt2() {
}
```

**Returns**

- the Delaunay class it belongs to

#### 6.4.2.4 getInsertionStrategy()

```cpp
ConstraintInsertionStrategy GEOM_FADE2D::ConstraintGraph2::getInsertionStrategy() const
```

**Returns**

- CIS_CONFORMING_DELAUNAY or CIS_CONstrained_DELAUNAY

#### 6.4.2.5 getOriginalConstraintSegments()

```cpp
void GEOM_FADE2D::ConstraintGraph2::getOriginalConstraintSegments {
    std::vector< ConstraintSegment2* > & vConstraintSegments_ ) const
```

Get the original, `ConstraintSegment2` objects. They are not subdivided but may be dead and have child segments (which may also be dead and have child segments...)

#### 6.4.2.6 getPolygonVertices()

```cpp
void GEOM_FADE2D::ConstraintGraph2::getPolygonVertices {
    std::vector< Point2* > & vVertices_ )
```

Use this method to retrieve the vertices of the present `ConstraintGraph2`. If it forms ONE closed polygon, then the vertices are ordered and oriented in counterclockwise direction, e.g. (a,b,c,c,d,d,a). Otherwise, they are returned in original order. Be aware that the order is only maintained if the `ConstraintGraph2` has been created with `Fade2D::createConstraint(......, bOrientedSegments=true).

**Note**

The segments of the present `ConstraintGraph2` may have been split. In this case, the split points are also contained in the result. If, in the above example, the `ConstraintSegment2(a,b)` has been subdivided at vertex x then the result is (a,x,x,b,b,c,c,d,d,a).

**See also**

- Do you already know Zone2::getBorderEdges() and edgesToPolygons()?
### 6.4.2.7 isConstraint() [1/2]

```cpp
bool GEOM_FADE2D::ConstraintGraph2::isConstraint (Point2 * p0, Point2 * p1) const
```

Checks if the edge (p0,p1) is a constraint of the present `ConstraintGraph2` object.

### 6.4.2.8 isConstraint() [2/2]

```cpp
bool GEOM_FADE2D::ConstraintGraph2::isConstraint (ConstraintSegment2 * pCSeg) const
```

The present `ConstraintGraph2` has been created using a set of edges and this method checks if the `ConstraintSegment2` `pCSeg` is one of them. Original edges that have been split are not alive anymore and are no members. But their child segments are members.

### 6.4.2.9 isOriented()

```cpp
bool GEOM_FADE2D::ConstraintGraph2::isOriented () const
```

Returns `true` if the constraint graph has been created with `bOrientedSegments=true` or if automatic reorientation was possible which is the case for simple polygons.

### 6.4.2.10 isPolygon()

```cpp
bool GEOM_FADE2D::ConstraintGraph2::isPolygon () const
```

Returns `true` when the present `ConstraintGraph` forms a closed polygon.

**Note**

This method won't check if it is a simple polygon (one without self-intersections).

### 6.4.2.11 isReverse()

```cpp
bool GEOM_FADE2D::ConstraintGraph2::isReverse (ConstraintSegment2 * pCSeg) const
```

Get the orientation of a `ConstraintSegment2`

A `ConstraintSegment2` `pCSeg` is unoriented because it may participate (with different orientations) in more than just one `ConstraintGraph2` and thus the vertices returned by `pCSeg->getSrc()` and `pCSeg->getTrg()` do not carry any orientation information. However, the orientation of `pCSeg` is stored in the `ConstraintGraph2` objects where `pCSeg` is a member and this method returns if the source and target vertex must be exchanged to match the present graph's direction.
6.4.2.12 show() [1/2]

void GEOM_FADE2D::ConstraintGraph2::show (  
    const std::string & name )

6.4.2.13 show() [2/2]

void GEOM_FADE2D::ConstraintGraph2::show (  
    Visualizer2 * pVis,  
    const Color & color )

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

- ConstraintGraph2.h

6.5 GEOM_FADE2D::ConstraintSegment2 Class Reference

A ConstraintSegment2 represents a Constraint Edge.

#include <ConstraintSegment2.h>

Public Member Functions

- Point2 * getSrc () const  
  Get the first endpoint.
- Point2 * getTrg () const  
  Get the second endpoint.
- bool isAlive () const  
  Check if the present ConstraintSegment2 is alive.
- ConstraintInsertionStrategy getCIS () const  
  Get the Constraint Insertion Strategy (CIS)
- bool operator< (const ConstraintSegment2 &pOther) const  
  operator<(...) Compares the vertex pointers of the endpoints, not the length
- Point2 * insertAndSplit (const Point2 &splitPoint)  
  Split a constraint segment.
- bool split_combinatorialOnly (Point2 *pSplit)  
  Split a constraint segment.
- bool splitAndRemovePrev (const Point2 &split)  
- void getChildrenRec (std::vector< ConstraintSegment2 * > &vChildrenConstraintSegments)  
  Get all children Recursively retrieve all children of the current ConstraintSegment2.
- void getChildrenAndSplitPoint (ConstraintSegment2 * &pCSeg0, ConstraintSegment2 * &pCSeg1, Point2 * &pSplitPoint)  
  Get the children and the split point Retrieve the two direct children of the current ConstraintSegment2 as well as the split point.

Public Attributes

- int label
Protected Attributes

- `Point2 * p0`
- `Point2 * p1`
- `ConstraintInsertionStrategy cis`
- `bool bAlive`
- `std::vector< ConstraintSegment2 * > vChildren`

Static Protected Attributes

- `static int runningLabel`

Friends

- `class ConstraintMgr`
- `class ConstraintGraph2`
- `std::ostream & operator<<(std::ostream &stream, const ConstraintSegment2 &cSeg)`

6.5.1 Detailed Description

A `ConstraintSegment2` can belong to more than one `ConstraintGraph2` object, thus it is unoriented. But the ConstraintGraph knows the orientation of its `ConstraintSegment2`'s.

6.5.2 Member Function Documentation

6.5.2.1 getCIS()

`ConstraintInsertionStrategy GEOM_FADE2D::ConstraintSegment2::getCIS () const`

Returns

the constraint insertion strategy (CIS) of the present object

6.5.2.2 getSrc()

`Point2* GEOM_FADE2D::ConstraintSegment2::getSrc () const`

Returns

the first vertex
6.5.2.3 getTrg()

Point2* GEOM_FADE2D::ConstraintSegment2::getTrg ( ) const

Returns

the second vertex

6.5.2.4 insertAndSplit()

Point2* GEOM_FADE2D::ConstraintSegment2::insertAndSplit ( const Point2 & splitPoint )

Splits the ConstraintSegment2 (which must be alive) at splitPoint.

It may be impossible to represent a point on a certain line segment using floating point arithmetic. Therefore it is highly recommended to split a ConstraintSegment2 object not just by inserting points into the triangulation but using the present method. It does not require that splitPoint is exactly on the segment.

Note

A splitted ConstraintSegment2 is dead and it has two child segments (which may also be dead and have children). The class is organized as a binary tree.

6.5.2.5 isAlive()

bool GEOM_FADE2D::ConstraintSegment2::isAlive ( ) const

Returns

if the object is alive

6.5.2.6 split_combinatorialOnly()

bool GEOM_FADE2D::ConstraintSegment2::split_combinatorialOnly ( Point2 * pSplit )

internal use only (unless you do something very unusual)

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

- ConstraintSegment2.h
Directed Edge.

```cpp
#include <Edge2.h>
```

**Public Member Functions**

- **Edge2** (const Edge2 &e_)
  - Constructor.
- **Edge2** (Triangle2 *pT, int oppIdx_)
- Edge2 & operator= (const Edge2 &other)
- bool operator< (const Edge2 &e) const
  - operator<() (const Edge2 &e)
- bool operator== (const Edge2 &e) const
  - operator==() (const Edge2 &e)
- bool operator!=(const Edge2 &e) const
  - operator!=(() (const Edge2 &e)
- Point2 * getSrc () const
  - Get the source point.
- Point2 * getTrg () const
  - Get the target point.
- void getPoints (Point2 *)&p1, Point2 *)&p2) const
  - Get the endpoints.
- double getLength2D () const
- Triangle2 * getTriangle () const
- void getTriangles (Triangle2 *)&pT0, Triangle2 *)&pT1, int &idx0, int &idx1) const

**Protected Attributes**

- Triangle2 * pT
- int oppIdx

**Friends**

- std::ostream & operator<< (std::ostream &stream, const Edge2 &e)

### 6.6.1 Constructor & Destructor Documentation

#### 6.6.1.1 Edge2()

