Introduction to Boost.Geometry

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- GDAL/OGR maintainer 2006-2008
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overview

what is Boost.Geometry?

- a library dedicated to programmers
- collection of types and algorithms
- solving computational geometry problems
- written in C++ programming language
- header-only library

what is Boost?

full name: Boost C++ Libraries

http://boost.org/

“The Boost C++ Libraries are a collection of free libraries that extend the functionality of C++”

» *Wikipedia*

history (1)

- 1995 - Geodan Geographic Library
- 2008 - 1st preview for Boost as Geometry Library
- 2009 - 4th preview for Boost as Generic Geometry Library (GGL)
- November 2009 - final review and acceptance to Boost collection as Boost.Geometry

Boost review

- start on November 5, 2009
- review manager: Hartmut Kaiser (Boost.Spirit)
- 14 reviewers
- finish on November 23, 2009
- final report on November 28, 2009
  - 12 votes Yes
  - 2 votes No
  - Several conditions of acceptance

conclusions

"The design is very clear. I think it can serve as a standard example of how to cover a big non trivial problem domain using meta-programming, partial specialization and tag dispatch to make it uniformly accessible by a set of generic algorithms"

future

- incorporate to Boost C++ Libraries
  - work steadily moves on
- release
  - Boost ~~1.44?~~ or 1.45 or 1.46 or ...

team

- Barend Gehrels at Geodan
  - lead developer and project manager
- Bruno Lalande
  - lead developer
- Mateusz Loskot
  - supporting developer

community

- GGL mailing list
  - http://lists.osgeo.org/mailman/listinfo/ggl
  - ~50 users

- Boost mailing lists
  - http://lists.boost.org
  - very large community with a couple of dozens hackers discussing ideas for Boost.Geometry

users

- Merkaartor (Open Street Map)
- Open Graph Router
- Flight Logbook
- Games (Tangram)
- Geodan

guardian.co.uk

potential

?

design

challenges

to design and implement a library as

- generic
- fast
- robust
- not specific to any domain
- extensible

programming tool satisfying many with usable
“explosion of capabilities”

technology

- C++ Programming Language
  - ISO/IEC 14882:2003
- C++ Standard Library
- Boost C++ Libraries
- Generic programming techniques

Metaprogramming (generic programming)

template

+

instantiation

+

compiler

=

final source code of a specific program

metaprogramming techniques

- templates – generic form of source (type)
- metafunctions – generate type at compile-time, type selection techniques, encapsulate computation algorithm
- traits – associates additional information
- tag dispatching – uses traits to distinguish types dispatch calls
- concepts – non-intrusive design - “generate” your own library of types and algorithms
- compile-time strategy pattern

concepts and models

"A concept is a set of requirements consisting of valid expressions, associated types, invariants, and complexity guarantees."

"A type that satisfies the requirements is said to model the concept"

- David Abrahams and Jeremy Siek

strategies

template

+

type parameters (traits)

+

instantiation

=

selection of algorithms

agnosticism of dimension

- dimension

```
point<int, 1, cartesian>

polygon<
  point<double, 2, spherical<radian>>>
```

agnosticism of coordinate type (1)

- support of different numeric types

```
point<int, 2, cartesian>

polygon<
  point<double, 3, spherical<radian>>>
```

agnosticism of coordinate type (2)

- support arbitrary precision arithmetic numbers
  - GMP and others (adapted by Boost.Math)
- algorithms select most precise type :
  - int + int → int
  - int + float → float
  - int + GMP → GMP
  - GMP + double → GMP

agnosticism of coordinate space

- points instantiated with coordinate system
- support user-defined coordinate systems
- traits and tag dispatching delegate computations to strategies suitable for specified coordinate system

```
point<int, 1, cartesian>

polygon<
  point<double, 2, spherical<radian>>>
```

features

Geometry Concepts

0-dimensional

boost::geometry::concept::Point
boost::geometry::concept::ConstPoint

1-dimensional

boost::geometry::concept::Segment
boost::geometry::concept::ConstSegment
boost::geometry::concept::Linestring
boost::geometry::concept::ConstLinestring

2-dimensional

boost::geometry::concept::Box
boost::geometry::concept::ConstBox
boost::geometry::concept::Ring
boost::geometry::concept::ConstRing
boost::geometry::concept::Polygon
boost::geometry::concept::ConstPolygon

