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Introduction to Boost.Geometry

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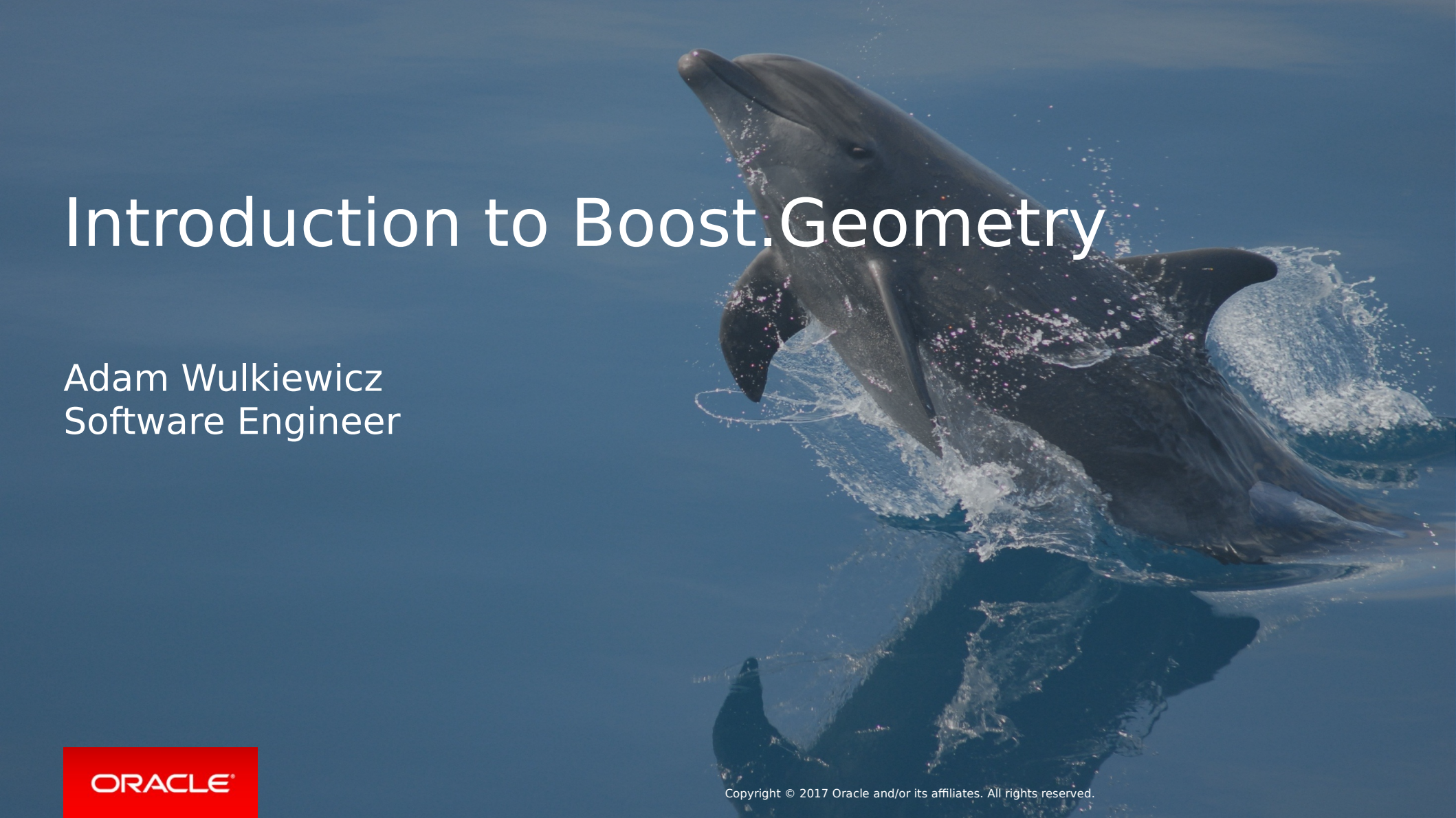

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Agenda

1. Boost.Geometry
2. Hello World!
3. Primitives
4. Algorithms
5. Spatial Index
6. Debugging Helpers

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Boost.Geometry

1. Part of Boost C++ Libraries
2. Header-only
3. C++03 support
4. Conditionally C++11
5. Metaprogramming, Tags dispatching
6. Primitives, Algorithms, Spatial Index
7. OGC SFA conformant