```cpp
GEOM_FADE2D::Edge2::Edge2 (  
    Triangle2 * pT,  
    int oppIdx_  
)
```
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( pT )</td>
<td>is the triangle from which the edge is constructed</td>
</tr>
<tr>
<td>( \text{oppIdx} )</td>
<td>is intra-triangle-index of the opposite vertex (of the edge) in ( pT )</td>
</tr>
</tbody>
</table>

The orientation of the constructed \texttt{Edge2} is counterclockwise (CCW) with respect to \( pT \). Example: \texttt{Edge2(pT,0)} creates an edge from \( pT \rightarrow \text{getCorner}(1) \) to \( pT \rightarrow \text{getCorner}(2) \).

### 6.6.2 Member Function Documentation

#### 6.6.2.1 getLength2D()

double GEOM_FADE2D::Edge2::getLength2D ( ) const

Get the length

Returns

the length of the edge

#### 6.6.2.2 getPoints()

void GEOM_FADE2D::Edge2::getPoints ( 
  Point2 * & p1,
  Point2 * & p2 ) const

returns the source point of the edge as \( p1 \) and the target point as \( p2 \)

#### 6.6.2.3 getSrc()

Point2* GEOM_FADE2D::Edge2::getSrc ( ) const

Returns

the source point of the edge, i.e. \( pT \rightarrow \text{getCorner}((\text{oppIdx+1})\%3) \)

#### 6.6.2.4 getTrg()

Point2* GEOM_FADE2D::Edge2::getTrg ( ) const

Returns

the target point of the edge, i.e. \( pT \rightarrow \text{getCorner}((\text{oppIdx+2})\%3) \)
6.6.2.5 getTriangle()

Triangle2* GEOM_FADE2D::Edge2::getTriangle() const

Get the triangle

Returns

the triangle whose directed edge the present edge is

6.6.2.6 getTriangles()

void GEOM_FADE2D::Edge2::getTriangles(
    Triangle2*& pT0,
    Triangle2*& pT1,
    int& idx0,
    int& idx1) const

Get the triangles

Returns

the two adjacent triangles of the present edge along with their intra-triangle-indices

Parameters

<table>
<thead>
<tr>
<th>pT0</th>
<th>is used to return the triangle whose directed edge the present edge is</th>
</tr>
</thead>
<tbody>
<tr>
<td>idx0</td>
<td>is the opposite intra-triangle-index in pT0 of the present edge</td>
</tr>
<tr>
<td>pT1</td>
<td>is the other adjacent triangle at the present edge (or NULL)</td>
</tr>
<tr>
<td>idx1</td>
<td>is the intra-triangle index of the present edge in pT1 (or -1)</td>
</tr>
</tbody>
</table>

6.6.2.7 operator!=()

bool GEOM_FADE2D::Edge2::operator!=(const Edge2& e) const [inline]

operator!=() returns true if the compared edges are different. Be aware that edges are directed and therefore two adjacent triangles do not share the same edge.

6.6.2.8 operator<()

bool GEOM_FADE2D::Edge2::operator<(const Edge2& e) const [inline]

operator<() does NOT compare edge lengths but the associated triangle pointers and intra-triangle indices. This is useful when edges are used in STL containers.
6.6.2.9 operator==()

bool GEOM_FADE2D::Edge2::operator== (const Edge2 & e) const [inline]

operator==() compares oriented edges, i.e., it returns only true when the two edges have been made from the same triangle and the same intra-triangle-index.

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

- Edge2.h

6.7 GEOM_FADE2D::Fade_2D Class Reference

Delaunay triangulation - the main class.

#include <Fade_2D.h>

Public Member Functions

- **Fade_2D** (unsigned numExpectedVertices=3)
  Constructor of the main triangulation class.
- bool checkValidity (bool bCheckEmptyCircleProperty, const std::string &msg) const
  Checks if a triangulation is valid.
- int setNumCPU (int numCPU)
  Set the number CPU cores for multithreading.
- void statistics (const std::string &s) const
  Statistics.
- void show (const std::string &postscriptFilename, bool bWithConstraints=true) const
  Draws the triangulation as postscript file.
- void show (Visualizer2 *pVis, bool bWithConstraints=true) const
  Draws the triangulation as postscript file using an existing Visualizer2 object.
- void remove (Point2 *pVertex)
  Remove a single vertex.
- void getConvexHull (bool bAllVertices, std::vector<Point2 *> &vConvexHullPointsOut)
  Compute the convex hull.
- Point2 * insert (const Point2 &p)
  Insert a single point.
- void insert (const std::vector<Point2> &vInputPoints)
  Insert a vector of points.
- void insert (const std::vector<Point2> &vInputPoints, std::vector<Point2 *> &vHandles)
  Insert points from a std::vector and store pointers in vHandles.
- void insert (int numPoints, double *aCoordinates, Point2 **aHandles)
  Insert points from an array.
- double measureTriangulationTime (std::vector<Point2> &vPoints)
  Measure the Delaunay triangulation time.
- Triangle2 * locate (const Point2 &p)
  Locate a triangle which contains p.
- void refine (Zone2 *pZone, double minAngleDegree, double minEdgeLength, double maxEdgeLength, bool bAllowConstraintSplitting)
Delaunay refinement.
- void refineAdvanced (MeshGenParams *pParameters)
  Delaunay refinement and grid meshing.
- size_t numberOfPoints () const
  Number of points.
- size_t numberOfTriangles () const
  Number of triangles.
- void getTrianglePointers (std::vector<Triangle2 *> &vAllTriangles) const
  Get pointers to all triangles.
- void getVertexPointers (std::vector<Point2 *> &vAllPoints) const
  Get pointers to all vertices.
- Triangle2 * getAdjacentTriangle (Point2 *p0, Point2 *p1) const
  Get adjacent triangle.
- bool is2D () const
  Check if the triangulation contains triangles (which is the case if at least 3 non-collinear points exist in the triangulation.
- ConstraintGraph2 * createConstraint (std::vector<Segment2> &vSegments, ConstraintInsertionStrategy cis, bool bOrientedSegments=false)
  Add constraint edges (edges, polyline, polygon)
- Zone2 * createZone (ConstraintGraph2 *pConstraintGraph, ZoneLocation zoneLoc, bool bVerbose=true)
  Create a zone.
- Zone2 * createZone (ConstraintGraph2 *pConstraintGraph, ZoneLocation zoneLoc, const Point2 &startPoint, bool bVerbose=true)
  Create a zone limited by a ConstraintGraph by growing from a start point.
- Zone2 * createZone (const std::vector<ConstraintGraph2> &vConstraintGraphs, ZoneLocation zoneLoc, const Point2 &startPoint, bool bVerbose=true)
  Create a zone limited by multiple ConstraintGraph2 objects by growing from a start point.
- Zone2 * createZone (std::vector<Triangle2 *> &vTriangles, bool bVerbose=true)
  Create a zone defined by a vector of triangles.
- void deleteZone (Zone2 *pZone)
  Delete a Zone2 object.
- void applyConstraintsAndZones ()
  Apply formerly defined conforming constraints and zones.
- Bbox2 computeBoundingBox () const
  Compute the axis-aligned bounding box of the points.
- bool isConstraint (Triangle2 *pT, int ith) const
  Check if an edge is a constraint edge.
- void getAliveConstraintSegments (std::vector<ConstraintSegment2 *> &vAliveConstraintSegments) const
  Get active (alive) constraint segments.
- void getAliveAndDeadConstraintSegments (std::vector<ConstraintSegment2 *> &vAllConstraintSegments) const
  Get all (alive and dead) constraint segments.
- ConstraintSegment2 * getConstraintSegment (Point2 *p0, Point2 *p1) const
  Retrieve a ConstraintSegment2.
- void getIncidentTriangles (Point2 *pVtx, std::vector<Triangle2 *> &vIncidentT) const
  Get incident triangles.
- void getIncidentVertices (Point2 *pVtx, std::vector<Point2 *> &vIncidentVertices) const
  Get incident vertices.
- void writeObj (const std::string &filename) const
  Write the current triangulation to an *.obj file.
- void writeObj (const std::string &filename, Zone2 *pZone) const
  Write a zone to an *.obj file.
• void writeWebScene (const char ∗ path) const
  Write the current triangulation to an *.obj file.
• void writeWebScene (const char ∗ path, Zone2 ∗ pZone) const
  Write a zone to an *.obj file.
• void subscribe (MsgType msgType, MsgBase ∗ pMsg)
  Register a message receiver.
• void unsubscribe (MsgType msgType, MsgBase ∗ pMsg)
  Unregister a message receiver.
• bool isConstraint (Point2 ∗ p0, Point2 ∗ p1) const
  Check if an edge is a constraint edge.
• bool isConstraint (Point2 ∗ pVtx) const
  Check if a vertex is a constraint vertex.
• void printLicense () const
• Zone2 ∗ importTriangles (std::vector<Point2 > &vPoints, bool bReorientIfNeeded, bool bCreateExtended←BoundingBox)
  Import triangles.
• Orientation2 getOrientation (const Point2 & p0, const Point2 & p1, const Point2 & p2)
  Compute the orientation of 3 points.
• void cutTriangles (const Point2 & knifeStart, const Point2 & knifeEnd, bool bTurnEdges…) 
  Cut through a triangulation.
• void cutTriangles (std::vector<Segment2 > &vSegments, bool bTurnEdgesIntoConstraints)
  Cut through a triangulation.
• Zone2 ∗ createZone_cookieCutter (std::vector<Segment2 > &vSegments, bool bProtectEdges)
  Cookie Cutter The Cookie Cutter cuts out a part of a triangulation and returns it as a Zone2 object.
• void enableMultithreading ()
  Enable multithreading (deprecated)

6.7.1 Detailed Description

Fade_2D represents a Delaunay triangulation in 2D or 2.5D (depends on the used namespace)

6.7.2 Constructor & Destructor Documentation

6.7.2.1 Fade_2D()

GEOM_FADE2D::Fade_2D::Fade_2D ( 
  unsigned numExpectedVertices = 3 ) [inline], [explicit]

Parameters

numExpectedVertices specifies the number of points that will probably be inserted.

This is a default parameter that does not need to be specified. By default the internal data structures are initialized for 3 points and they are automatically reconfigured later if necessary.
This method establishes conforming constraint segments and zones which depend on them. For technical reasons conforming constraint segments are not immediately established but inserted at the end of the triangulation process. This step must be triggered manually i.e., it is up to the user to call applyConstraintsAndZones() before the resulting triangulation is used. If afterwards the triangulation is changed in any way, applyConstraintsAndZones() must be called again.

**checkValidity()**

Checks the validity of the data structure.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bCheckEmptyCircleProperty</code></td>
<td>specifies if (slow!) multiprecision arithmetic shall be used to recheck the empty circle property</td>
</tr>
<tr>
<td><code>msg</code></td>
<td>is a debug string that will be shown in terminal output so that you know which checkValidity call currently runs.</td>
</tr>
</tbody>
</table>

This method is thought for development purposes. Don't call it method unless you assume that something is wrong with the code.

**computeBoundingBox()**

If no points have been inserted yet, then the returned Bbox2 object is invalid and its member function `Bbox2::is<Valid>()` returns false.

**createConstraint()**

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vSegments</code></td>
<td>are segments which shall appear as edges of the triangulation. The segments may be automatically reordered and reoriented, see <code>bOrientedSegments</code> below.</td>
</tr>
</tbody>
</table>
**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>cis</strong></td>
<td>is the Constraint Insertion Strategy (please compare the images):</td>
</tr>
<tr>
<td></td>
<td>- CIS_CONSTRAINED_DELAUNAY inserts the constraint segments without</td>
</tr>
<tr>
<td></td>
<td>subdivision unless existing vertices or existing constraint segments</td>
</tr>
<tr>
<td></td>
<td>are crossed. <strong>This is the recommended constraint insertion strategy</strong></td>
</tr>
<tr>
<td></td>
<td>for most cases.</td>
</tr>
<tr>
<td></td>
<td>- CIS_CONFORMING_DELAUNAY subdivides the segments until they naturally</td>
</tr>
<tr>
<td></td>
<td>appear as edges of the Delaunay triangulation i.e., the empty</td>
</tr>
<tr>
<td></td>
<td>circumcircle property is maintained. Advantages and disadvantages of</td>
</tr>
<tr>
<td></td>
<td>the conforming insertion strategy are:</td>
</tr>
<tr>
<td></td>
<td>– Better shaped triangles are made around conforming constraint</td>
</tr>
<tr>
<td></td>
<td>segments. Be aware that well shaped triangles can also be obtained with</td>
</tr>
<tr>
<td></td>
<td>CIS_CONSTRAINED_DELAUNAY when the mesh generator is used afterwards.</td>
</tr>
<tr>
<td></td>
<td>See <strong>refineAdvanced</strong>().</td>
</tr>
<tr>
<td></td>
<td>– Conforming constraint segments may enforce a huge number of tiny</td>
</tr>
<tr>
<td></td>
<td>triangles in narrow geometric settings and full insertion may even be</td>
</tr>
<tr>
<td></td>
<td>impossible in extremely narrow situations.</td>
</tr>
<tr>
<td></td>
<td>– Intersecting conforming constraint segments are not supported by</td>
</tr>
<tr>
<td></td>
<td>design</td>
</tr>
<tr>
<td></td>
<td>– Conforming constraint segments are not immediately established, see</td>
</tr>
<tr>
<td></td>
<td><strong>applyConstraintsAndZones</strong>().</td>
</tr>
<tr>
<td><strong>bOrientedSegments</strong></td>
<td>specifies whether the segments in vSegments are oriented (oriented, not ordered). To maintain backwards compatibility <strong>bOrientedSegments</strong> is a default parameter and it defaults to false. Fade will maintain the orientation of the segments only when <strong>bOrientedSegments=true</strong>. This regards functions like <strong>ConstraintGraph2::getPolygonVertices</strong>() when the order of the returned vertices is important. Another consequence is when later a <strong>Zone2</strong> object shall be constructed from this <strong>ConstraintGraph2</strong>. This is only possible if either this value is true (then the algorithm will assume that all segments exist in counterclockwise orientation) or when the value is false and the segments can be automatically reoriented and reordered such that they form one closed polygon.</td>
</tr>
</tbody>
</table>

**Returns**

a pointer to the new **ConstraintGraph2** object
Figure 7 Delaunay triangulation without constraints

Figure 8 Constraint insertion with CIS_CONSTRAINED_DELAUNAY
6.7.3.5 createZone() [1/4]

```cpp
Zone2* GEOM_FADE2D::Fade_2D::createZone (  
    ConstraintGraph2 * pConstraintGraph,  
    ZoneLocation zoneLoc,  
    bool bVerbose = true  
)
```

A Zone2 object is an area of a triangulation, possibly bounded by a ConstraintGraph.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>zoneLoc</code></td>
<td>is ZL_INSIDE, ZL_OUTSIDE or ZL_GLOBAL.</td>
</tr>
<tr>
<td><code>pConstraintGraph</code></td>
<td>points to a formerly created ConstraintGraph2 object (which must contain a simple polygon) or is NULL in case of zoneLoc==ZLGLOBAL.</td>
</tr>
<tr>
<td><code>bVerbose</code></td>
<td>is by default true and causes a warning if NULL is returned.</td>
</tr>
</tbody>
</table>

**Returns**

a pointer to the new Zone2 object or NULL if no triangles exist or pConstraintGraph->isOriented() returns false.
See also

deleteZone(Zone2* pZone).

Figure 10 Zones in a triangulation

6.7.3.6 createZone() [2/4]

Zone2* GEOM_FADE2D::Fade_2D::createZone (
    const std::vector< ConstraintGraph2* > & vConstraintGraphs,
    ZoneLocation zoneLoc,
    const Point2 & startPoint,
    bool bVerbose = true )

A Zone2 object is an area of the triangulation, see createZone

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>vConstraintGraphs</td>
<td>is a vector of ConstraintGraph objects</td>
</tr>
<tr>
<td>zoneLoc</td>
<td>must be ZL_GROW</td>
</tr>
<tr>
<td>startPoint</td>
<td>is the point from which the area is grown until the borders specified in vConstraintGraphs are reached</td>
</tr>
<tr>
<td>bVerbose</td>
<td>is by default true and causes a warning if NULL is returned.</td>
</tr>
</tbody>
</table>

Returns

a pointer to the new Zone2 object (or NULL if zoneLoc!=ZL_GROW or no triangles exist)

6.7.3.7 createZone() [3/4]

Zone2* GEOM_FADE2D::Fade_2D::createZone ( ConstraintGraph2* pConstraintGraph,
A `Zone2` object is an area of the triangulation, see `createZone`.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pConstraintGraph</code></td>
<td>is a constraint whose edges specify the area’s border</td>
</tr>
<tr>
<td><code>zoneLoc</code></td>
<td>must be ZL_GROW</td>
</tr>
<tr>
<td><code>startPoint</code></td>
<td>is the point from which the area is grown until the borders specified in pConstraint are reached</td>
</tr>
<tr>
<td><code>bVerbose</code></td>
<td>is by default true and causes a warning if NULL is returned.</td>
</tr>
</tbody>
</table>

**Returns**

a pointer to the new `Zone2` object (or NULL if `zoneLoc`!=ZL_GROW or no triangles exist)

---

**6.7.3.8 createZone() [4/4]**

