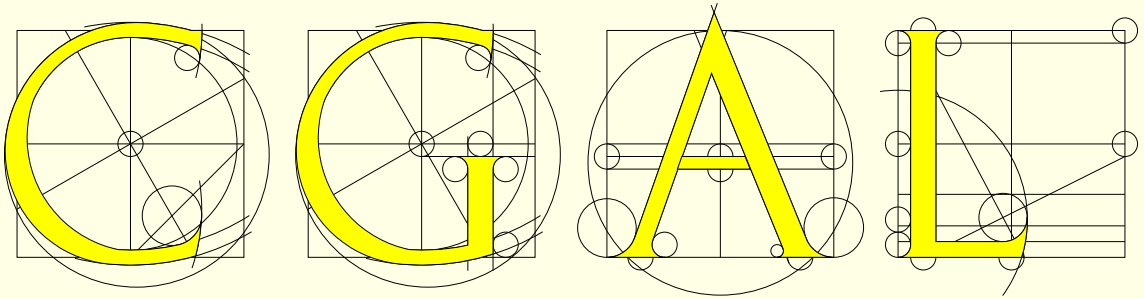


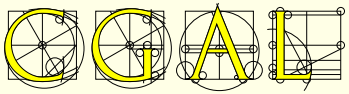
Computational Geometry Algorithms Library

www.cgal.org

Monique Teillaud

Overview

- The CGAL Open Source Project
- Structure of CGAL
- The Kernel

The  Open Source Project

Goals

- Promote the research in Computational Geometry (CG)
- *"make the large body of geometric algorithms developed in the field of CG available for industrial applications"*

$\Rightarrow$ **robust programs**

CG Impact Task Force Report, 1996

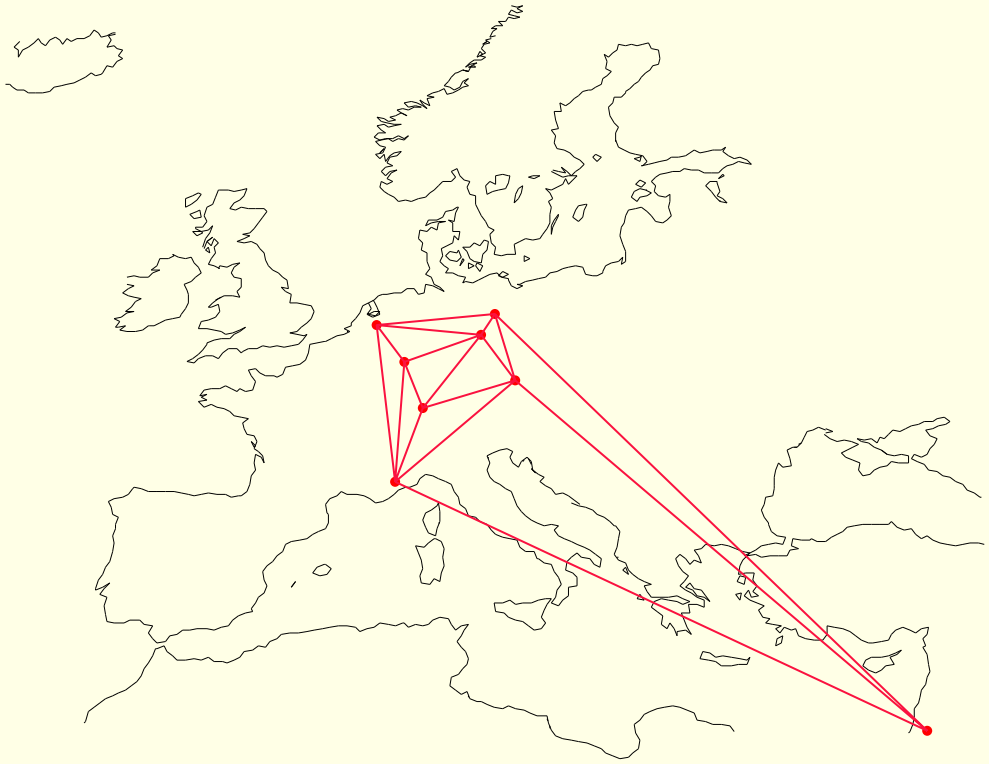
Among the key recommendations:

- Production and distribution of usable (and useful) geometric codes
- Reward structure for implementations in academia

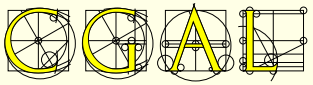
History

Development started in 1995

Consortium of 8 European sites
Two ESPRIT LTR European Projects (1996-1999)



Utrecht University (XYZ Geobench)
INRIA Sophia Antipolis (C++GAL)
ETH Zürich (Plageo)
MPI Saarbrücken (LEDA)
Tel Aviv University
Freie Universität Berlin
RISC Linz
Martin-Luther-Universität Halle



- Work continued after the end of European support (1999) in several sites.