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Boost.Geometry

1. Documentation:
   www.boost.org/libs/geometry
2. Mailing list:
   lists.boost.org/geometry
3. GitHub:
   github.com/boostorg/geometry

boost GEOMETRY

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Hello World!

```
#include <boost/geometry.hpp>
#include <boost/geometry/geometries/geometries.hpp>
#include <iostream>
namespace bg = boost::geometry;

int main() {
  using point = bg::model::point
                  <double, 2, bg::cs::geographic<bg::degree>>;

  // Lodz -> Brussels
  std::cout << bg::distance(point(19.454722, 51.776667),
                            point(4.350000, 50.833333));
}
```

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Hello World! - result

```
1056641.830203
```


```
maps.google.com
```

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Primitives

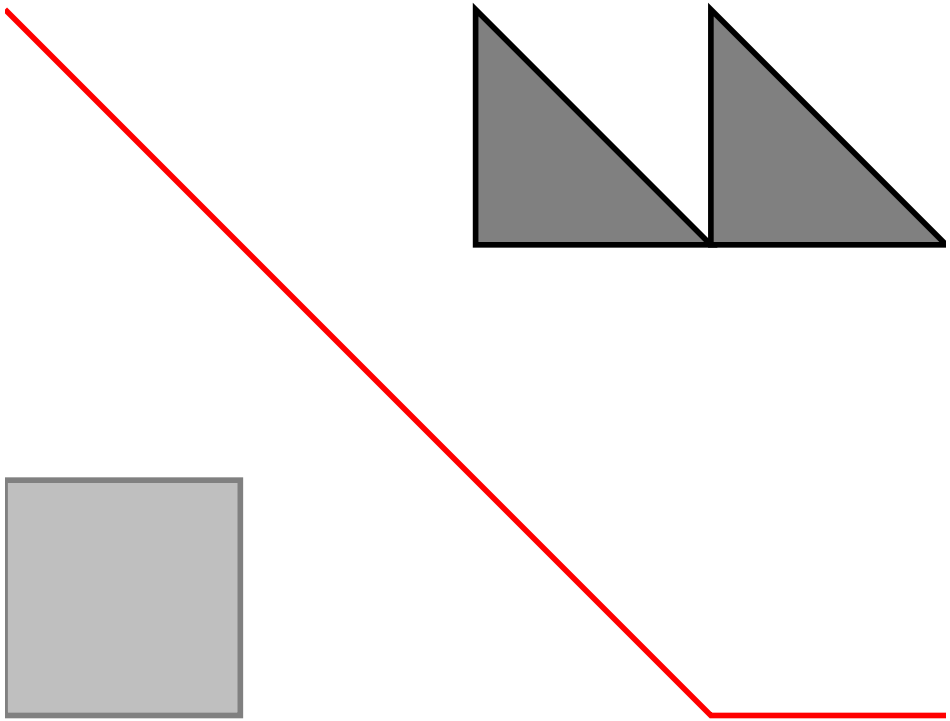
1. Point, MultiPoint
2. Segment, Linestring, MultiLinestring
3. Ring, Polygon, MultiPolygon
4. Box

Primitives

```
using point = bg::model::point<double, 2, bg::cs::cartesian>;
using linestring = bg::model::linestring<point>;
using polygon = bg::model::polygon<point>;
using multi_polygon = bg::model::multi_polygon<polygon>;

linestring ls;
polygon poly;
multi_polygon mpoly;

bg::read_wkt("LINESTRING(0 3, 3 0, 4 0)", ls);
bg::read_wkt("POLYGON((0 0, 0 1, 1 1, 1 0, 0 0))", poly);
bg::read_wkt("MULTIPOLYGON(((2 2,2 3,3 2,2 2)),((3 2,3 3,4 2,3 2)))",
             mpoly);

std::cout << bg::distance(ls, poly) << '\n'
          << bg::distance(ls, mpoly);
```