```cpp
Zone2* GEOM_FADE2D::Fade_2D::createZone (  
    std::vector< Triangle2* > & vTriangles,  
    bool bVerbose = true )
```

A `Zone2` object is an area of the triangulation, see `createZone`.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vTriangles</code></td>
<td>specifies a simple polygon.</td>
</tr>
<tr>
<td><code>bVerbose</code></td>
<td>is by default true and causes a warning if NULL is returned.</td>
</tr>
</tbody>
</table>

**Returns**

a pointer to the new `Zone2` object (or NULL if `vTriangles` is empty)

---

**6.7.3.9 createZone_cookieCutter()**

```cpp
Zone2* GEOM_FADE2D::Fade_2D::createZone_cookieCutter (  
    std::vector< Segment2 > & vSegments,  
    bool bProtectEdges )
```

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>vSegments</code></td>
<td>specifies a simple polygon.</td>
</tr>
<tr>
<td><code>bProtectEdges</code></td>
<td>specifies if existing triangles shall be protected with constraint segments.</td>
</tr>
</tbody>
</table>
Returns

a Zone2 object consisting of all triangles inside the polygon or NULL when the operation has failed due to
wrong preconditions.

Properties: The input polygon (vSegments) does not need to have certain height values, the z-coordinates
are computed automatically. The input polygon is automatically trimmed when it is outside the convex hull of the
triangulation. Insertion of intersection points could flip existing edges in the triangulation, this can be avoided using
bProtectEdges=true. The operation may create constraint segments.

6.7.3.10 cutTriangles() [1/2]

```cpp
void GEOM_FADE2D::Fade_2D::cutTriangles(
    const Point2 & knifeStart,
    const Point2 & knifeEnd,
    bool bTurnEdgesIntoConstraints)
```

**Parameters**

- **knifeStart** is one point of the knife segment
- **knifeEnd** is the second point of the knife segment
- **bTurnEdgesIntoConstraints** turns all 3 edges of each intersected triangle into constraint segments.

This method inserts a constraint edge knife(knifeStart,knifeEnd). If existing edges $E$ are intersected by knife, then
knife is subdivided at the intersection points $P$.

In any case knife will exist (in a possibly subdivided form) in the result. But a consequence of the insertion of the
points $P$ is that the edges $E$ and even edges which are not intersected by knife may be flipped. Use bTurnEdgesIntoConstraints=true to avoid that.

**Note**

The intersection point of two line segments may not be exactly representable in double precision floating point
arithmetic and thus tiny rounding errors may occur. As a consequence two very close intersection points may
be rounded to the same coordinates.

When more than one knife segment is inserted then the method void cutTriangles(std::vector<Segment2>& vSegments,bool bTurnEdgesIntoConstraints) should be used. The reason is that each individual cut operation changes the triangulation and thus iterative calls to the present version of the method can lead to a different result.

6.7.3.11 cutTriangles() [2/2]

```cpp
void GEOM_FADE2D::Fade_2D::cutTriangles(
    std::vector<Segment2> & vSegments,
    bool bTurnEdgesIntoConstraints)
```

**Parameters**

- **vSegments** are the knife segments
- **bTurnEdgesIntoConstraints** specifies if intersected edges shall automatically be turned into constraints

Generated by Doxygen
Same method as void cutTriangles(const Point2& knifeStart, const Point2& knifeEnd, bool bTurnEdgesIntoConstraints) but it takes a vector of segments instead of a single segment. This is the recommended method to cut through a triangulation when more than one knife segment exists.

### 6.7.3.12 deleteZone()

```cpp
tvoid GEOM_FADE2D::Fade_2D::deleteZone ( 
    Zone2 * pZone )
```

Zone2 objects are automatically destroyed with their Fade_2D objects. In addition this method provides the possibility to eliminate Zone2 objects earlier.

**Note**

Zones are designed transparently: When two zones Z1 and Z2 are combined to a new one Z3 (for example through a boolean operation) then Z1,Z2,Z3 form a tree such that changes in the leaf nodes Z1 and Z2 can propagate up to the root node Z3. For this reason Z1 and Z2 must be alive as long as Z3 is used.

### 6.7.3.13 enableMultithreading()

```cpp
tvoid GEOM_FADE2D::Fade_2D::enableMultithreading ( )
```

Deprecated: Use setNumCPU() instead. This method is kept for compatibility with existing applications. Internally it calls setNumCPU(0) to automatically determine and use the number of available CPU cores.

### 6.7.3.14 getAdjacentTriangle()

```cpp
tTriangle2* GEOM_FADE2D::Fade_2D::getAdjacentTriangle ( 
    Point2 * p0, 
    Point2 * p1 ) const
```

Returns

the triangle that has the edge (p0,p1) or NULL if no such edge is present

**Note**

Recall the counter-clockwise enumeration of vertices in a triangle. If (p0,p1) is used, the unique triangle with the CCW oriented edge (p0,p1) is returned, using (p1,p0) one gets the other adjacent triangle.

### 6.7.3.15 getConstraintSegment()

```cpp
tConstraintSegment2* GEOM_FADE2D::Fade_2D::getConstraintSegment ( 
    Point2 * p0, 
    Point2 * p1 ) const
```

Returns

a pointer to the ConstraintSegment2 between p0 and p1 or NULL if the segment is not a constraint edge (or dead because it has been splitted)

### 6.7.3.16 getConvexHull()

```cpp
tvoid GEOM_FADE2D::Fade_2D::getConvexHull ( 
    bool bAllVertices, 
    std::vector<Point2> & vConvexHullPointsOut )
```
6.7.3.17 getIncidentTriangles()

```cpp
void GEOM_FADE2D::Fade_2D::getIncidentTriangles (  
    Point2 * pVtx,  
    std::vector< Triangle2 * > & vIncidentT ) const
```

Stores pointers to all triangles around pVtx into vIncidentT

6.7.3.18 getIncidentVertices()

```cpp
void GEOM_FADE2D::Fade_2D::getIncidentVertices (  
    Point2 * pVtx,  
    std::vector< Point2 * > & vIncidentVertices ) const
```

Stores pointers to all vertices around pVtx into vIncidentVertices

6.7.3.19 getOrientation()

```cpp
Orientation2 GEOM_FADE2D::Fade_2D::getOrientation (  
    const Point2 & p0,  
    const Point2 & p1,  
    const Point2 & p2 )
```

Returns

ORIENTATION2_COLLINEAR, ORIENTATION2_CW (clockwise) or ORIENTATION2_CCW (counterclockwise)

6.7.3.20 getTrianglePointers()

```cpp
void GEOM_FADE2D::Fade_2D::getTrianglePointers (  
    std::vector< Triangle2 * > & vAllTriangles ) const
```

This command fetches the existing triangles

Parameters

| out | vAllTriangles | is used to return the triangles |

---

Generated by Doxygen
Note

that the lifetime of data from the Fade2D datastructures does exceed the lifetime of the Fade2D object.

6.7.3.21 getVertexPointers()

void GEOM_FADE2D::Fade_2D::getVertexPointers (  
    std::vector<Point2 *> & vAllPoints ) const

Parameters

- **vAllPoints** is an empty vector of `Point2` pointers.

Stores pointers to all vertices of the triangulation in `vAllPoints`. The order in which the points are stored is not necessarily the insertion order. For geometrically identical points which have been inserted multiple times, only one pointer exists. Thus `vAllPoints.size()` can be smaller than the number of inserted points.

Note

that the lifetime of data from the Fade2D datastructures does exceed the lifetime of the Fade2D object.

6.7.3.22 importTriangles()

Zone2* GEOM_FADE2D::Fade_2D::importTriangles (  
    std::vector<Point2> & vPoints,  
    bool bReorientIfNeeded,  
    bool bCreateExtendedBoundingBox )

This method imports triangles into an empty Fade object. The triangles do not need to satisfy the empty circle property.

Parameters

- **vPoints** contains the input vertices (3 subsequent ones per triangle)
- **bReorientIfNeeded** specifies if the orientations of the point triples shall be checked and corrected. If the point triples are certainly oriented in counterclockwise order then the orientation test can be skipped.
- **bCreateExtendedBoundingBox** can be used to insert 4 dummy points of an extended bounding box. This is convenient in some cases. Use false if you are unsure.

Returns

- a pointer to a `Zone2` object or NULL if the input data is invalid
Warning

This method requires 100% correct input. A frequent source of trouble is when client software reads the points that shall be used from an ASCII file. The ASCII format is convenient but it can **introduce rounding errors that cause intersections and flipped triangle orientations**. Thus it is highly recommended to transfer point coordinates with binary files. See also readPointsBIN() and writePointsBIN().

### 6.7.3.23 insert() [1/4]

```cpp
Point2* GEOM_FADE2D::Fade_2D::insert (
    const Point2 & p )
```

**Parameters**

- **p** is the point to be inserted.

**Returns**

a pointer to the point in the triangulation

The triangulation keeps a copy of p. The return value is a pointer to this copy. If duplicate points are inserted, the triangulation does not create new copies but returns a pointer to the copy of the very first insertion.

**Note**

This method offers a very good performance but it is still faster if all points are passed at once, if possible.

### 6.7.3.24 insert() [2/4]

```cpp
void GEOM_FADE2D::Fade_2D::insert {
    const std::vector<Point2> & vInputPoints
}
```

**Parameters**

- **vInputPoints** contains the points to be inserted.

**Note**

Use Fade_2D::setNumCPU() to activate multithreading

### 6.7.3.25 insert() [3/4]

```cpp
void GEOM_FADE2D::Fade_2D::insert {
    const std::vector<Point2> & vInputPoints,
    std::vector<Point2 *> & vHandles }
```
Parameters

<table>
<thead>
<tr>
<th>vInputPoints</th>
<th>contains the points to be inserted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>vHandles</td>
<td>(empty) is used by Fade to return Point2 pointers</td>
</tr>
</tbody>
</table>

Internally, the triangulation keeps copies of the inserted points which are returned in vHandles (in the same order). If duplicate points are contained in vInputPoints then only one copy will be made and a pointer to this unique copy will be stored in vHandles for every occurrence.

Note

Use Fade_2D::setNumCPU() to activate multithreading

6.7.3.26 insert() [4/4]

```cpp
void GEOM_FADE2D::Fade_2D::insert (  
    int numPoints,  
    double * aCoordinates,  
    Point2 ** aHandles )
```

Parameters

<table>
<thead>
<tr>
<th>numPoints</th>
<th>is the number of points to be inserted</th>
</tr>
</thead>
<tbody>
<tr>
<td>aCoordinates</td>
<td>is an array of 2n double values, e.g. {x0,y0,x1,y1,...,xn,yn}</td>
</tr>
<tr>
<td>aHandles</td>
<td>is an empty array with size n where pointers to the inserted points will be stored by Fade</td>
</tr>
</tbody>
</table>

Note

Use Fade_2D::setNumCPU() to activate multithreading

6.7.3.27 is2D()

```cpp
bool GEOM_FADE2D::Fade_2D::is2D ( ) const
```

As long as all inserted points are collinear the triangulation does not contain triangles. This is clearly the case as long as less than three input points are present but it may also be the case when 3 or more points have been inserted when all these points are collinear. These points are then in a pending state, i.e. they will be triangulated as soon as the first non-collinear point is inserted.

![Figure 11: Triangles are generated as soon as the first non-collinear point is inserted.](image.png)
6.7.3.28 isConstraint() [1/3]

```cpp
bool GEOM_FADE2D::Fade_2D::isConstraint ( Triangle2* pT, int ith ) const
```

Returns whether the edge in triangle `pT` which is opposite to the `ith` vertex is a constraint edge.

6.7.3.29 isConstraint() [2/3]

```cpp
bool GEOM_FADE2D::Fade_2D::isConstraint ( Point2* p0, Point2* p1 ) const
```

Returns whether the edge `(p0,p1)` is a constraint edge.

6.7.3.30 isConstraint() [3/3]

```cpp
bool GEOM_FADE2D::Fade_2D::isConstraint ( Point2* pVtx ) const
```

Returns whether the vertex `pVtx` belongs to a constraint edge.

6.7.3.31 locate()