- January, 2003: **creation of Geometry Factory**

INRIA startup
sells commercial licenses, support, customized developments

- November, 2003:

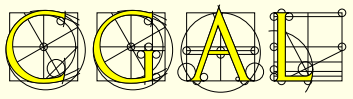
Release 3.0
Open Source Project

- December, 2004: Release 3.1

License

- *kernel* under **LGPL**
- *basic library* under **QPL**
  - free use for Open Source code
  - commercial license needed otherwise

- A guarantee for CGAL users
- Allows CGAL to become a standard
- Opens CGAL for new **contributions**



in numbers

- 400.000 lines of C++ code
- >2000 pages manual

- release cycle of ∼12 months

- CGAL 2.4: 9300 downloads (18 months)
- CGAL 3.1: 7329 downloads (9 months)

- 4000 subscribers to the announcement list (7000 for gcc)
- 800 users registered on discussion list (600 in gcc-help)
- 50 developers registered on developer list

Supported platforms

- Linux, Windows, Mac OS X, Irix, Solaris
- g++, VC++, Intel C++, MipsPRO CC, SunPro CC

Development process

Editorial Board created in 2001.

- responsible for the **quality** of CGAL

  New packages are **reviewed**.

$\longrightarrow$ helps authors to get **credit** for their work.

CG Impact Task Force Report, 1996
Reward structure for implementations in academia

- decides about technical matters
- coordinates communication and promotion
- ...

Andreas Fabri (Geometry Factory)
Efi Fogel (Tel Aviv University)
Bernd Gärtner (ETH Zürich)
Michael Hoffmann (ETH Zürich)
Menelaos Karavelas (University of Notre Dame, USA → Greece)
Lutz Kettner (Max-Planck-Institut für Informatik)
Sylvain Pion (INRIA Sophia Antipolis)
Monique Teillaud (INRIA Sophia Antipolis)
Remco Veltkamp (Utrecht University)
Ron Wein (Tel Aviv University)
Mariette Yvinec (INRIA Sophia Antipolis)

Tools

- Own manual tools: LaTeX $\longrightarrow$ ps, pdf, html
- CVS server for version management