Functions

boost::geometry::concept::check
boost::geometry::concept::check_concepts_and_equal_dimensions

Geometry Models

0-dimensional

boost::geometry::point
boost::geometry::point_xy
boost::geometry::point_2d
boost::geometry::point_3d

1-dimensional

boost::geometry::segment
boost::geometry::segment_2d
boost::geometry::linestring
boost::geometry::linestring_2d
boost::geometry::linestring_3d

2-dimensional

boost::geometry::box
boost::geometry::box_2d
boost::geometry::box_3d
boost::geometry::box
boost::geometry::linear_ring
boost::geometry::ring_2d
boost::geometry::ring_3d
boost::geometry::polygon
boost::geometry::polygon_2d
boost::geometry::polygon_3d

Adapted:
Boost.Tuple, Boost.Array, C Array, std::vector, std::deque, std::pair

Core

Metafunctions

boost::geometry::cs_tag
boost::geometry::coordinate_type
boost::geometry::coordinate_system
boost::geometry::dimension
boost::geometry::geometry_id
boost::geometry::interior_type
boost::geometry::is_linear
boost::geometry::is_multi
boost::geometry::is_radian
boost::geometry::point_order
boost::geometry::point_type
boost::geometry::ring_type
boost::geometry::replace_point_type
boost::geometry::reverse_dispatch
boost::geometry::tag
boost::geometry::topological_dimension

Access Functions

boost::geometry::exterior_ring
boost::geometry::get
boost::geometry::get_as_radian
boost::geometry::interior_rings
boost::geometry::num_interior_rings
boost::geometry::num_points
boost::geometry::set
boost::geometry::set_from_radian

Classes

boost::geometry::exception
boost::geometry::centroid_exception

Coordinate Systems

Classes

boost::geometry::cs::cartesian
boost::geometry::cs::geographic
boost::geometry::cs::polar
boost::geometry::cs::spherical

Iterators

Metafunctions

boost::geometry::range_type

Classes

boost::geometry::circular_iterator
boost::geometry::ever_circling_iterator
boost::geometry::one_section_segment_iterator
boost::geometry::section_iterator
boost::geometry::segment_iterator

Functions

boost::geometry::make_segment_iterator
boost::geometry::operator==
boost::geometry::operator!=

Algorithms

Geometry Constructors

boost::geometry::make
boost::geometry::make_inverse
boost::geometry::make_zero

Predicates

boost::geometry::disjoint
boost::geometry::equals
boost::geometry::intersects
boost::geometry::overlaps
boost::geometry::selected
boost::geometry::within

Append

boost::geometry::append

Area

boost::geometry::area

Assign

boost::geometry::assign
boost::geometry::assign_box_corners
boost::geometry::assign_inverse
boost::geometry::assign_point_from_index
boost::geometry::assign_point_to_index
boost::geometry::assign_zero

Buffer

boost::geometry::buffer
boost::geometry::make_buffer

Centroid

boost::geometry::centroid
boost::geometry::make_centroid

Clear

boost::geometry::clear

Combine

boost::geometry::combine

Convert

boost::geometry::convert

Convex Hull

boost::geometry::convex_hull
boost::geometry::convex_hull_inserter

Correct

boost::geometry::correct

Distance

boost::geometry::distance

Difference

boost::geometry::difference
boost::geometry::sym_difference

Dissolve

boost::geometry::dissolve

Envelope

boost::geometry::envelope
boost::geometry::make_envelope

for_each

boost::geometry::for_each_point
boost::geometry::for_each_segment

Intersection

boost::geometry::intersection_inserter

Length

boost::geometry::length

Overlay

boost::geometry::copy_segments
boost::geometry::copy_segment_point
boost::geometry::copy_segment_points
boost::geometry::enrich_intersection_points
boost::geometry::get_turns
boost::geometry::traverse

Perimeter

boost::geometry::perimeter

Reverse

boost::geometry::reverse

Section

boost::geometry::get_section
boost::geometry::sectionalize

Simplify

boost::geometry::simplify
boost::geometry::simplify_inserter

Transform

boost::geometry::transform

Union

boost::geometry::union_inserter

Unique

boost::geometry::unique

Miscellaneous Utilities

boost::geometry::parse

Strategies

Area

boost::geometry::strategy_area
boost::geometry::area_result
boost::geometry::strategy::area::by_triangles
boost::geometry::strategy::area::huiller