```cpp
Triangle2* GEOM_FADE2D::Fade_2D::locate ( const Point2 & p )
```

Figure 12 Point location

The `Fade_2D` class can be used as a data structure for point location. This method returns a pointer to a triangle which contains `p`. 
Parameters

\( p \) is the query point

Returns

a pointer to a Triangle2 object (or NULL if is2D()==false or if \( p \) is outside the triangulation)

6.7.3.32 measureTriangulationTime()

double GEOM_FADE2D::Fade_2D::measureTriangulationTime ( std::vector< Point2 > & vPoints )

This method evaluates the performance of single- and multithreaded point insertion into a Delaunay triangulation.

Parameters

\textbf{in} \textit{vPoints} are the points to be inserted

Returns

the total wall-time for point insertion in seconds

Note

The method cleans up the triangulation (objects, memory) on exit. Thus the time measured outside this method may be slightly larger than the returned time that is exactly the time needed to triangulate the input points.
Use Fade_2D::setNumCPU() to activate multithreading

6.7.3.33 numberOfPoints()

size_t GEOM_FADE2D::Fade_2D::numberOfPoints ( ) const

Returns

the number of points in the triangulation

Note

Due to possibly duplicate input points the number of points is not stored somewhere but freshly computed in \( O(n) \) time. This is fast but you are advised to avoid calling this method over-frequently in a loop. Duplicate point insertions count only once.
6.7.3.34  

**numberOfTriangles()**

```
size_t GEOM_FADE2D::Fade_2D::numberOfTriangles ( ) const
```

**Returns**

the number of triangles in the triangulation (or 0 as long as is2D() is false).

6.7.3.35  

**printLicense()**

```
void GEOM_FADE2D::Fade_2D::printLicense ( ) const
```

Prints informations about the currently used license.

6.7.3.36  

**refine()**

```
void GEOM_FADE2D::Fade_2D::refine ( 
    Zone2 ∗ pZone,
    double minAngleDegree,
    double minEdgeLength,
    double maxEdgeLength,
    bool bAllowConstraintSplitting
)
```

Creates a mesh inside the area given by a *Zone2* object.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>pZone</em></td>
<td>is the zone whose triangles are refined. Allowed zoneLocation values are ZL_INSIDE and ZL_BOUNDED.</td>
</tr>
<tr>
<td><em>minAngleDegree</em></td>
<td>(up to 30) is the minimum interior triangle angle</td>
</tr>
<tr>
<td><em>minEdgeLength</em></td>
<td>is a lower threshold on the edge length. Triangles with smaller edges are not refined.</td>
</tr>
<tr>
<td><em>maxEdgeLength</em></td>
<td>is an upper threshold on the edge length. Triangles with larger edges are always refined.</td>
</tr>
<tr>
<td><em>bAllowConstraintSplitting</em></td>
<td>specifies if constraint edges may be splitted</td>
</tr>
</tbody>
</table>

**Note**

The behavior of the present method had to be changed in Fade v1.39: Only ZL_INSIDE and ZL_BOUNDED zones are accepted. But you can easily convert other types of zones to ZL_BOUNDED using *Zone2::convertToBoundedZone*().

6.7.3.37  

**refineAdvanced()**

```
void GEOM_FADE2D::Fade_2D::refineAdvanced ( 
    MeshGenParams ∗ pParameters
)
```

This method calls an advanced Delaunay mesh generator and grid mesher. The parameters are encapsulated in the *MeshGenParams* class. This class provides default parameters that can be used as is. Alternatively client code
can derive from MeshGenParams and overwrite the methods and parameters to gain full control over the mesh generation process.

6.7.38 remove()

```cpp
void GEOM_FADE2D::Fade_2D::remove (
    Point2 * pVertex )
```

**Parameters**

| pVertex | shall be removed. |

**Note**

pVertex must not be a vertex of a ConstraintGraph2 or ConstraintSegment2 object. If this is the case, the vertex is not removed and a warning is issued.

6.7.39 setNumCPU()

```cpp
int GEOM_FADE2D::Fade_2D::setNumCPU ( 
    int numCPU )
```

**Parameters**

| numCPU | is the number of CPU cores to be used. The special value numCPU=0 means: auto-detect and use the number of available CPU cores. |

**Returns**

the number of CPU cores that will be used (useful in case of auto-detection)

**Characteristics:**

- This setting affects Fade_2D::measureTriangulationTime() and Fade_2D::insert() which is by default single-threaded to avoid undeliberate nested multithreading (an application may run Fade in a thread).
- For technical reasons points should be inserted before any constraint segments so that the algorithm can fully benefit from multithreading.
- Fade continues support for very old compilers and systems but multithreading is not available for VS2008, VS2010 and CentOS6.4 library versions.

6.7.40 show() [1/2]

```cpp
void GEOM_FADE2D::Fade_2D::show ( 
    const std::string & postscriptFilename,
    bool bWithConstraints = true ) const
```

**show()** is a convenience function for quick outputs with a default look. It is also possible to use the Visualizer2 class directly to draw arbitrary circles, line segments, vertices and labels with custom colors.
Parameters

<table>
<thead>
<tr>
<th>postscriptFilename</th>
<th>is the output name, i.e. &quot;myFile.ps&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>bWithConstraints</td>
<td>specifies if constraint segments shall be shown (default: true)</td>
</tr>
</tbody>
</table>

6.7.3.41 show() [2/2]

```cpp
void GEOM_FADE2D::Fade_2D::show (  
    Visualizer2 * pVis,  
    bool bWithConstraints = true ) const
```

This overload of the show() method allows to add further geometric primitives to the Visualizer2 object before it is finally written.

Parameters

| pVis        | is the pointer of a Visualizer2 object that may already contain geometric primitives or that may later be used to draw further elements |
| bWithConstraints | specifies if constraint segments shall be shown (default: true) |

Note

The postscript file must be finalized with Visualizer2::writeFile().

6.7.3.42 statistics()

```cpp
void GEOM_FADE2D::Fade_2D::statistics (  
    const std::string & s ) const
```

Prints mesh statistics to stdout.

6.7.3.43 subscribe()

```cpp
void GEOM_FADE2D::Fade_2D::subscribe (  
    MsgType msgType,  
    MsgBase * pMsg )
```

Parameters

| msgType | is the type of message the subscriber shall receive, e.g. MSG_PROGRESS or MSG_WARNING |
| pMsg    | is a pointer to a custom class derived from MsgBase |

6.7.3.44 unsubscribe()

```cpp
void GEOM_FADE2D::Fade_2D::unsubscribe (  
```

Generated by Doxygen
MsgType msgType,
MsgBase * pMsg )

Parameters

<table>
<thead>
<tr>
<th>msgType</th>
<th>is the type of message the subscriber shall not receive anymore</th>
</tr>
</thead>
<tbody>
<tr>
<td>pMsg</td>
<td>is a pointer to a custom class derived from MsgBase</td>
</tr>
</tbody>
</table>

6.7.3.45 writeObj() [1/2]

```cpp
void GEOM_FADE2D::Fade_2D::writeObj (  
    const std::string & filename ) const
```

Visualizes the current triangulation. The *.obj format represents a 3D scene but can also be used with 2D triangles (all z-values are zero then).

6.7.3.46 writeObj() [2/2]

```cpp
void GEOM_FADE2D::Fade_2D::writeObj (  
    const std::string & filename,  
    Zone2 * pZone ) const
```

Visualizes a Zone2 object. The *.obj format represents a 3D scene but can also be used with 2D triangles (all z-values are zero then).

6.7.3.47 writeWebScene() [1/2]

```cpp
void GEOM_FADE2D::Fade_2D::writeWebScene (  
    const char * path ) const
```

Made for terrain visualizations in 2.5D but will work also for 2D.

6.7.3.48 writeWebScene() [2/2]

```cpp
void GEOM_FADE2D::Fade_2D::writeWebScene (  
    const char * path,  
    Zone2 * pZone ) const
```

Made for terrain visualizations in 2.5D but will work also for 2D.

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

- Fade_2D.h

6.8 GEOM_FADE2D::Func_gtEdge2D Struct Reference

Functor to sort edges by 2d length (descending)

```cpp
#include <Edge2.h>
```
6.9 GEOM_FADE2D::Func_ltEdge2D Struct Reference

Functor to sort edges by 2d length (ascending)

```
#include <Edge2.h>
```

Public Member Functions

- `bool operator()(const Edge2 &e0, const Edge2 &e1) const`

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

- `Edge2.h`

6.10 GEOM_FADE2D::Func_ltUndirected Struct Reference

Public Member Functions

- `bool operator()(const Edge2 &eA, const Edge2 &eB) const`

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

- `Edge2.h`

6.11 GEOM_FADE2D::Label Class Reference

Text-Label.

```
#include <Label.h>
```

Public Member Functions

- `Label(const Point2 &p_, const std::string &s_, bool bWithMark_=true, int fontSize_=8)`  
  Constructs a Text-Label.
Public Attributes

- Point2 p
- std::string s
- bool bWithMark
- int fontSize

6.11.1 Detailed Description

See also

Visualizer2 where Label objects are used for visualizations

6.11.2 Constructor & Destructor Documentation

6.11.2.1 Label()

GEOM_FADE2D::Label::Label (  
    const Point2 & p,  
    const std::string & s,  
    bool bWithMark = true,  
    int fontSize = 8 )

Parameters

<table>
<thead>
<tr>
<th>p_</th>
<th>is the point where the label appears</th>
</tr>
</thead>
<tbody>
<tr>
<td>s_</td>
<td>is the text to be shown</td>
</tr>
<tr>
<td>bWithMark_</td>
<td>switches between text-only and text-with-mark</td>
</tr>
<tr>
<td>fontSize_</td>
<td></td>
</tr>
</tbody>
</table>

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

- Label.h

6.12 GEOM_FADE2D::MeshGenParams Class Reference

Parameters for the mesh generator.

#include <MeshGenParams.h>

Public Member Functions

- MeshGenParams (Zone2 *pZone_)
- virtual double getMaxTriangleArea (Triangle2 *pT)
  
getMaxTriangleArea(Triangle2* pT)
- virtual double getMaxEdgeLength (Triangle2 *pT)
  
getMaxEdgeLength(Triangle2* pT)
- void addLockedConstraint (ConstraintSegment2 *pConstraintSegment)
  
Constraint Segments that shall not be splitted.
Public Attributes

- **Zone2∗pZone**
  Zone to be meshed.
- **double minAngleDegree**
  Minimum interior triangle angle.
- **double minEdgeLength**
  Minimum edge length.
- **double maxEdgeLength**
  Maximum edge length.
- **double maxTriangleArea**
  maxTriangleArea
- **bool bAllowConstraintSplitting**
  bAllowConstraintSplitting
- **double growFactor**
  growFactor
- **double growFactorMinArea**
  growFactorMinArea
- **double capAspectLimit**
  capAspectLimit
- **Vector2 gridVector**
  gridVector
- **double gridLength**
  gridLength
- **bool bKeepExistingSteinerPoints**
  Steiner points from previous refinements.
- **int command**
  Command.

### 6.12.1 Detailed Description

This class serves as container for mesh generator parameters. Client code can provide a class which derives from `MeshGenParams` and which provides custom implementations of the `getMaxTriangleArea(Triangle∗pT)` method or the `getMaxEdgeLength(Triangle∗pT)` method in order to gain control over the local density of the generated mesh. When the meshing algorithm decides if a certain triangle T must be refined, then it calls these functions.

**See also**

http://www.geom.at/advanced-mesh-generation/

### 6.12.2 Member Function Documentation

#### 6.12.2.1 addLockedConstraint()

```cpp
def void GEOM_FADE2D::MeshGenParams::addLockedConstraint ( ConstraintSegment2 ∗ pConstraintSegment )
```

In case that some `ConstraintSegment2` can be splitted and others must not be splitted use `bAllowConstraintSplitting=true` and add the ones that must not be splitted.

#### 6.12.2.2 getMaxEdgeLength()

```cpp
def virtual double GEOM_FADE2D::MeshGenParams::getMaxEdgeLength ( Triangle2 ∗ pT ) [inline], [virtual]
```
Parameters

\( pT \) is a triangle for which the meshing algorithm checks if it must be refined.

The default implementation of the present class returns the value maxEdgeLength (which is DBL_MAX if not changed by the user). This method can be overridden by the client software in order to control the local mesh density.

![Figure 13 User Controlled Mesh Density, Edge Length](image)

6.12.2.3 getMaxTriangleArea()

