

## CGAL @ RFIAP 2018



Simon Giraudot GeometryFactory

### **Mission Statement**

"Make the large body of geometric algorithms developed in the field of computational geometry available for industrial applications"

CGAL EU Project Proposal, 1996

### CGAL 2D Algorithms and Data Structures



Triangulation



Mesh Generation







Polyline Simplification





Straight Skeleton



Arrangement

**Boolean Operations** 

Neighborhood Queries

Minkowski Sum

Voronoi Diagram



### CGAL 3D Algorithms and Data Structures





Tetrahedralization Operations

Mesh Generation



Polyhedral Surface



Deformation



Boolean





Skeleton



Segmentation



Classification



Hole Filling

### **CGAL** in Numbers

- 700,000 lines of C++ code
  - 10,000 downloads/year (+ Linux distributions)
    - 3,500 manual pages (user and reference manual)
    - 1,000 subscribers to user mailing list
      - 200 commercial users
      - 120 software components
        - 20 active developers
        - 6 months release cycle
        - 2 licenses: Open Source and commercial

## The CGAL Library

- C++ template class library
- Header only
- Cross platform: Windows, Linux, MacOs Android
- Supported compilers: VC++, g++, clang
- For several packages Java/Python bindings (using Swig)
- Dependencies
  - Boost: selected libraries
  - GMP, Mpfr: exact number types
  - Eigen: algebraic solvers
  - LAStools: I/O for LAS file format
  - OpenCV: random forests

## The CGAL Project

- Started 1996 as EU Research Project
- Academic project partners make long term commitment
- Editorial Board
  - Steers and animates the project
  - Reviews submissions
- Development infrastructure
  - CGAL on github, doxygen, travis, nightly testsuite (~40 platforms)
  - Two developer meetings per year

### GeometryFactory

- 6 engineers with a PhDs in CS with focus on geometric computing
- Sales of CGAL software components
- Support to increase customer productivity
- Backed by the CGAL Open Source Project
- Actively involved in the CGAL Project:
  3 EB members (including release management)

### Licenses

- Open Source Licenses:
  - LGPL for Foundation Layer
  - GPL for other packages
- Commercial Licenses
  - Annual Research Licenses for entire CGAL
  - Commercial License for components





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| cgal.org                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Тор | Getting Started | Organization of the Manual | Package Overview | Acknowledging CGAL |              |   |   |   |    | C     | <b>Q-</b> Sea | rch |     |     | ) |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |     |                 | 2 I                        |                  |                    |              |   |   |   |    |       |               |     |     |     |   |

### CGAL 4.8 - Manual

| CGAL 4.8 - Manual                          | Package Overview       |                                                                                           |                                                  |  |  |  |  |  |  |
|--------------------------------------------|------------------------|-------------------------------------------------------------------------------------------|--------------------------------------------------|--|--|--|--|--|--|
| Getting Started                            |                        |                                                                                           |                                                  |  |  |  |  |  |  |
| V Package Overview                         | Arithmatic and Alasha  |                                                                                           |                                                  |  |  |  |  |  |  |
| Arithmetic and Algebra                     | Arithmetic and Algebra |                                                                                           |                                                  |  |  |  |  |  |  |
| Combinatorial Algorithms                   | Algebraic Foundations  |                                                                                           |                                                  |  |  |  |  |  |  |
| Geometry Kernels                           |                        |                                                                                           |                                                  |  |  |  |  |  |  |
| Convex Hull Algorithms                     | G                      | Michael Hemmer                                                                            |                                                  |  |  |  |  |  |  |
| Polygons                                   | $\{+, -, *\}$          | This package defines what algebra means for CGAL, in terms of concepts, classes           | Introduced in: CGAL 3.3<br>BibTeX: cgal:b-af-16a |  |  |  |  |  |  |
| Cell Complexes and Polyhedra               | is $zero(r)$           | and functions. The main features are: (i) explicit concepts for interoperability of types |                                                  |  |  |  |  |  |  |
| Arrangements                               | 10_2010(x)             | (ii) separation between algebraic types (not necessarily embeddable into the reals),      | License: LGPL                                    |  |  |  |  |  |  |
| Triangulations and Delaunay Triangulations | gcd(x,y)               | and number types (embeddable into the reals).                                             |                                                  |  |  |  |  |  |  |
| Voronoi Diagrams                           |                        | User Manual Reference Manual                                                              |                                                  |  |  |  |  |  |  |
| Mesh Generation                            | Normalian Tomas        |                                                                                           |                                                  |  |  |  |  |  |  |
| Shape Reconstruction                       | Number Types           |                                                                                           |                                                  |  |  |  |  |  |  |
| Geometry Processing                        |                        |                                                                                           |                                                  |  |  |  |  |  |  |
| Spatial Searching and Sorting              |                        | Michael Hemmer, Susan Hert, Sylvain Pion, and Stefan Schirra                              |                                                  |  |  |  |  |  |  |
| Geometric Optimization                     |                        | This package provides number type concents as well as number type classes and             | Introduced in: CGAL 1.0                          |  |  |  |  |  |  |
| Interpolation                              | .1                     | wrapper classes for third party number type toncepts as well as number type classes and   | BibTeX: cgal:hhkps-nt-16a                        |  |  |  |  |  |  |
| Kinetic Data Structures                    | aoupte                 | User Manual Reference Manual                                                              | License: LGPL                                    |  |  |  |  |  |  |
| Support Library                            |                        |                                                                                           |                                                  |  |  |  |  |  |  |
| Visualization                              |                        |                                                                                           |                                                  |  |  |  |  |  |  |
| ► Developer Manual 🗸                       | Modular Arithmetic     |                                                                                           |                                                  |  |  |  |  |  |  |