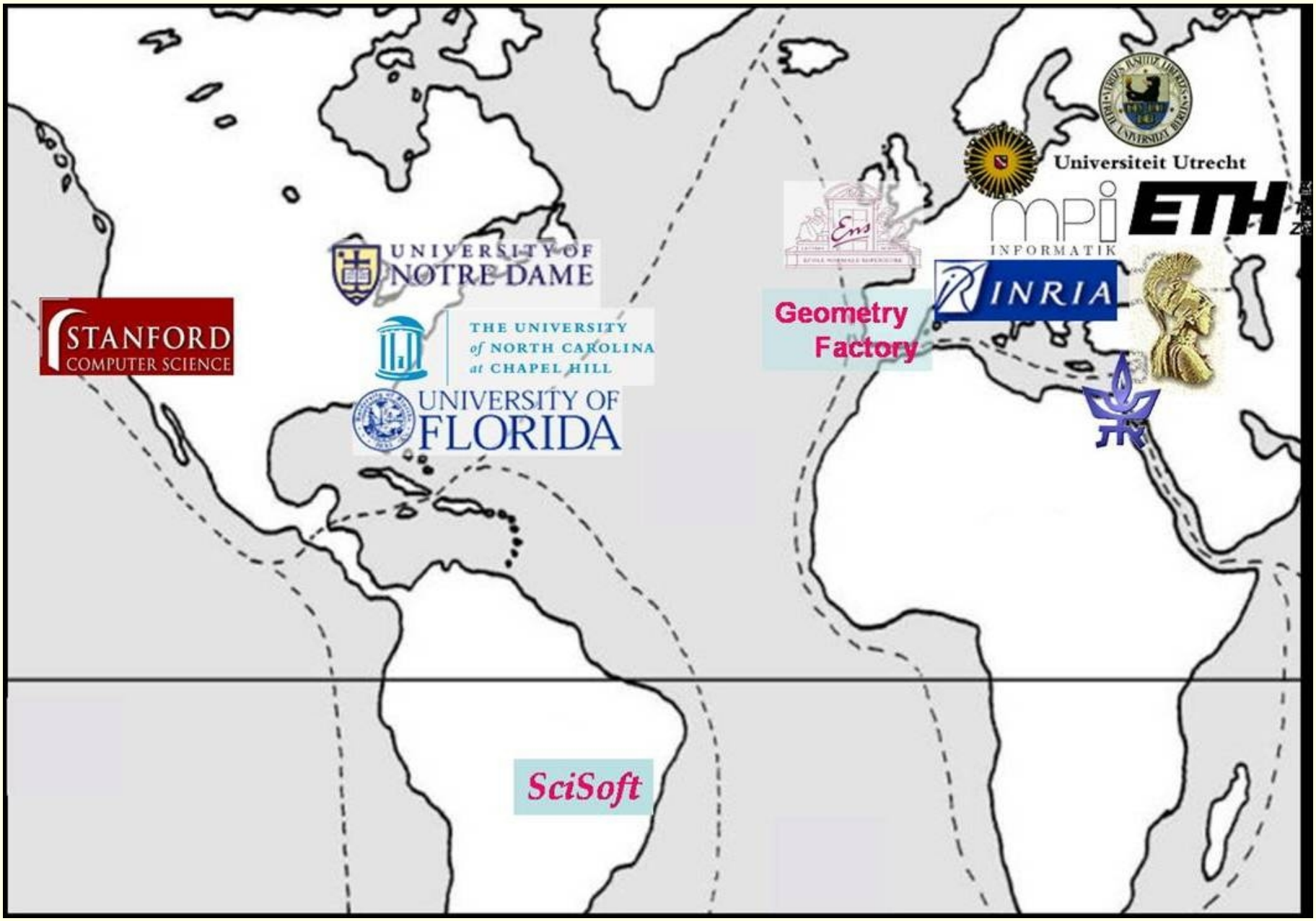
- Developer manual
- mailing list for developers
- 1-2 developers meetings per year, 1 week long

- 1 internal release per day
- Automatic **test suites** running on all supported compilers/platforms

Credit

Contributors keep their identity

- up to 3.0.1: names of authors mentioned in the Preface.
- 3.1: **Names of authors** appear at the beginning of each chapter.
  Section on history of the package at the end of each chapter, with names of all contributors.
- CGAL developers listed on the "People" web page.
- Authors publish **papers** (conferences, journals) on their packages.
- **Copyright** kept by the institution of the authors.


Universiteit Utrecht
ETH
INFORMATIK
INRIA
Geometry
Factory
UNIVERSITY OF
NOTRE DAME
STANFORD
COMPUTER SCIENCE
THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL
UNIVERSITY OF
FLORIDA
SciSoft

Users

Projects using CGAL

Leonidas J. Guibas' and co-workers, Stanford University.

Tamal K. Dey's and co-workers, The Ohio State University.

Nina Amenta and co-workers, The University of Texas at Austin.

Xiangmin Jiao, University of Illinois at Urbana-Champaign.
(Surface Mesh Overlay)