```cpp
virtual double GEOM_SADE2D::MeshGenParams::getMaxTriangleArea ( Triangle2 * pT ) [inline], [virtual]
```

Parameters

\( pT \) is a triangle for which the meshing algorithm checks if it must be refined.

The default implementation of the present class returns the value maxTriangleArea (which is the default value DBL_MAX if not changed by the user). This method can be overridden by the client software in order to control the local mesh density.
6.12.3 Member Data Documentation

6.12.3.1 bAllowConstraintSplitting

bool GEOM_FADE2D::MeshGenParams::bAllowConstraintSplitting

Defines if constraint segments can be splitted. Default: yes

6.12.3.2 bKeepExistingSteinerPoints

bool GEOM_FADE2D::MeshGenParams::bKeepExistingSteinerPoints

A previous call to refine() or refineAdvanced() may have created Steiner points. These may be partially or entirely removed during a later refinement call, even (!) if this later refinement takes place in a different zone. It depends on your application if this behavior is desired or not. Usually you want to preserve the points, thus the default value of /p bKeepExistingSteinerPoints is true.

6.12.3.3 capAspectLimit

double GEOM_FADE2D::MeshGenParams::capAspectLimit

Limits the quotient edgeLength / height. Default value: 10.0

6.12.3.4 command

int GEOM_FADE2D::MeshGenParams::command

A command for development, not for public use. Will vanish soon.
6.12.3.5 gridLength

\begin{verbatim}
double GEOM_FADE2D::MeshGenParams::gridLength
\end{verbatim}

Set gridLength > 0 to mesh large enough areas with grid points. Border areas and narrow stripes where a grid does not fit are automatically meshed using classic Delaunay methods. By default gridLength=0 (off).

Note

The length of the diagonals in the grid is \sqrt(2) \times gridLength and the algorithm may automatically adapt the gridLength a bit such that the grid fits better into the shape.

Figure 15 Grid Meshing axis aligned

6.12.3.6 gridVector

\begin{verbatim}
Vector2 GEOM_FADE2D::MeshGenParams::gridVector
\end{verbatim}

When grid-meshing is used the grid is aligned to the gridVector. By default gridVector is axis aligned.

Figure 16 Grid Meshing along Vector2(1.0,0.3)
6.12.3.7  
growFactor

double GEOM_FADE2D::MeshGenParams::growFactor

Limits the growth of adjacent triangles. The mesh is constructed such that for any two adjacent triangles t0 and t1 (where t0 is the larger one) \( \frac{\text{area}(t0)}{\text{area}(t1)} < \text{growFactor} \). Recommendation: \( \text{growFactor} > 5.0 \), Default: \( \text{growFactor}=\text{DBL_MAX} \)

6.12.3.8  
growFactorMinArea

double GEOM_FADE2D::MeshGenParams::growFactorMinArea

The growFactor value is ignored for triangles with a smaller area than growFactorMinArea. This value prevents generation of hundreds of tiny triangles around one that is unusually small. Default: 0.001

6.12.3.9  
maxEdgeLength

double GEOM_FADE2D::MeshGenParams::maxEdgeLength

This value is returned by the default implementation of getMaxEdgeLength(Triangle* pT). Larger edges are automatically subdivided. If a custom implementation of getMaxEdgeLength(Triangle* pT) is provided then this value is ignored. Default value: DBL_MAX.

6.12.3.10  
maxTriangleArea

double GEOM_FADE2D::MeshGenParams::maxTriangleArea

This value is returned by the default implementation of getMaxTriangleArea(Triangle* pT). Larger triangles are automatically subdivided. If a custom implementation of getMaxTriangleArea(Triangle* pT) is provided then this value is ignored. Default value: DBL_MAX.

6.12.3.11  
minAngleDegree

double GEOM_FADE2D::MeshGenParams::minAngleDegree

Minimum interior angle: Default: 20.0, maximum: 30.0

6.12.3.12  
minEdgeLength

double GEOM_FADE2D::MeshGenParams::minEdgeLength

Edges below the minimum length are not subdivided. This parameter is useful to avoid tiny triangles. Default: 0.001

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

- MeshGenParams.h

6.13  
GEOM_FADE2D::MsgBase Class Reference

MsgBase

#include <MsgBase.h>
Public Member Functions

- virtual void update (MsgType msgType, const std::string &s, double d)=0

6.13.1 Detailed Description

**MsgBase** is a base class from which message subscriber classes (for example widgets, progress bars, ...) can be derived which then receive messages (progress, warnings, ...) from Fade.

See also

http://www.geom.at/progress-bar/

6.13.2 Member Function Documentation

6.13.2.1 update()

virtual void GEOM_FADE2D::MsgBase::update (  
    MsgType msgType,  
    const std::string & s,  
    double d ) [pure virtual]

This method must be defined in derived classes. It is automatically called everytime Fade has a message of type msgType.

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

- MsgBase.h

6.14 GEOM_FADE2D::Point2 Class Reference

Point.

#include <Point2.h>
Public Member Functions

- **Point2** (const double x, const double y)
  Constructor.
- **Point2** ()
  Default constructor.
- **Point2** (const Point2 &p)
  Copy constructor.
- double x () const
  Get the x-coordinate.
- double y () const
  Get the y-coordinate.
- void xy (double &x, double &y) const
  Get the x- and y-coordinate.
- double getMaxAbs () const
  Get max(abs(x), abs(y)).
- bool operator< (const Point2 &p) const
  Less than operator.
- bool operator> (const Point2 &p) const
  Greater than operator.
- bool operator== (const Point2 &p) const
  Equality operator.
- bool operator!= (const Point2 &p) const
  Inequality operator.
- Triangle2 *getIncidentTriangle () const
  Get the associated triangle.
- void set (const double x, const double y, int customIndex)
  Set the coordinates and customIndex.
- void change (const double x, const double y)
- void set (const Point2 &pnt)
  Set the coordinates.
- void setCustomIndex (int customIndex)
  Set a custom index.
- int getCustomIndex () const
  Get the custom index.
- void setIncidentTriangle (Triangle2 *pT)
  Associate a triangle with the point.
- Vector2 operator- (const Point2 &other) const
  Returns a vector from other to *this.
- Point2 operator+ (const Vector2 &vec) const
  Add vector and point.
- Point2 operator- (const Vector2 &vec) const
  Subtract vector from point.

Protected Attributes

- double coordX
- double coordY
- Triangle2 *pAssociatedTriangle
- int customIndex

Generated by Doxygen
Friends

- class Dt2
- `std::ostream & operator<<(std::ostream &stream, const Point2 &pnt)`
- `std::istream & operator>>(std::istream &stream, Point2 &pnt)`

6.14.1 Detailed Description

This class represents a point in 2D with x- and y-coordinates and an additional pointer to an associated triangle.

6.14.2 Constructor & Destructor Documentation

6.14.2.1 `Point2()` [1/3]

```
GEOM_FADE2D::Point2::Point2 (const double x_, const double y_) [inline]
```

Parameters

<table>
<thead>
<tr>
<th>x→</th>
<th>x-coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>_t→</td>
<td></td>
</tr>
</tbody>
</table>

| y→ | y-coordinate |
| _t→|             |

6.14.2.2 `Point2()` [2/3]

```
GEOM_FADE2D::Point2::Point2 () [inline]
```

The coordinates are initialized to `-DBL_MAX`

6.14.2.3 `Point2()` [3/3]

```
GEOM_FADE2D::Point2::Point2 (const Point2 & p_) [inline]
```

Create a point as a copy of p_. The associated triangle pointer is initialized to NULL

6.14.3 Member Function Documentation
6.14.3.1  getCustomIndex()

\begin{verbatim}
int GEOM_FADE2D::Point2::getCustomIndex ( ) const [inline]
\end{verbatim}

Returns
\begin{verbatim}
the custom index.
\end{verbatim}

Note
\begin{verbatim}
The custom index defaults to -1. It is not the index of the point in the triangulation (such an index does not exist) but an arbitrary value which can be set by the user.
\end{verbatim}

See also
\begin{verbatim}
void setCustomIndex(int customIndex_)
A best practices example that deals with indices: http://www.geom.at/runtime/
\end{verbatim}

6.14.3.2  getIncidentTriangle()

\begin{verbatim}
Triangle2* GEOM_FADE2D::Point2::getIncidentTriangle ( ) const [inline]
\end{verbatim}

Returns
\begin{verbatim}
the associated triangle
\end{verbatim}

6.14.3.3  getMaxAbs()

\begin{verbatim}
double GEOM_FADE2D::Point2::getMaxAbs ( ) const [inline]
\end{verbatim}

6.14.3.4  operator"!=(

\begin{verbatim}
bool GEOM_FADE2D::Point2::operator!=( const Point2 & p ) const [inline]
\end{verbatim}

Compares the x and y coordinates

Note
\begin{verbatim}
Although a point has a z-coordinate in the 2.5D version only x and y a compared by this method
\end{verbatim}
### 6.14.3.5 \( \text{operator}\langle() \)

```c
bool GEOM_FADE2D::Point2::operator< (const Point2 & p) const [inline]
```

Compares the x and y coordinates

**Note**

Although a point has a z-coordinate in the 2.5D version only x and y are compared by this method

### 6.14.3.6 \( \text{operator}\==() \)

```c
bool GEOM_FADE2D::Point2::operator== (const Point2 & p) const [inline]
```

Compares the x and y coordinates

**Note**

Although a point has a z-coordinate in the 2.5D version only x and y are compared by this method

### 6.14.3.7 \( \text{operator}\>() \)

```c
bool GEOM_FADE2D::Point2::operator> (const Point2 & p) const [inline]
```

Compares the x and y coordinates

**Note**

Although a point has a z-coordinate in the 2.5D version only x and y are compared by this method

### 6.14.3.8 \( \text{set}() \) [1/2]

```c
void GEOM_FADE2D::Point2::set (const double x_, const double y_, int customIndex_) const [inline]
```

**Internal method**

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_ )</td>
<td>x-coordinate</td>
</tr>
<tr>
<td>( y_ )</td>
<td>y-coordinate</td>
</tr>
<tr>
<td>( _ )</td>
<td>Arbitrary index, use -1 if not required</td>
</tr>
</tbody>
</table>

Generated by Doxygen
6.14.3.9 set() [2/2]

void GEOM_FADE2D::Point2::set ( 
    const Point2 & pnt ) [inline]

Parameters

| pnt | is the point whose coordinates are assigned to the current point |

6.14.3.10 setCustomIndex()

void GEOM_FADE2D::Point2::setCustomIndex ( 
    int customIndex_ ) [inline]

An arbitrary index can be assigned to a point. Use getCustomIndex() to retrieve it later.

Note

This method is provided for the users' convenience. It has nothing to do with the internal data structures of Fade 2D and using this method is optional. By default this index is -1.

See also

int getCustomIndex()
A best practices example that deals with indices: http://www.geom.at/runtime/

6.14.3.11 setIncidentTriangle()

void GEOM_FADE2D::Point2::setIncidentTriangle ( 
    Triangle2 * pT ) [inline]

Parameters

| pT | will be associated with the triangle |

6.14.3.12 x()

double GEOM_FADE2D::Point2::x ( ) const [inline]

Returns

the x-coordinate
6.14.3.13 xy()

```c
void GEOM_FADE2D::Point2::xy ( 
    double & x_,
    double & y_ ) const [inline]
```

**Parameters**

<table>
<thead>
<tr>
<th>x←</th>
<th>x-coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>_←</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>y←</th>
<th>y-coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>_←</td>
<td></td>
</tr>
</tbody>
</table>

6.14.3.14 y()

```c
double GEOM_FADE2D::Point2::y ( ) const [inline]
```

**Returns**

the y-coordinate

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

- Point2.h

6.15 GEOM_FADE2D::Segment2 Class Reference

Segment.