Primitives - result

```
0.707107
0.707107
```

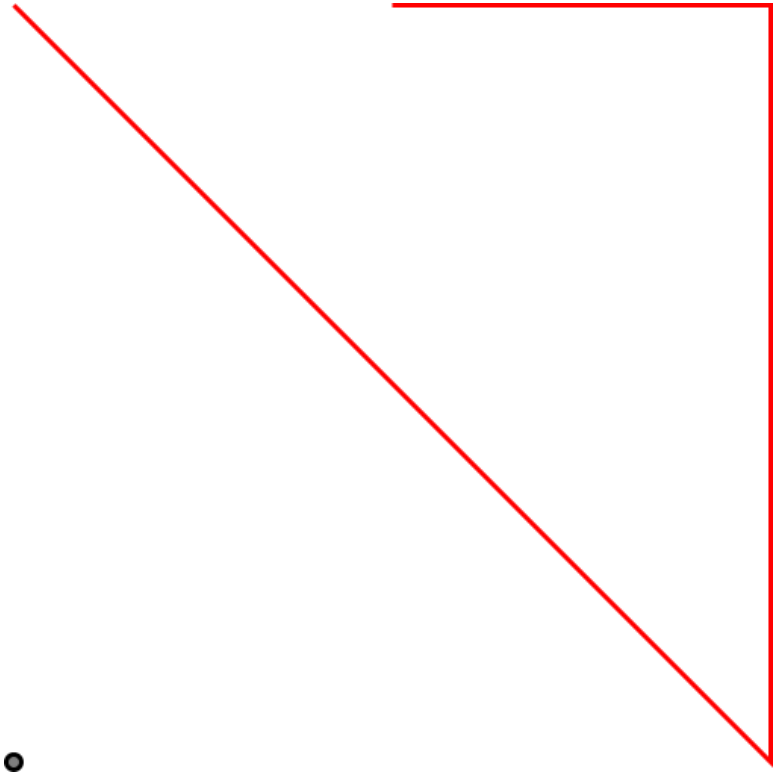


Primitives - adaptation

```
#include <boost/geometry.hpp>
#include <boost/geometry/geometries/register/point.hpp>
#include <boost/geometry/geometries/register/linestring.hpp>
#include <iostream>
#include <vector>
namespace bg = boost::geometry;

struct my_point { double x, y; };

BOOST_GEOMETRY_REGISTER_POINT_2D(my_point, double, bg::cs::cartesian, x, y)
BOOST_GEOMETRY_REGISTER_LINESTRING(std::vector<my_point>)

int main() {
  my_point pt{0, 0};
  std::vector<my_point> ls{{0, 1}, {1, 0}, {1, 1}, {0.5, 1}};

  std::cout << bg::distance(pt, ls);
}
```

Primitives - result

```
0.707107
```



Algorithms

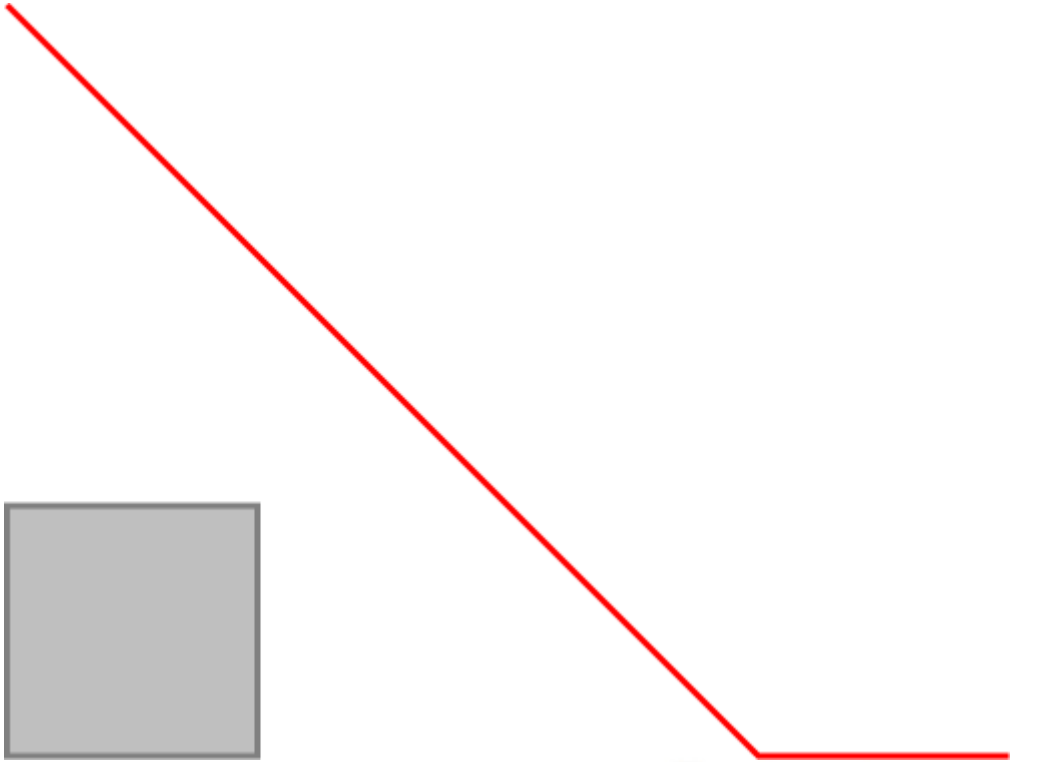
1. area, length, perimeter, num_points,
2. crosses, disjoint, distance, equals, intersects, overlaps, relate, relation, within,
3. centroid, convex_hull, envelope, buffer, simplify
4. difference, intersection, sym_difference, union_,
5. more...