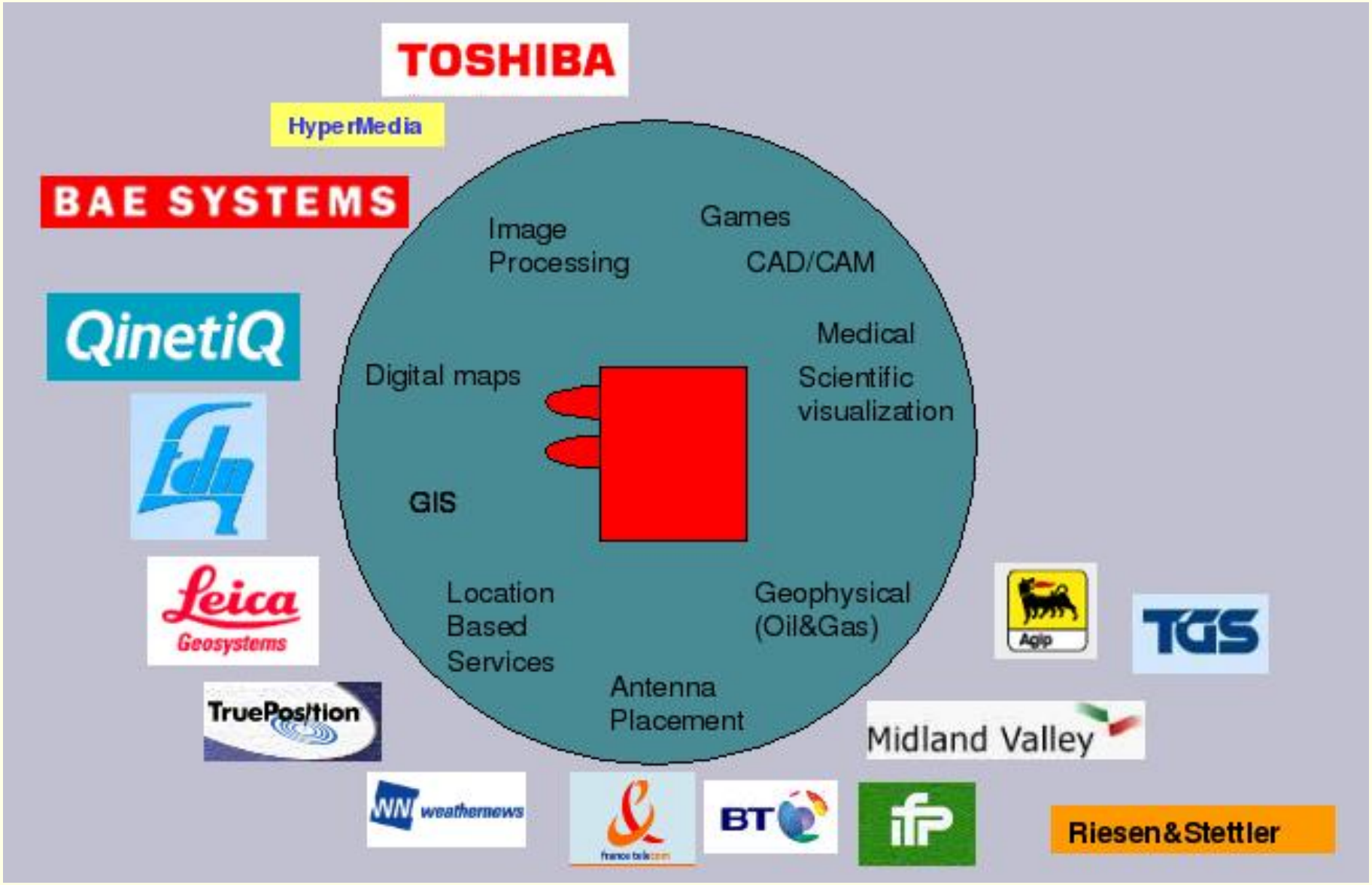
Peter Coveney and co-workers, University of London.

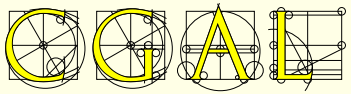
. . .

Teaching

- Leo Guibas, Siu Wing Cheng, . . .

Commercial customers of Geometry Factory



Structure of 

Basic Library

Algorithms and Data Structures

Kernel

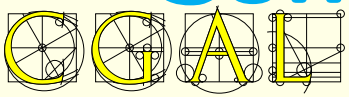
Geometric objects
Geometric operations

core library

configurations, assertions, ...

Support Library

Visualization
File I/O
NumberTypes
Generators
...

Contents of the  Basic Library

Convex Hull

[MPI]