```c
#include <Segment2.h>
```

**Public Member Functions**

- Segment2 (const Point2 &src_, const Point2 &trg_)  
  Create a Segment2.
- Segment2 ()
- Point2 getSrc () const
- Point2 getTrg () const
- double getSqLen2D () const
- void swapSrcTrg ()
- bool operator==(const Segment2 &other) const

**Protected Attributes**

- Point2 src
- Point2 trg
Friends

- `std::ostream & operator<<(std::ostream &stream, Segment2 seg)`

6.15.1 Detailed Description

6.15.2 Constructor & Destructor Documentation

6.15.2.1 Segment2() [1/2]

```cpp
GEOM_FADE2D::Segment2::Segment2(
    const Point2 & src_,
    const Point2 & trg_)
```

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>src_</code></td>
<td>First endpoint (source)</td>
</tr>
<tr>
<td><code>trg_</code></td>
<td>Second endpoint (target)</td>
</tr>
</tbody>
</table>

6.15.2.2 Segment2() [2/2]

```cpp
GEOM_FADE2D::Segment2::Segment2()
```

Create a `Segment2` Default constructor

6.15.3 Member Function Documentation

6.15.3.1 getSqLen2D()

```cpp
double GEOM_FADE2D::Segment2::getSqLen2D() const
```

Get the squared length

6.15.3.2 getSrc()

```cpp
Point2 GEOM_FADE2D::Segment2::getSrc() const
```

Get the source point

Returns

the source point
6.15.3.3 getTrg()

Point2 GEOM_FADE2D::Segment2::getTrg ( ) const

Get the target point

Returns

the target point

6.15.3.4 operator==()

bool GEOM_FADE2D::Segment2::operator== ( const Segment2 & other ) const

operator==

Undirected equality operator

6.15.3.5 swapSrcTrg()

void GEOM_FADE2D::Segment2::swapSrcTrg ( )

Internally swaps the source and target point

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

- Segment2.h

6.16 GEOM_FADE2D::SegmentChecker Class Reference

SegmentChecker identifies intersecting line segments.

#include <SegmentChecker.h>

Public Member Functions

- SegmentChecker (const std::vector< Segment2 * >&vSegments_)
- Segment2 * getSegment (size_t i) const
- size_t getNumberOfSegments () const
- int getIndex (Segment2 *pSeg) const
- void subscribe (MsgType msgType, MsgBase *pMsg)
- void unsubscribe (MsgType msgType, MsgBase *pMsg)
- void showSegments (const std::string &name) const
- void showIllegalSegments (bool bAlsoEndPointIntersections, const std::string &name) const
- void getIllegalSegments (bool bAlsoEndPointIntersections, std::vector< Segment2 * >&vIllegalSegmentsOut) const
- SegmentIntersectionType getIntersectionType (const Segment2 *pSeg1, const Segment2 *pSeg2) const
- void getIntersectors (Segment2 *pTestSegment, bool bAlsoEndPointIntersections, std::vector< std::pair< Segment2 *, SegmentIntersectionType > >&vIntersectorsOut) const
- void getIntersectionPoint (SegmentIntersectionType typ, const Segment2 &seg0, const Segment2 &seg1, Point2 &ispOut) const
- std::string getIntersectionTypeString (SegmentIntersectionType sit) const
6.16.1 Detailed Description

SegmentChecker takes a bunch of line segments and fully automatically identifies illegal segment intersections. The intersection points can be computed in 2D and in 2.5D. Further this class offers visualization methods. Due to the underlying datastructure the search algorithm scales very well to large inputs.

Figure 17 Polylines: Intersecting segments are automatically found

See also

http://www.geom.at/segment-checker/

6.16.2 Constructor & Destructor Documentation

6.16.2.1 SegmentChecker()

GEOM_FADE2D::SegmentChecker::SegmentChecker (  
    const std::vector< Segment2 * > & vSegments_ ) [explicit]
**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Segments</code></td>
<td>contains the segments to be checked</td>
</tr>
</tbody>
</table>

### 6.16.3 Member Function Documentation

#### 6.16.3.1 `getIllegalSegments()`

```cpp
def getIllegalSegments(bool bAlsoEndPointIntersections, std::vector<Segment2 *> & vIllegalSegmentsOut) const
```

**Get illegal segments**

Returns segments which are involved in intersections. Intersections at endpoints are only reported when `bAlsoEndPointIntersections` is true.

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bAlsoEndPointIntersections</code></td>
<td>specifies if intersections at endpoints shall be detected</td>
</tr>
<tr>
<td><code>vIllegalSegmentsOut</code></td>
<td>is the output vector</td>
</tr>
</tbody>
</table>

#### 6.16.3.2 `getIndex()`

```cpp
def getIndex(Segment2 * pSeg) const
```

**Returns the index of a segment**

**Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pSeg</code></td>
<td>is the segment whose index is returned</td>
</tr>
</tbody>
</table>

#### 6.16.3.3 `getIntersectionPoint()`

```cpp
void getIntersectionPoint(SegmentIntersectionType typ, const Segment2 & seg0, const Segment2 & seg1, Point2 & ispOut) const
```

**Compute the intersection point of two segments**

Use `getIntersectionType()` to determine the segment intersection type `sit`.
Parameters

<table>
<thead>
<tr>
<th>typ</th>
<th>is the intersection type (SIT_POINT or SIT_ENDPOIINT for the present method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>seg0,seg1</td>
<td>are the intersecting segments</td>
</tr>
<tr>
<td>out</td>
<td>ispOut</td>
</tr>
</tbody>
</table>

Note

$pSeg1$ and $pSeg2$ do not need to be from the set that has been used to initialize the SegmentChecker.

6.16.3.4 getIntersectionSegment()

```cpp
void GEOM_FADE2D::SegmentChecker::getIntersectionSegment (  
    const Segment2 & seg0,  
    const Segment2 & seg1,  
    Segment2 & issOut ) const
```

Computes the intersection segment of two collinear intersecting segments

Parameters

<table>
<thead>
<tr>
<th>seg0,seg1</th>
<th>are intersecting segments such that their SegmentIntersectionType is SIT_SEGMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>issOut</td>
<td>is the computed intersection of seg0 and seg1</td>
</tr>
</tbody>
</table>

Note

$pSeg1$ and $pSeg2$ do not need to be from the set that has been used to initialize the present object

6.16.3.5 getIntersectionType()

```cpp
SegmentIntersectionType GEOM_FADE2D::SegmentChecker::getIntersectionType (  
    const Segment2 * pSeg1,  
    const Segment2 * pSeg2 ) const
```

Get the intersection type of two segments

Parameters

| pSeg1,pSeg2 | are the segments to be checked |

Returns

- SIT_NONE (no intersection),
- SIT_SEGMENT (collinear intersection),
- SIT_POINT (intersection somewhere between the endpoints) or
- SIT_ENDPOIINT (endpoint intersection)
Note

\( pSeg1 \) and \( pSeg2 \) do not need to be from the set that has been used to initialize the present object

### 6.16.3.6 getIntersectionTypeString()

```cpp
std::string GEOM_FADE2D::SegmentChecker::getIntersectionTypeString ( SegmentIntersectionType sit ) const
```

Return the intersection type as a human readable string. This is a convenience function

**Parameters**

- \( sit \) is an intersection type to be converted to a string

### 6.16.3.7 getIntersectors()

```cpp
void GEOM_FADE2D::SegmentChecker::getIntersectors ( 
    Segment2 * pTestSegment,
    bool bAlsoEndPointIntersections,
    std::vector< std::pair< Segment2 *, SegmentIntersectionType > > & vIntersectors
) const
```

Return segments that intersect a certain segment along with their intersection type

**Parameters**

- \( pTestSegment \) is the segment to be analyzed
- \( bAlsoEndPointIntersections \) specifies if intersections of type SIT_ENDPOINT shall also be reported.
- \( vIntersectorsOut \) is the output vector. It returns segments which intersect \( pTestSegment \) along with their intersection type

### 6.16.3.8 getNumberOfSegments()

```cpp
size_t GEOM_FADE2D::SegmentChecker::getNumberOfSegments () const
```

Returns the number of segments contained in this \texttt{SegmentChecker} object

### 6.16.3.9 getSegment()

```cpp
Segment2* GEOM_FADE2D::SegmentChecker::getSegment ( size_t i ) const
```

Returns the \( i \)-th segment
Parameters

\[ i \] is the index of the segment to be returned

### 6.16.3.10 showIllegalSegments()

```cpp
void GEOM_FADE2D::SegmentChecker::showIllegalSegments(
    bool bAlsoEndPointIntersections,
    const std::string & name) const
```

Write a postscript file, highlight illegal segments

Parameters

<table>
<thead>
<tr>
<th>bAlsoEndPointIntersections</th>
<th>specifies if intersections at endpoints are also illegal</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>is the output filename</td>
</tr>
</tbody>
</table>
Figure 18 Visualization of polyline intersections

6.16.3.11 showSegments()

void GEOM_FADE2D::SegmentChecker::showSegments (const std::string &name) const

Write all segments, with and without intersection, to a postscript file
Parameters

| name  | is the output filename |

Figure 19 Line segments written to a postscript file

6.16.3.12 subscribe()

```c
void GEOM_FADE2D::SegmentChecker::subscribe (  
    MsgType msgType,  
    MsgBase *pMsg  
)
```

Register a progress bar object

The SegmentChecker does its job typically in fractions of a second. But inputs may contain a quadratic number of intersections and such tasks take a while. Therefore a user defined message object (your own progress-bar class) can be registered in order to get progress updates. This step is optional.
Parameters

<table>
<thead>
<tr>
<th>msgType</th>
<th>is the message type. For progress information the type is always MSG_PROGRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pMsg</td>
<td>is a user defined progress bar which derives from Fade's <code>MsgBase</code>.</td>
</tr>
</tbody>
</table>

6.16.3.13 unsubscribe()

```c++
void GEOM_FADE2D::SegmentChecker::unsubscribe {
    MsgType msgType,
    MsgBase * pMsg )
```

Unregister a progress bar object

Parameters

<table>
<thead>
<tr>
<th>msgType</th>
<th>is the message type. For progress information the type is always MSG_PROGRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pMsg</td>
<td>is a user defined class which derives from Fade's <code>MsgBase</code></td>
</tr>
</tbody>
</table>

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

- SegmentChecker.h

6.17 GEOM_FADE2D::Triangle2 Class Reference

Triangle.

```
#include <Triangle2.h>
```

Public Member Functions

- `Triangle2 ()`  
  Constructor.
- `Point2 * getCorner (const int ith) const`
  Get the i-th corner of the triangle.
- `std::pair < Point2, bool > getDual () const`
  Get the dual Voronoi vertex.
- `Point2 getBarycenter () const`
  Get the barycenter of a triangle.
- `double getInteriorAngle2D (int ith) const`
  Get interior 2D angle.
- `double getArea2D () const`
  Get 2D Area.
- `Triangle2 * getOppositeTriangle (const int ith) const`
  Get the i-th neighbor triangle.
- `int getIntraTriangleIndex (const Point2 *p) const`
  Get the index of p in the triangle.
• int getIntraTriangleIndex (const Triangle2 *pTriangle) const
  Get the neighbor index of pTriangle.
• int getIntraTriangleIndex (const Point2 *p0, const Point2 *p1) const
  Get the index of (p0,p1)
• double getSquaredEdgeLength2D (int ith) const
  Method for internal use.
• void setOppTriangle (const int ith, Triangle2 *pTriangle)
  Set the i-th neighbor triangle.
• void setProperties (Point2 *pI, Point2 *pJ, Point2 *pK)
  Set all corners.
• void clearProperties ()
  Clear all corners and neighbor pointers.
• void setPropertiesAndOppT (Point2 *pI, Point2 *pJ, Point2 *pK,
  Triangle2 *pNeig0, Triangle2 *pNeig1, Triangle2 *pNeig2)
  Set all corners and neighbor triangles.
• void setVertexPointer (const int ith, Point2 *pp)
  Set the i-th corner.
• bool hasVertex (Point2 *pVtx) const
  Has vertex.
• bool hasVertex (const Point2 &vtx) const
  Has vertex.
• bool hasOnEdge (int i, const Point2 &q) const
  Has point on edge.
• int getMaxIndex () const
  Get the index of the largest edge.
• int getMinIndex () const
  Get the index of the smallest edge.
• double getMaxSqEdgeLen2D () const
  Get the maximum squared 2D edge length.

Protected Member Functions

• double computeArea (double l0, double l1, double l2) const
• bool isAccurateCC (int maxIdx, const Point2 &cc) const
• bool getCC_strategy1 (double avgOffX, double avgOffY, Point2 &cc) const
• void getCC_strategy2 (int maxIdx, double avgOffX, double avgOffY, Point2 &cc) const
• void getCommonOffset (double &x, double &y) const

Protected Attributes

• Point2 *aVertexPointer [3]
• Triangle2 *aOppTriangles [3]

Friends

• std::ostream & operator<< (std::ostream &stream, const Triangle2 &c)
• void registerTriangles (Triangle2 *fromTriangle, int ith, Triangle2 *toTriangle, int jth)
6.17.1 Detailed Description

Triangle2 is a triangle in the Fade_2D triangulation. It holds three Point2 pointers to its corners. The corners are numbered in counterclockwise order. We refer to these indices as intra-triangle-indices.

Each triangle has three neighbors which can be accessed through intra-triangle-indices: The i-th neighbor triangle of a certain triangle T is the one which shares an edge with T such that this edge does not include the i-th corner of T.

![Figure 20 Indices and neighborships, tb is the 0-th neighbor of ta and ta is the 2nd neighbor of tb.](image)

See also TriangleAroundVertexIterator to find out how to access all triangles incident to a certain vertex.

6.17.2 Constructor & Destructor Documentation

6.17.2.1 Triangle2()

GEOM_FADE2D::Triangle2::Triangle2 ( ) [inline]

6.17.3 Member Function Documentation

6.17.3.1 getArea2D()

double GEOM_FADE2D::Triangle2::getArea2D ( ) const

Returns the 2D area of the triangle.

Note: The getArea() method is deprecated and replaced by getArea2D() to keep the names consistent.

6.17.3.2 getBarycenter()

Point2 GEOM_FADE2D::Triangle2::getBarycenter ( ) const

Returns the barycenter of the triangle.
6.17.3.3 getCorner()

```cpp
Point2* GEOM_FADE2D::Triangle2::getCorner (const int ith) const [inline]
```

**Returns**

A pointer to the i-th corner point of the triangle.

![Figure 21 Intra triangle indices are ordered counterclockwise](image)

**Parameters**

| ith | is the intra-triangle-index, ith={0,1,2}. |

6.17.3.4 getDual()