Algorithms

```
linestring ls;
polygon poly;

bg::read_wkt("LINESTRING(0 3, 3 0, 4 0)", ls);
bg::read_wkt("POLYGON((0 0, 0 1, 1 1, 1 0, 0 0))", poly);

std::cout << "length    " << bg::length(ls) << '\n'
          << "area      " << bg::area(poly) << '\n'
          << "perimeter " << bg::perimeter(poly);
```

Algorithms - result

```
length    5.242641
area      1.000000
perimeter 4.000000
```



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Algorithms

```
linestring ls;
polygon poly;

bg::read_wkt("LINESTRING(0 1.5, 1.5 0)", ls);
bg::read_wkt("POLYGON((0 0, 0 1, 1 1, 1 0, 0 0))", poly);

std::cout << "intersects " << bg::intersects(ls, poly) << '\n'
          << "relation   " << bg::relation(ls, poly).str() << '\n'
          << "within     " << bg::within(ls, poly);
```

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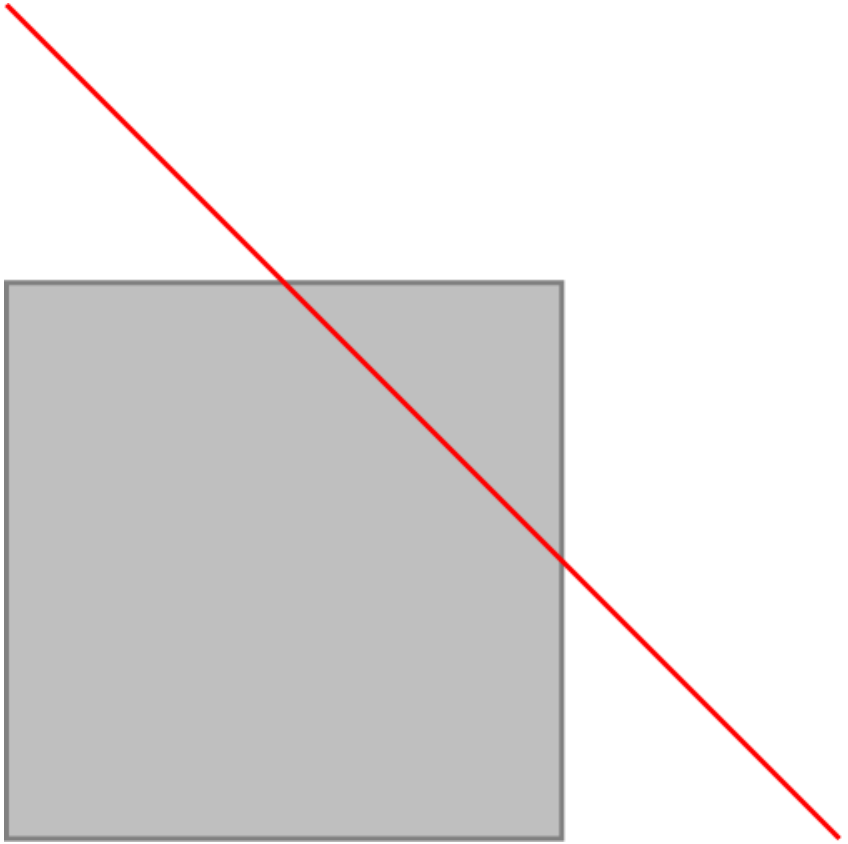
Algorithms - result

```
intersects 1
relation   101FF0212
within     0
```



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Algorithms

```
point p;
linestring ls;
box b;
polygon poly;

bg::read_wkt("LINESTRING(0 0, 1 3, 2 0, 4 4, 0 1)", ls);

bg::centroid(ls, p);
bg::envelope(ls, b);
bg::convex_hull(ls, poly);

std::cout << "centroid " << bg::wkt(p) << '\n'
          << "envelope " << bg::wkt(b) << '\n'
          << "hull     " << bg::wkt(poly);
```