Buffer

boost::geometry::strategy::buffer::join_miter
boost::geometry::strategy::buffer::join_bevel
boost::geometry::strategy::buffer::join_round

Centroid

boost::geometry::strategy_centroid
boost::geometry::strategy::centroid_::bashein_detmer
boost::geometry::strategy::centroid_::centroid_average

Compare

boost::geometry::strategy_compare
boost::geometry::strategy::compare::default_strategy
boost::geometry::strategy::compare::circular_comparator

Convex Hull

boost::geometry::strategy_convex_hull
boost::geometry::strategy::convex_hull::graham_andrew

Distance

boost::geometry::strategy_distance
boost::geometry::strategy_distance_segment
boost::geometry::cartesian_distance
boost::geometry::distance_result
boost::geometry::make_distance_result
boost::geometry::close_to_zero
boost::geometry::fuzzy_equals
boost::geometry::strategy::distance::projected_point
boost::geometry::strategy::distance::pythagoras
boost::geometry::strategy::distance::cross_track
boost::geometry::strategy::distance::haversine

Intersection

boost::geometry::de9im
boost::geometry::de9im_segment
boost::geometry::segment_intersection_points
boost::geometry::strategy_intersection
boost::geometry::strategy::intersection::liang_barsky
boost::geometry::strategy::intersection::relate_cartesian_segments
boost::geometry::strategy::intersection::relate_cartesian_segments

Side

boost::geometry::strategy_side
boost::geometry::side_info
boost::geometry::strategy::side::course
boost::geometry::strategy::side::side_by_triangle
boost::geometry::strategy::side::side_by_cross_track

Simplify

boost::geometry::strategy::simplify::douglas_peucker

Transform

boost::geometry::strategy_transform
boost::geometry::strategy::copy_direct
boost::geometry::strategy::copy_per_coordinate
boost::geometry::strategy::degree_radian_w
boost::geometry::strategy::degree_radian_w_3
boost::geometry::strategy::from_spherical_2_to_cartesian_3
boost::geometry::strategy::from_spherical_3_to_cartesian_3
boost::geometry::strategy::from_cartesian_3_to_spherical_2
boost::geometry::strategy::from_cartesian_3_to_spherical_3
boost::geometry::strategy::inverse_transformer
boost::geometry::strategy::map_transformer
boost::geometry::strategy::ublas_transformer
boost::geometry::strategy::translate_transformer
boost::geometry::strategy::scale_transformer
boost::geometry::strategy::rotate_transformer

Within

boost::geometry::strategy::winding
boost::geometry::strategy::crossings_multiply
boost::geometry::strategy::franklin

Miscellaneous Utilities

boost::geometry::strategy::not_implemented

Policies

Compare

boost::geometry::equal_to
boost::geometry::greater
boost::geometry::less

Relate

boost::geometry::policies::relate::direction_type
boost::geometry::policies::relate::segments_de9im
boost::geometry::policies::relate::segments_direction
boost::geometry::policies::relate::segments_intersection_points
boost::geometry::policies::relate::segments_tupled

Strategy Concepts

boost::geometry::concept::AreaStrategy
boost::geometry::concept::CentroidStrategy
boost::geometry::concept::ConvexHullStrategy
boost::geometry::concept::PointDistanceStrategy
boost::geometry::concept::PointSegmentDistanceStrategy

boost::geometry::concept::SegmentIntersectStrategy
boost::geometry::concept::SimplifyStrategy
boost::geometry::concept::WithinStrategy

Arithmetic

Add

boost::geometry::add_point
boost::geometry::add_value

Subtract

boost::geometry::subtract_point
boost::geometry::subtract_value

Multiply

boost::geometry::multiply_point
boost::geometry::multiply_value

Divide

boost::geometry::divide_point
boost::geometry::divide_value

Products

boost::geometry::cross_product
boost::geometry::dot_product

Extensions

TODO

...

performance

http://trac.osgeo.org/ggl/wiki/Performance

"We are aware of the weaknesses of performance tests and that it is hard to design objective benchmarks"

"There are so many differences in behaviour in all libraries under different circumstances, it appeared to be impossible or at least very difficult to compare libraries in one benchmark"

Try it yourself!

http://svn.osgeo.org/osgeo/foss4g/benchmarking/geometry_libraries/

Thank you!

Boost.Geometry
http://trac.osgeo.org/ggl/

presented today with friendly support from Cadcorp