```cpp
std::pair<Point2, bool> GEOM_FADE2D::Triangle2::getDual() const
```

**Returns**

A `std::pair<Point2, bool>`, where the first component is the dual Voronoi vertex (circumcenter) of the triangle and the second component is a boolean value which is true if the vertex is accurate.

**Note**

The true dual Voronoi vertex of an almost collinear Delaunay triangle can be outside the bounds of floating point arithmetic. In such cases this method returns a point with very large coordinates but still inside the range of double precision floating point arithmetic, and it will inform the user by setting the boolean return value to false.

Such cases can easily be avoided by insertion of four dummy vertices around the triangulation, e.g., at coordinates ten times larger than the domain of the data points. This will automatically restrict the Voronoi diagram of the data points to this range.

6.17.3.5 getInteriorAngle2D()

```cpp
double GEOM_FADE2D::Triangle2::getInteriorAngle2D (int ith) const
```

**Note:** The getArea() method is deprecated and replaced by `getInteriorAngle2D()` to keep the names consistent.

**Returns**

The interior 2D angle at the ith vertex.
6.17.3.6 getIntraTriangleIndex() [1/3]

```cpp
int GEOM_FADE2D::Triangle2::getIntraTriangleIndex (  
    const Point2 * p ) const [inline]
```

![Figure 22 Intra triangle index of a vertex pointer](image)

**Parameters**

- `p` is a pointer to a vertex in `*this`.

**Returns**

the intra-triangle-index 0, 1 or 2 of `p` in `*this`.

6.17.3.7 getIntraTriangleIndex() [2/3]

```cpp
int GEOM_FADE2D::Triangle2::getIntraTriangleIndex (  
    const Triangle2 * pTriangle ) const [inline]
```

![Figure 23 pTriangle is the 0-th neighbor of `*this`](image)

**Parameters**

- `pTriangle` is a neighbor triangle of `*this`.

**Returns**

the intra-triangle-index of the vertex in `*this` which is opposite (i.e., does not touch the neighbor) `pTriangle`.
6.17 GEOM_FADE2D::Triangle2 Class Reference

6.17.3.8 getIntraTriangleIndex()

```cpp
int GEOM_FADE2D::Triangle2::getIntraTriangleIndex (const Point2 * p0, const Point2 * p1) const [inline]
```

Returns
the index of the edge (p0,p1) in the triangle

6.17.3.9 getOppositeTriangle()

```cpp
Triangle2 * GEOM_FADE2D::Triangle2::getOppositeTriangle (const int ith) const [inline]
```

Returns the *i*-th neighbor triangle, i.e. the one opposite to the *i*-th corner.

![Figure 24 Neighbors of a triangle](image)

**Parameters**

*ith* is the intra-triangle-index of the opposite corner of *this*

Returns
the *i*-th neighbor triangle, i.e. the one opposite to the *i*-th vertex or NULL if no neighbor triangle exists which is the case at the convex hull edges of the triangulation.

6.17.3.10 getSquaredEdgeLength2D()

```cpp
double GEOM_FADE2D::Triangle2::getSquaredEdgeLength2D (int ith) const
```

Internal use squared edge length

Returns the squared length of the *ith* edge.
6.17.3.11 hasOnEdge()

```cpp
bool GEOM_FADE2D::Triangle2::hasOnEdge (  
    int i,  
    const Point2 & q ) const
```

Returns

if \( q \) is exactly on the \( i \)-th edge

6.17.3.12 hasVertex()[1/2]

```cpp
bool GEOM_FADE2D::Triangle2::hasVertex (  
    Point2 * pVtx ) const
```

Returns

if \( pVtx \) is a corner of the triangle

6.17.3.13 hasVertex()[2/2]

```cpp
bool GEOM_FADE2D::Triangle2::hasVertex (  
    const Point2 & vtx ) const
```

Returns

if \( vtx \) is a corner of the triangle

6.17.3.14 setOppTriangle()

```cpp
void GEOM_FADE2D::Triangle2::setOppTriangle (  
    const int ith,  
    Triangle2 * pTriangle ) [inline]
```

Figure 25 Make \( pTriangle \) the 0-th neighbor of *this
Parameters

<table>
<thead>
<tr>
<th>ith</th>
<th>is the index of the corner of *this which does not touch pTriangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>pTriangle</td>
<td>is a pointer to the triangle which shares two corners with *this</td>
</tr>
</tbody>
</table>

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

- Triangle2.h

---

6.18 GEOM_FADE2D::TriangleAroundVertexIterator Class Reference

Iterator for all triangles around a given vertex.

#include <TriangleAroundVertexIterator.h>

Public Member Functions

- **TriangleAroundVertexIterator** (const Point2 *pPnt_)
  Constructor.
- **TriangleAroundVertexIterator** (Point2 *pPnt_, Triangle2 *pTr_)
  Constructor.
- **TriangleAroundVertexIterator** (const TriangleAroundVertexIterator &it)
  Copy constructor.
- **TriangleAroundVertexIterator &** operator=(const TriangleAroundVertexIterator &other)
  Proceed to the next triangle (the one in counterclockwise order)
- **TriangleAroundVertexIterator &** operator-- ()
  Proceed to the previous triangle (the one in clockwise order)
- **bool operator==** (const TriangleAroundVertexIterator &rhs)
  Check if the center points and the current triangles of the iterators are the same.
- **bool operator!=** (const TriangleAroundVertexIterator &rhs)
  Check if the center points or the current triangles of the iterators are different.
- **Triangle2 *** operator+ ()
  Returns a pointer to the current triangle (or NULL)
- **Triangle2 *** previewNextTriangle ()
  Preview next triangle (CCW direction)
- **Triangle2 *** previewPrevTriangle ()
  Preview previous triangle (CW direction)

Protected Member Functions

- **void loop ()**

Protected Attributes

- const Point2 * pPnt
- Triangle2 * pTr
- Triangle2 * pSavedTr
6.18.1 Detailed Description

Iterates over all triangles incident to a given vertex in a circular manner. Thereby, counterclockwise is the positive direction.

![Figure 26 Left: the iterator visits the triangles around a vertex. Right: The iterator 'jumps' over the border edges of the triangulation](image)

6.18.2 Constructor & Destructor Documentation

6.18.2.1 TriangleAroundVertexIterator()

GEOM_FADE2D::TriangleAroundVertexIterator::TriangleAroundVertexIterator (const Point2 * pPnt_) [inline], [explicit]

Parameters

| $pPnt_\leftarrow$ | is the vertex whose incident triangles can be visited with the iterator |

The iterator will start at an arbitrary triangle

6.18.2.2 TriangleAroundVertexIterator()

GEOM_FADE2D::TriangleAroundVertexIterator::TriangleAroundVertexIterator (Point2 * pPnt_, Triangle2 * pTr_) [inline]

Parameters

| $pPnt_\leftarrow$ | is the vertex whose incident triangles can be visited with the iterator |
| $pTr_\leftarrow$ | is the triangle where the iterator will start |
6.18.2.3 TriangleAroundVertexIterator() [3/3]

GEOM_FADE2D::TriangleAroundVertexIterator::TriangleAroundVertexIterator (const TriangleAroundVertexIterator & it) [inline]

6.18.3 Member Function Documentation

6.18.3.1 operator!=(

bool GEOM_FADE2D::TriangleAroundVertexIterator::operator!= (const TriangleAroundVertexIterator & rhs) [inline]

6.18.3.2 operator*

Triangle2* GEOM_FADE2D::TriangleAroundVertexIterator::operator* ( ) [inline]

Dereferencing the iterator yields a pointer to the triangle to which the iterator points.

Warning

This method might yield NULL at the border of a triangulation.

6.18.3.3 operator++()

TriangleAroundVertexIterator& GEOM_FADE2D::TriangleAroundVertexIterator::operator++ ( ) [inline]

Warning

At the border of a triangulation, two border edges exist which are incident to the center vertex. Consequently, the neighbor triangles are NULL there. If operator++() leads the iterator off the triangulation then the iterator will point to NULL. Another call to operator++() will set the iterator to the next triangle in counterclockwise order.

6.18.3.4 operator--()

TriangleAroundVertexIterator& GEOM_FADE2D::TriangleAroundVertexIterator::operator-- ( ) [inline]

Warning

At the border of a triangulation, two border edges are incident to the center vertex. Consequently, the neighbor triangles are NULL there. If operator--() leads the iterator off the triangulation then the iterator will point to NULL. Another call to operator--() will set the iterator to the next triangle in clockwise order.
6.18.3.5 operator==()

bool GEOM_FADE2D::TriangleAroundVertexIterator::operator== ( const TriangleAroundVertexIterator & rhs ) [inline]

6.18.3.6 previewNextTriangle()

Triangle2* GEOM_FADE2D::TriangleAroundVertexIterator::previewNextTriangle() [inline]

Returns

the next triangle (the one in CCW direction) without changing the current position.

Warning

This method might yield NULL at the border of a triangulation.

6.18.3.7 previewPrevTriangle()

Triangle2* GEOM_FADE2D::TriangleAroundVertexIterator::previewPrevTriangle() [inline]

Returns

the previous triangle (the one in CW direction) without changing the current position.

Warning

This method might yield NULL at the border of a triangulation.

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

- TriangleAroundVertexIterator.h

6.19 GEOM_FADE2D::UserPredicateT Class Reference

User defined predicate.

#include <UserPredicates.h>

Public Member Functions

- virtual bool operator() (const Triangle2 *)=0
6.19.1 Detailed Description

See also

http://www.geom.at/remove-border-triangles/

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

- UserPredicates.h

6.20 GEOM_FADE2D::Vector2 Class Reference

Vector.

#include <Vector2.h>

Public Member Functions

- Vector2 (const double x_, const double y_)
  Constructor.
- Vector2 ()
  Default constructor.
- Vector2 (const Vector2 &v_)
  Copy constructor.
- Vector2 orthogonalVector () const
  Get an orthogonal vector (CCW direction)
- bool isDegenerate () const
  isDegenerate
- double x () const
  Get the x-value.
- double y () const
  Get the y-value.
- void set (const double x_, const double y_)
  Set the values.
- double sqLength () const
  Get the squared length of the vector.
- double length () const
  Get the length of the vector.
- Vector2 operator* (const Vector2 &other) const
  Scalar product.
- Vector2 operator* (double val) const
  Multiply by a scalar value.
- Vector2 operator/ (double val) const
  Divide by a scalar value.

Protected Attributes

- double valX
- double valY
6.20.1 Detailed Description

This class represents a vector in 2D

6.20.2 Constructor & Destructor Documentation

6.20.2.1 Vector2() [1/3]

GEOM_FADE2D::Vector2::Vector2 ( const double x_, const double y_ )

6.20.2.2 Vector2() [2/3]

GEOM_FADE2D::Vector2::Vector2 ( )

The vector is initialized to (0,0)

6.20.2.3 Vector2() [3/3]

GEOM_FADE2D::Vector2::Vector2 ( const Vector2 & v_ )

Create a copy of vector v_

6.20.3 Member Function Documentation

6.20.3.1 isDegenerate()

bool GEOM_FADE2D::Vector2::isDegenerate ( ) const

Returns

true if the vector length is 0, false otherwise.

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

• Vector2.h

6.21 GEOM_FADE2D::Visualizer2 Class Reference

Visualizer2 is a general Postscript writer. It draws the objects Point2, Segment2, Triangle2, Circle2 and Label.

#include <Visualizer2.h>
Public Member Functions

- **Visualizer2** (const std::string &filename_)
  
  Constructor.

- void **addObject** (const Segment2 &seg, const Color &c)
  
  Add a Segment2 object to the visualization.

- void **addObject** (const Edge2 &edge, const Color &c)
  
  Add an Edge2 object to the visualization.

- void **addObject** (const std::vector<Point2> &vPoints, const Color &c)
  
  Add a vector of Point2 objects to the visualization.

- void **addObject** (const std::vector<Point2*> &vPoints, const Color &c)
  
  Add a vector of Point2* to the visualization.

- void **addObject** (const std::vector<Segment2> &vSegments, const Color &c)
  
  Add a vector of Segment2 objects to the visualization.

- void **addObject** (const std::vector<ConstraintSegment2*> &vConstraintSegments, const Color &c)
  
  Add a vector of ConstraintSegment2 objects to the visualization.

- void **addObject** (const std::vector<Edge2> &vSegments, const Color &c)
  
  Add a vector of Edge2 objects to the visualization.

- void **addObject** (const std::vector<Triangle2> &vT, const Color &c)
  
  Add a vector of Triangle2 objects to the visualization.

- void **addObject** (const std::vector<Triangle2*> &vT, const Color &c)
  
  Add a Triangle2 vector to the visualization.

- void **addObject** (const Label &lab, const Color &c)
  
  Add a Label object to the visualization.

- void **addHeaderLine** (const std::string &s)
  
  Add a header line to the visualization.

- void **writeFile** ()
  
  Finish and write the postscript file.

Protected Member Functions

- void **writeHeaderLines** ()

- Point2 **scaledPoint** (const Point2 &p)

- double **scaledDouble** (const double &d)

- void **changeColor** (float r, float g, float b, float linewidth, bool bFill)

- void **changeColor** (const Color &c)

- void **writeHeader** (const std::string &title)

- void **writeFooter** ()

- void **writeLabel** (Label l)

- void **writeLine** (const Point2 &pSource, const Point2 &pTarget)

- void **writeTriangle** (const Point2 &p0, const Point2 &p1, const Point2 &p2, bool bFill, double width)

- void **writeTriangle** (const Triangle2 &pT, bool bFill, double width)

- void **writePoint** (Point2 &p1, float size)

- void **writeCircle** (const Point2 &p1, double radius, bool bFill)

- void **periodicStroke** ()

- void **setRange** ()
Protected Attributes

- std::ofstream outFile
- std::vector<std::pair<Segment2, Color>> vSegments
- std::vector<std::pair<Circle2, Color>> vCircles
- std::vector<std::pair<Point2, Color>> vPoints
- std::vector<std::pair<Triangle2, Color>> vTriangles
- std::vector<std::pair<Label, Color>> vLabels
- int updateCtr
- Bbox2 bbox
- bool bFill
- Color lastColor
- std::string filename
- std::vector<std::string> vHeaderLines
- bool bFileClosed

6.21.1 Detailed Description

See also

\[\text{http://www.geom.at/example2-traversing/}\]

Figure 27 Example output of the Visualizer

6.21.2 Constructor & Destructor Documentation

6.21.2.1 Visualizer2()

GEOM_FADE2D::Visualizer2::Visualizer2 (const std::string & filename_) [explicit]

Parameters

| filename_ ← _ | is the name of the postscript file to be written |
6.22 GEOM_FADE2D::Zone2 Class Reference

6.21.3 Member Function Documentation

6.21.3.1 writeFile()

void GEOM_FADE2D::Visualizer2::writeFile()

Note

This method must be called at the end when all the objects have been added.

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

- Visualizer2.h

6.22 GEOM_FADE2D::Zone2 Class Reference

Zone2 is an exactly defined area of a triangulation.

#include <Zone2.h>

Public Member Functions

- ZoneLocation getZoneLocation() const
  Get the zone location.
- Zone2 * convertToBoundedZone() const
  Convert a zone to a bounded zone.
- void show(const std::string &postscriptFilename, bool bShowFull, bool bWithConstraints) const
  Postscript visualization.
- void show(Visualizer2 *pVisualizer, bool bShowFull, bool bWithConstraints) const
  Postscript visualization.
- void unifyGrid(double tolerance)
- void getTriangles(std::vector<Triangle2 *> &vTriangles_) const
  Get the triangles of the zone.
- void getVertices(std::vector<Point2 *> &vVertices_) const
  Get the vertices of the zone.
- void statistics(const std::string &s) const
- ConstraintGraph2 *getConstraintGraph() const
  Get the associated constraint.
- size_t getNumberOfTriangles() const
  Get the number of triangles.
- void getConstraintGraphs(std::vector<ConstraintGraph2 *> &vConstraintGraphs_) const
  Get the associated constraint graphs.
- size_t numberOfConstraintGraphs() const
  Get a the number of ConstraintGraph2 objects.
- void debug(std::string name="")
  Development function.
- Bbox2 getBoundingBox() const
  Compute the bounding box.
- void getBoundaryEdges(std::vector<Edge2 *> &vEdges) const
  Compute the boundary edges of the zone.
- void getBoundarySegments(std::vector<Segment2 *> &vSegments) const
  Compute the boundary segments of the zone.
- double getArea2D() const
  Get 2D Area.
- void getBorderEdges(std::vector<Edge2 *> &vBorderEdgesOut) const
  Get border edges.
Protected Attributes

- Dt2 * pDt
- ZoneLocation zoneLoc

Friends

- Zone2 * zoneUnion (Zone2 * pZone0, Zone2 * pZone1)
  Compute the union of two zones.
- Zone2 * zoneIntersection (Zone2 * pZone0, Zone2 * pZone1)
  Compute the intersection of two zones.
- Zone2 * zoneDifference (Zone2 * pZone0, Zone2 * pZone1)
  Compute the difference of two zones.
- Zone2 * zoneSymmetricDifference (Zone2 * pZone0, Zone2 * pZone1)
  Compute the symmetric difference of two zones.
- Zone2 * peelOffIf (Zone2 * pZone, UserPredicateT * pPredicate, bool bVerbose)

6.22.1 Detailed Description

See also

http://www.geom.at/example4-zones-defined-areas-in-triangulations/
http://www.geom.at/boolean-operations/
createZone in the Fade2D class

6.22.2 Member Function Documentation

6.22.2.1 convertToBoundedZone()

Zone2* GEOM_FADE2D::Zone2::convertToBoundedZone ()

The mesh generation algorithms refine() and refineAdvanced() require a zone object that is bounded by constraint segments. This is always the case for zones with zoneLocation ZL_INSIDE but other types of zones may be unbounded. For convenience this method is provided to create a bounded zone from a possibly unbounded one.

Returns

a pointer to a new Zone2 object with zoneLocation ZL_RESULT_BOUNDED or this if this->getZoneLocation() is ZL_INSIDE.

6.22.2.2 getArea2D()

double GEOM_FADE2D::Zone2::getArea2D () const

Returns the 2D area of the zone.

Note: The getArea() method is deprecated and replaced by getArea2D() to keep the names consistent.
6.22.2.3 getBorderEdges()