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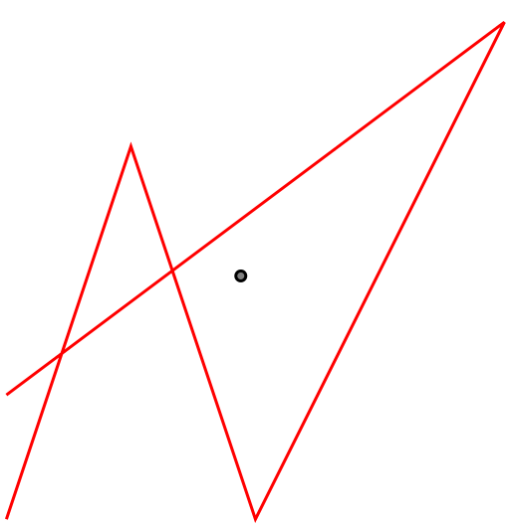
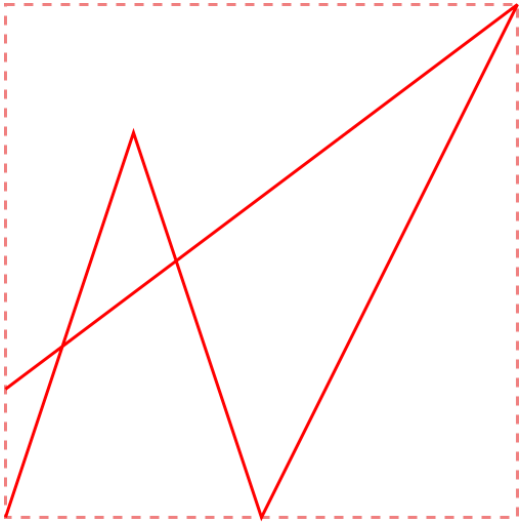
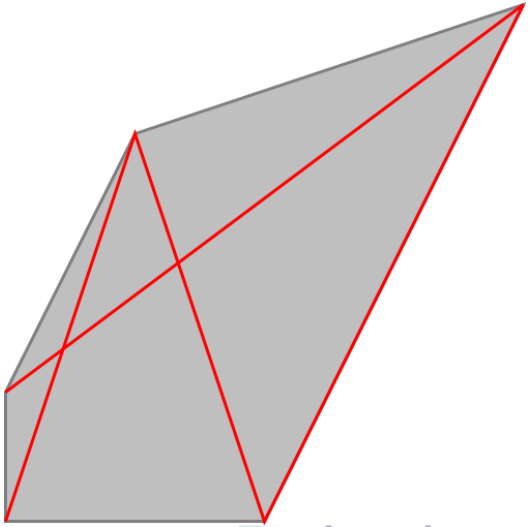
Algorithms - result

```
centroid POINT(1.882734 1.958075)
envelope POLYGON((0 0,0 4,4 4,4 0,0 0))
hull     POLYGON((0 0,0 1,1 3,4 4,2 0,0 0))
```







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Algorithms

```
linestring ls;
multi_polygon mpoly;

bg::read_wkt("LINESTRING(0 0, 1 3, 2 0, 4 4, 0 1)", ls);

namespace bgsb = bg::strategy::buffer;
bg::buffer(ls, mpoly, bgsb::distance_symmetric<double>(0.5),
                      bgsb::side_straight(),
                      bgsb::join_round(32),
                      bgsb::end_round(32),
                      bgsb::point_circle(32));

std::cout << bg::wkt(mpoly);
```

Algorithms - result

```
MULTIPOLYGON(((1.588304 2.816228,3.700000 4.400000,3.781519 4.449740,3.871007
4.483074,3.965200 4.498788,4.060663 4.496306,4.153913 4.475721,4.241549 4.437783,4.320374
4.383876,4.387512 4.315966,4.440515 4.236530,4.477449 4.148467,4.496967 4.054987,4.498357
3.959502,4.481569 3.865495,4.447214 3.776393,2.447214 -0.223607,2.394997 -0.306557,2.327601
-0.377727,2.247615 -0.434381,2.158114 -0.474342,2.062536 -0.496074,1.964555
-0.498742,1.867937 -0.482244,1.776393 -0.447214,1.693443 -0.394997,1.622273
-0.327601,1.565619 -0.247615,1.525658 -0.158114,1.078363 1.183772,0.869395
1.027046,0.474342 -0.158114,0.434381 -0.247615,0.377727 -0.327601,0.306557
-0.394997,0.223607 -0.447214,0.132063 -0.482244,0.035445 -0.498742,-0.062536 -0.496074,-
0.158114 -0.474342,-0.247615 -0.434381,-0.327601 -0.377727,-0.394997 -0.306557,-0.447214
-0.223607,-0.482244 -0.132063,-0.498742 -0.035445,-0.496074 0.062536,-0.474342 0.158114,-
0.320943 0.618309,-0.333787 0.627728,-0.400000 0.700000,-0.450841 0.783801,-0.484357
0.875910,-0.499259 0.972787,-0.494975 1.070711,-0.471669 1.165917,-0.430237 1.254747,-
0.372272 1.333787,-0.300000 1.400000,0.019494 1.639620,0.525658 3.158114,0.564586
3.245794,0.619542 3.324425,0.688504 3.391114,0.768932 3.443405,0.857867 3.479373,0.952034
3.497694,1.047966 3.497694,1.142133 3.479373,1.231068 3.443405,1.311496 3.391114,1.380458
3.324425,1.435414 3.245794,1.474342 3.158114,1.588304 2.816228),(2.092621 1.303276,2.605573
2.329179,1.921637 1.816228,2.092621 1.303276)))
```