- 5 different algorithms in 2D
- 3 different algorithms in 3D

Triangulations and related

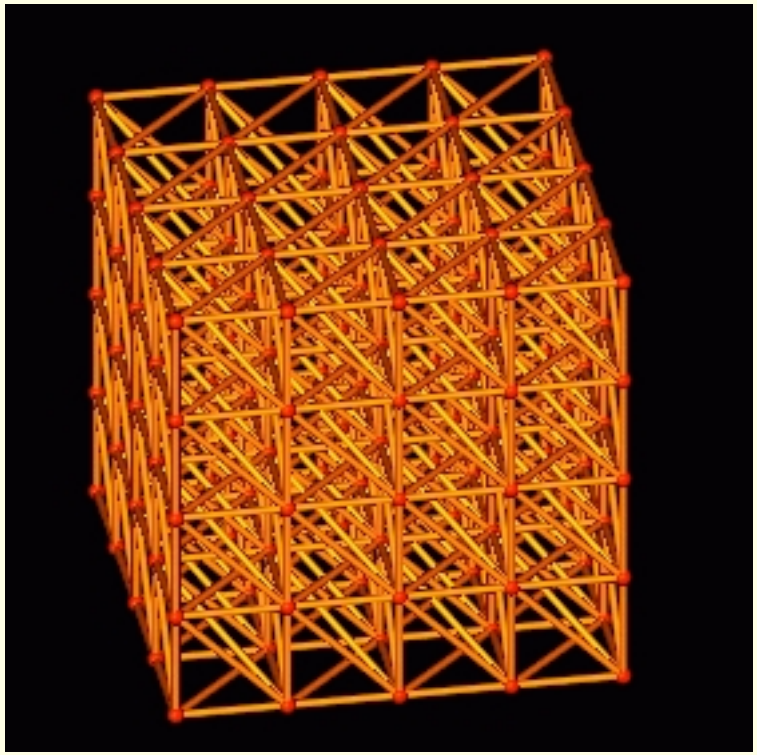
[INRIA]

- 2D/3D Triangle/Tetrahedron based data-structure

- Fully dynamic 2D/3D Delaunay triangulation
  Delaunay hierarchy [Devillers '98 '02]

- 2D/3D Regular Triangulations
(fully dynamic in 3.2?)
- 2D Constrained Delaunay Triangulation

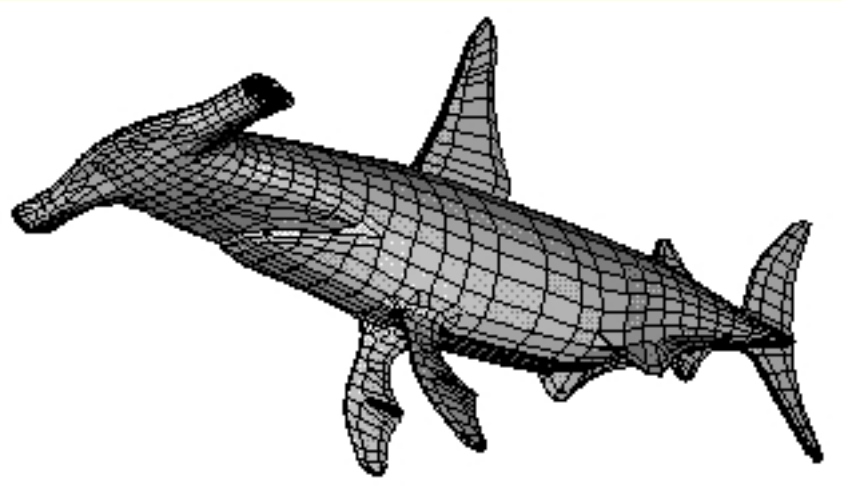
- 2D Apollonius diagram
- 2D Segment Voronoi Diagram
- 2D Meshes



Polyhedra

[MPI]

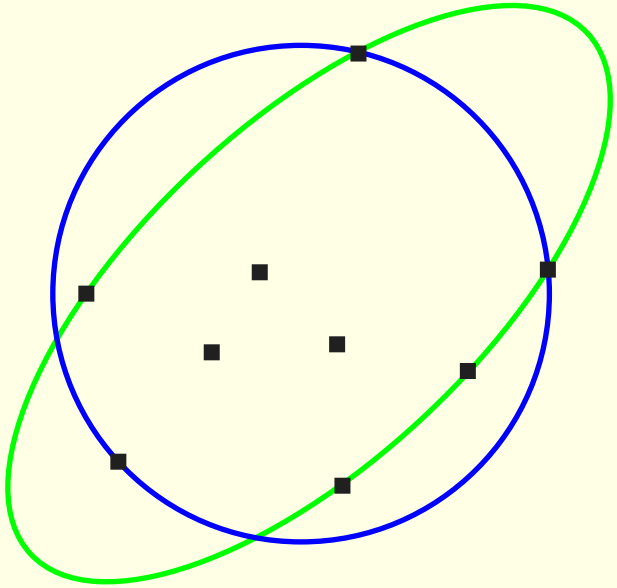
- Half-edge data-structure
- Polyhedral surface
  (orientable 2-manifold with boundary)
- 2D Nef polygons
- 3D Nef polyhedra



Geometric Optimization

[ETH]

- Smallest enclosing circle and ellipse in 2D
- Smallest enclosing sphere in dD
- Largest empty rectangle
- . . .