```cpp
global void GEOM_FADE2D::Zone2::getBorderEdges { 
    std::vector< Edge2 > & vBorderEdgesOut ) const
```

**Returns**
- the CCW oriented border edges of the zone

6.22.2.4 getConstraintGraph()

```cpp
ConstraintGraph2* GEOM_FADE2D::Zone2::getConstraintGraph ( ) const
```

**Returns**
- a pointer to the ConstraintGraph2 object which defines the zone.
- or NULL for ZL_RESULT-, ZL_GROW and ZL_GLOBAL_-zones.

6.22.2.5 getConstraintGraphs()

```cpp
global void GEOM_FADE2D::Zone2::getConstraintGraphs { 
    std::vector< ConstraintGraph2 * > & vConstraintGraphs_ ) const
```

6.22.2.6 getNumberOfTriangles()

```cpp
size_t GEOM_FADE2D::Zone2::getNumberOfTriangles ( ) const
```

**Warning**
- This method is fast but O(n), so don't call it frequently in a loop.

6.22.2.7 getTriangles()

```cpp
global void GEOM_FADE2D::Zone2::getTriangles { 
    std::vector< Triangle2 * > & vTriangles_ ) const
```

This command fetches the existing triangles of the zone.

**Note**
- Fade_2D::void applyConstraintsAndZones() must be called after the last insertion of points and constraints.
- that the lifetime of data from the Fade2D datastructures does exceed the lifetime of the Fade2D object.
6.22.8  getVertices()

```cpp
void GEOM_FADE2D::Zone2::getVertices (
   std::vector< Point2 * > & vVertices_ ) const
```

6.22.9  getZoneLocation()

```cpp
ZoneLocation GEOM_FADE2D::Zone2::getZoneLocation ( ) const
```

**Returns**

- **ZL_INSIDE** if the zone applies to the triangles inside one or more `ConstraintGraph2` objects
- **ZL_OUTSIDE** if the zone applies to the outside triangles
- **ZL_GLOBAL** if the zone applies (dynamically) to all triangles
- **ZL_RESULT** if the zone is the result of a set operation
- **ZL_GROW** if the zone is specified by a set of constraint graphs and an inner point

![Figure 28 An outside zone and inside zone](image)

6.22.10  numberOfConstraintGraphs()

```cpp
size_t GEOM_FADE2D::Zone2::numberOfConstraintGraphs ( ) const
```

A `Zone2` object might be defined by zero, one or more `ConstraintGraph2` objects.

6.22.11  show()[1/2]

```cpp
void GEOM_FADE2D::Zone2::show (  
   const std::string & postscriptFilename,  
   bool bShowFull,  
   bool bWithConstraints ) const
```
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>postscriptFilename</td>
<td>is the name of the output file.</td>
</tr>
<tr>
<td>bShowFull</td>
<td>specifies if only the zone or the full triangulation shall be drawn</td>
</tr>
<tr>
<td>bWithConstraints</td>
<td>specifies if constraint edges shall be drawn</td>
</tr>
</tbody>
</table>

6.22.2.12 show() [2/2]

```cpp
define GEOM_FADE2D::Zone2::show (  
    Visualizer2 * pVisualizer,  
    bool bShowFull,  
    bool bWithConstraints  
) const
```

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pVisualizer</td>
<td>is a pointer to an existing Visualizer2 object.</td>
</tr>
</tbody>
</table>

Note

You must call pVisualizer->writeFile() before program end

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bShowFull</td>
<td>specifies if only the zone or the full triangulation shall be drawn</td>
</tr>
<tr>
<td>bWithConstraints</td>
<td>specifies if constraint edges shall be drawn</td>
</tr>
</tbody>
</table>

6.22.2.13 statistics()

```cpp
define GEOM_FADE2D::Zone2::statistics (  
    const std::string & s  
) const
```

Statistics

Prints statistics to stdout.

6.22.2.14 unifyGrid()

```cpp
define GEOM_FADE2D::Zone2::unifyGrid (  
    double tolerance  
)
```

Unify Grid

A Delaunay triangulation not unique when when 2 or more triangles share a common circumcircle. As a consequence the four corners of a rectangle can be triangulated in two different ways: Either the diagonal proceeds from the lower left to the upper right corner or it connects the other two corners. Both solutions are valid and an arbitrary one is applied when points are triangulated. To improve the repeatability and for reasons of visual appearance this method unifies such diagonals to point from the lower left to the upper right corner (or in horizontal direction).
Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tolerance</td>
<td>is 0 when only exact cases of more than 3 points on a common circumcircle shall be changed. But in practice input data can be disturbed by noise and tiny rounding errors such that grid points are not exactly on a grid. The numeric error is computed as $error = \frac{\text{abs}(\text{diagonalA} - \text{diagonalB})}{\max(\text{diagonalA,diagonalB})}$ and tolerance is an upper threshold to allow modification despite such tiny inaccuracies. Use with caution, such flips break the empty circle property and this may or may not fit your setting.</td>
</tr>
</tbody>
</table>

6.22.3  Friends And Related Function Documentation

6.22.3.1  zoneDifference

```cpp
Zone2* zoneDifference (    Zone2 * pZone0,    Zone2 * pZone1 ) [friend]
```

Returns

a new zone containing the triangles of *pZone0 minus the ones of *pZone1

Note

*pZone0 and pZone1 must belong to the same Fade_2D object.*

6.22.3.2  zoneIntersection

```cpp
Zone2* zoneIntersection (    Zone2 * pZone0,    Zone2 * pZone1 ) [friend]
```

Returns

a new zone containing the intersection of *pZone0 and *pZone1

Note

*pZone0 and pZone1 must belong to the same Fade_2D object.*
6.22.3.3 zoneSymmetricDifference

\texttt{Zone2* zoneSymmetricDifference (}
\texttt{Zone2* pZone0,}
\texttt{Zone2* pZone1) [friend]}

Returns

a new zone containing the triangles that are present in one of the zones but not in the other one.

Note

\texttt{pZone0} and \texttt{pZone1} must belong to the same \texttt{Fade\_2D} object.

6.22.3.4 zoneUnion

\texttt{Zone2* zoneUnion (}
\texttt{Zone2* pZone0,}
\texttt{Zone2* pZone1) [friend]}

Returns

a new zone containing the union of the triangles of \texttt{*pZone0} and \texttt{*pZone1}

Note

\texttt{pZone0} and \texttt{pZone1} must belong to the same \texttt{Fade\_2D} object.

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

- Zone2.h

7 File Documentation

7.1 Color.h File Reference

#include "common.h"

Classes

- class \texttt{GEOM\_FADE2D::Color}

Color.

Enumerations

- enum \texttt{GEOM\_FADE2D::Colorname} {
  \texttt{CRED, CGREEN, CBLUE, CBLACK,}
  \texttt{CPINK, CGRAY, CORANGE, CLIGHTBLUE,}
  \texttt{CLIGHTBROWN, CDARKBROWN, CPURPLE, COLIVE,}
  \texttt{CLAWNGREEN, CPALEGREEN, CCYAN, CYELLOW,}
  \texttt{CWHITE} }

Predefined colors for convenience.

Functions

- std::ostream & \texttt{GEOM\_FADE2D::operator<< (std::ostream &stream, const Color &c)
add
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