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Algorithms

```
polygon poly1, poly2;
multi_polygon mpoly1, mpoly2;

bg::read_wkt("POLYGON((0 0,0 3,1 2.9,2 2.6,2.6 2,2.9 1,3 0,0 0))",
             poly1);
bg::read_wkt("POLYGON((1 1,1 4,4 4,4 1,1 1))", poly2);

bg::intersection(poly1, poly2, mpoly1);
bg::sym_difference(poly1, poly2, mpoly2);

std::cout << bg::wkt(mpoly1) << '\n';
          << bg::wkt(mpoly2);
```

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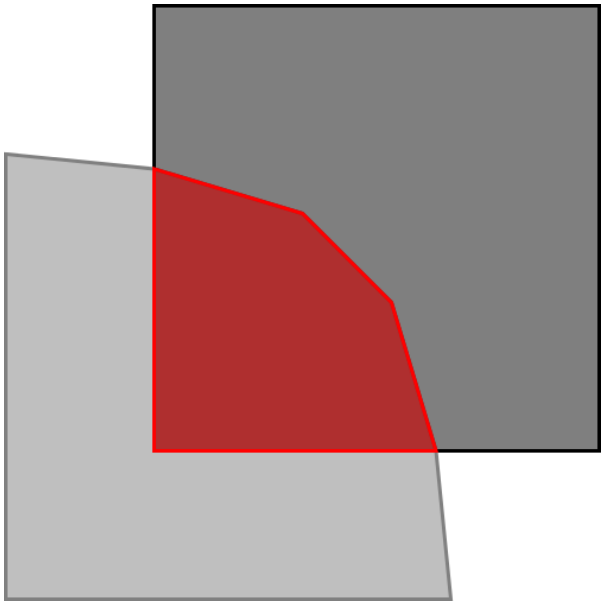
Algorithms - result

```
MULTIPOLYGON(((1 3,2 3,3 2,3 1,1 1,1 3)))
MULTIPOLYGON(((1 3,1 1,3 1,3 0,0 0,0 3,1 3)),
             ((1 3,1 4,4 4,4 1,3 1,3 2,2 3,1 3)))
```



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Spatial Index

1. R-tree
2. linear, quadratic or r*-tree
3. bulk-loading
4. user-defined value type
5. various spatial and knn query
6. stateful-allocator, move semantics, etc.

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Spatial Index

```
#include <boost/geometry.hpp>
#include <boost/geometry/geometries/geometries.hpp>
#include <boost/geometry/index/rtree.hpp>
#include <iostream>
#include <vector>
namespace bg = boost::geometry;

using point = bg::model::point<double, 2, bg::cs::cartesian>;
using polygon = bg::model::polygon<point>;
using box = bg::model::box<point>;

using value = std::pair<box, std::size_t>;
using rtree = bg::index::rtree<value, bg::index::rstar<16>>;
```

Spatial Index cont.

```
int main() {
  std::vector<polygon> polys(4);
  bg::read_wkt("POLYGON((0 0, 0 1, 1 0, 0 0))", polys[0]);
  bg::read_wkt("POLYGON((1 1, 1 2, 2 1, 1 1))", polys[1]);
  bg::read_wkt("POLYGON((2 2, 2 3, 3 2, 2 2))", polys[2]);
  bg::read_wkt("POLYGON((3 3, 3 4, 4 3, 3 3))", polys[3]);

  rtree rt;
  for (std::size_t i = 0 ; i < polys.size() ; ++i) {
    box b = bg::return_envelope<box>(polys[i]);
    rt.insert(std::make_pair(b, i));
  }
```