### CGAL 4.8 - Manual

#### Arithmetic and Algebra

- Combinatorial Algorithms
- Geometry Kernels
- Convex Hull Algorithms
- Polygons
- Cell Complexes and Polyhedra
- Arrangements
- Triangulations and Delaunay Triangulations
- Voronoi Diagrams
- Mesh Generation
- Shape Reconstruction

#### Geometry Processing

Polygon Mesh Processing 3D Surface Subdivision Methods Triangulated Surface Mesh Segmentation Triangulated Surface Mesh Simplification Triangulated Surface Mesh Deformation Triangulated Surface Mesh Shortest Paths Triangulated Surface Mesh Skeletonization Approximation of Ridges and Umbilics on Triangula Estimation of Local Differential Properties of Point

### Geometry Processing

#### Polygon Mesh Processing



Sébastien Loriot, Jane Tournois, Ilker O. Yaz for each This package provides a collection of methods and classes for polygon mesh Solvers processing algorithms. License User Manual Reference Manual Window

#### Introduced in: CGAL 4.7 Depends on: documented for each function; CGAL and Solvers BibTeX: cgal:lty-pmp-16a License: GPL Windows Demo: Operations on Polyhedra Common Demo DIIs: dlls

#### **3D Surface Subdivision Methods**

#### Le-Jeng Andy Shiue



Subdivision methods recursively refine a control mesh and generate points approximating the limit surface. This package consists of four popular subdivision methods and their refinement hosts. Supported subdivision methods include Catmull-Clark, Loop, Doo-Sabin and sqrt(3) subdivisions. Their respective refinement hosts are Pqq, PTq, Dqq and sqrt(3) refinements. Variations of those methods can be easily extended by substituting the geometry computation of the refinement host.

Introduced in: CGAL 3.2 BibTeX: cgal:s-ssm2-16a License: LGPL Windows Demo: Operations on Polyhedra Common Demo DIIs: dlls

User Manual Reference Manual

## **Outliers Removal**

- Sort points by average squared distances to m nearest neighbors
- Cut at specified percentile





## Smoothing

- For each point
  - Find m nearest neighbors
  - Fit plane or jet (smooth parametric surface)
  - Project





(noisy point set)

(smoothed point set)

### Surface Curvature and Normal Estimation







### min curvature directions



max curvature directions

### Efficient RANSAC

- Shape types : plane, cone, cylinder, sphere, torus
- Maximal distance



# Meshing an Implicit function from a Point Set Poisson Surface Reconstruction

- Construct *Poisson implicit function P* in ambient space around the input points
- Mesh the 0-surface of P



### **Poisson Surface Reconstruction**

- Works well for uneven distribution of points
- Used for reconstruction of geological bodies





# Contribute to CGAL

- New functionality for an existing class
- The prototype for your latest paper
- The outcome of one of your student projects
- Mentor development of your paper by GSoC students
- Review in your field of expertise
- Interface with another software project

# Contributors ...

- Stay owner of contributed package
- Get recognition and visibility
- Profit
  - from a well defined workflow
  - from shared infrastructure and maintenance
  - from peer-review





Straight Skeleton Alpha Shapes KD Tree **Tetrahedral Mesh Generation** Arrangements Surface Reconstruction Point Cloud Processing Mesh Simplification / Segmentation / Deformation www.cgal.org