Arrangements

[Tel-Aviv]

- Line segments or polylines
- Conic arcs with Leda or Core

Completely new version in CGAL 3.2

Search Structures

Arbitrary dimension

- Range-tree, Segment-tree, kD-tree
- Window query
- Approximate nearest neighbors
- . . .

Work in Progress

Kinetic Data Structures
[Russel Karavelas]

Surface reconstruction
[Oudot Rey]

3D Meshes
[Rineau Yvinec]

Parameterization
[Alliez]

Curved Kernel
Extension of the CGAL kernel
Algebraic issues
[Emiris Kakargias Pion Tsigaridas Teillaud SoCG'04]

. . .

The GOAL Kernel

In the kernel

Elementary geometric objects

Elementary computations on them

Primitives
2D, 3D, dD
- Point
- Vector
- Triangle
- Iso_rectangle
- Circle

. . .

Predicates
- comparison
- Orientation
- InSphere

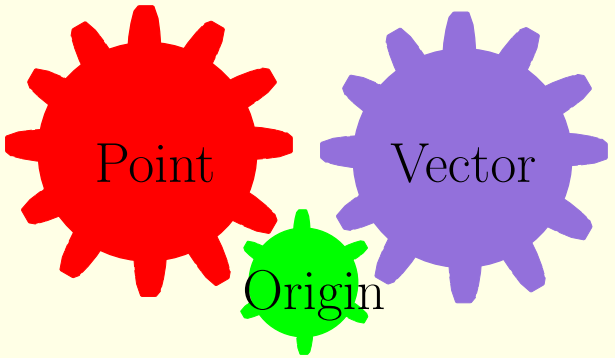
. . .

Constructions
- intersection
- squared distance

. . .

Affine geometry

Point - Origin $\rightarrow$ Vector
Point - Point $\rightarrow$ Vector
Point + Vector $\rightarrow$ Point



Point + Point **illegal**

midpoint(a,b) = a + 1/2 x (b-a)

Kernels and Number Types

Cartesian representation

$$\text{Point} \left| \begin{array}{l} x = \frac{hx}{hw} \\ y = \frac{hy}{hw} \end{array} \right.$$

Homogeneous representation

$$\text{Point} \left| \begin{array}{l} hx \\ hy \\ hw \end{array} \right.$$

Intersection of two lines

$$\begin{cases} a_1 x + b_1 y + c_1 = 0 \\ a_2 x + b_2 y + c_2 = 0 \end{cases}$$

$$(x, y) = \left(\frac{\begin{vmatrix} b_1 & c_1 \\ b_2 & c_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}}, -\frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}} \right)$$

$$\begin{cases} a_1 hx + b_1 hy + c_1 hw = 0 \\ a_2 hx + b_2 hy + c_2 hw = 0 \end{cases}$$

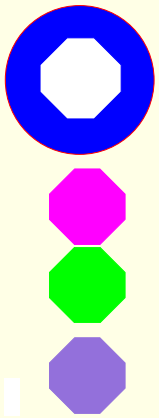
$$(hx, hy, hw) = \left(\begin{vmatrix} b_1 & c_1 \\ b_2 & c_2 \end{vmatrix}, -\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}, \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix} \right)$$

Field operations

Ring operations

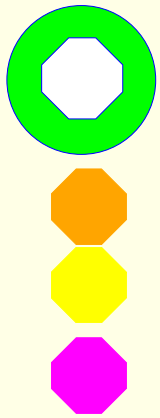
C++ Templates

`CGAL::Cartesian< FT >` (`CGAL::Simple_Cartesian`)
`CGAL::Homogeneous< RT >` (`CGAL::Simple_Homogeneous`)



Cartesian Kernels : Field type

- `double`
- `Quotient<Gmpz>`
- `leda_real`



Homogeneous Kernels : Ring type

- `int`
- `Gmpz`
- `double`

⟶ **Flexibility**

```
typedef double                          NumberType;
typedef Cartesian< NumberType >         Kernel;
typedef Kernel::Point_2                 Point;
```