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Spatial Index cont.

```
    polygon qpoly;
    bg::read_wkt("POLYGON((0.25 0.25,0.5 1.5,0.9 0.9,1.5 0.5,0.25 0.25))",
                 qpoly);
    box qbox = bg::return_buffer<box>(bg::return_envelope<box>(qpoly),
                                      0.0001);

    std::vector<value> result;
    rt.query(bg::index::intersects(qbox), std::back_inserter(result));

    for (value const& v : result) {
      std::cout << bg::wkt(polys[v.second])
                << (bg::intersects(polys[v.second], qpoly)
                    ? " intersects" : " not intersects") << std::endl;
    }
}
```

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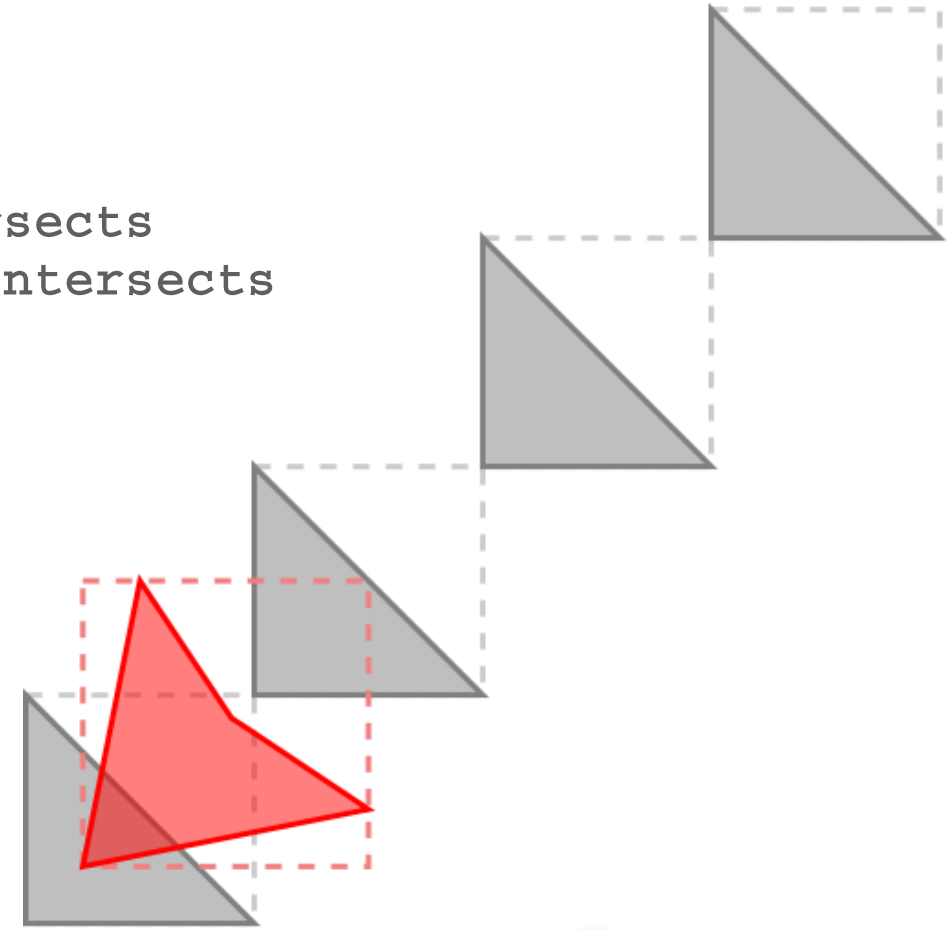
Spatial Index

```
POLYGON((0 0,0 1,1 0,0 0)) intersects
POLYGON((1 1,1 2,2 1,1 1)) not intersects
```



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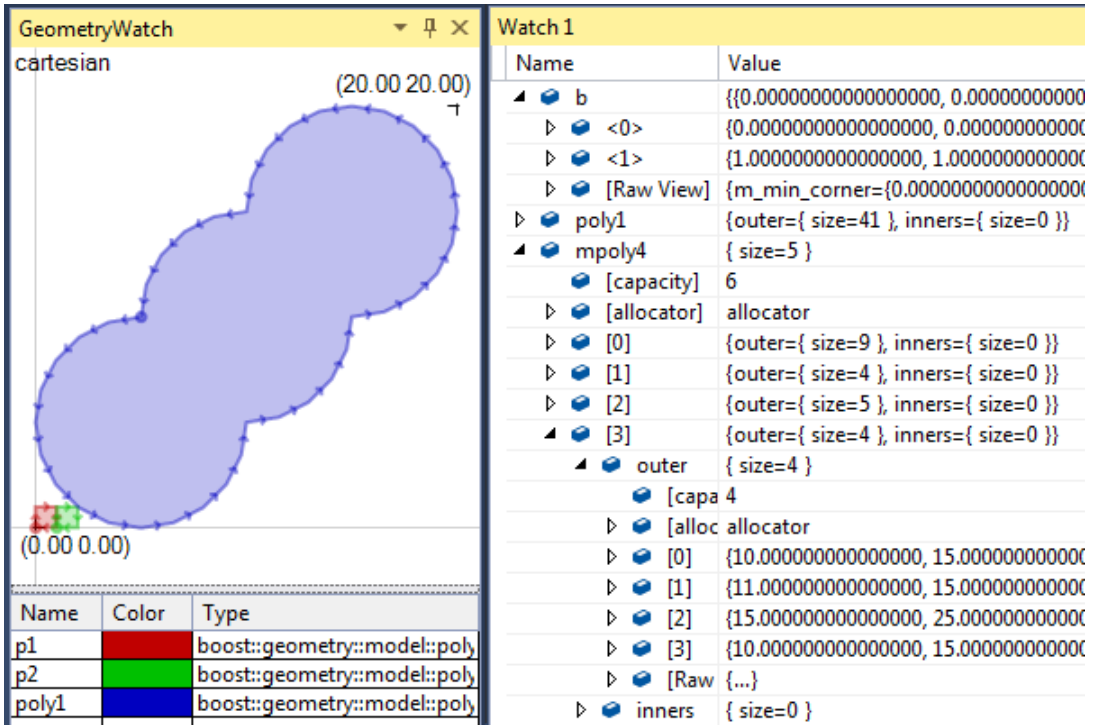
Debugging Helpers

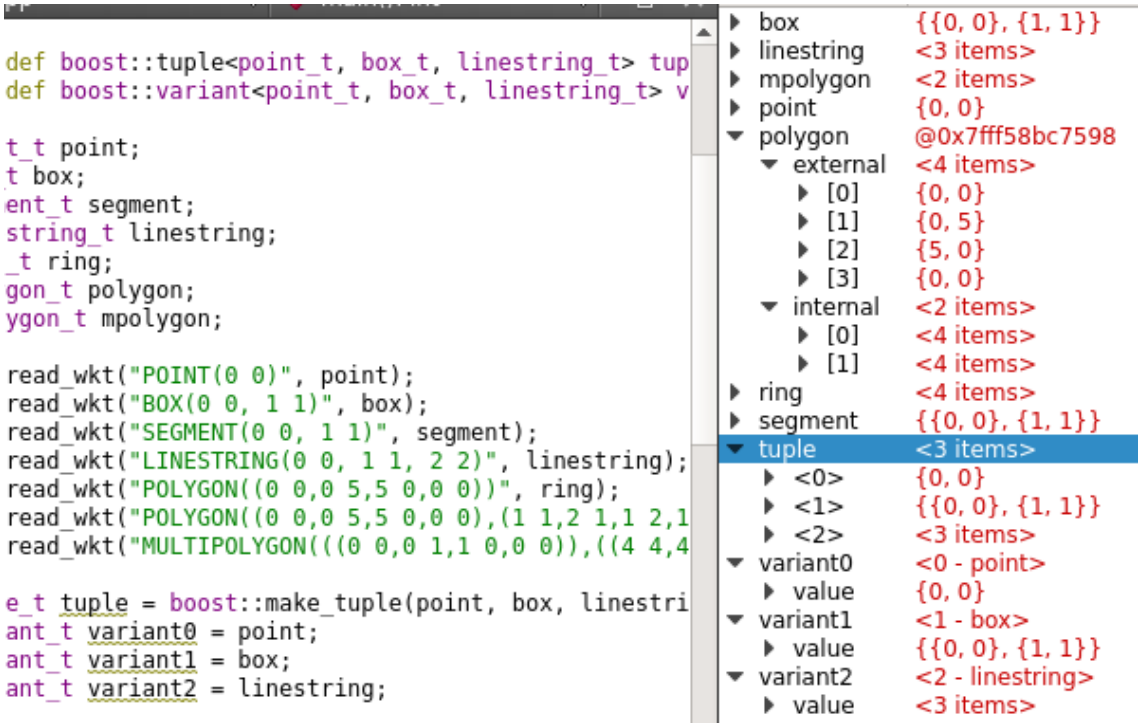
Visual Studio 2015 GraphicalDebugging extension



github.com/awulkiew/graphical-debugging

Debugging Helpers

QtCreator
Debugging Helpers



github.com/awulkiew/debugging-helpers

Thanks!

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Applications & Platform Services

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