Tools, Generic Programming, CGAL, and 2D Arrangement of CGAL

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Tools, Toolkits, and Libraries

- Computational Geometry
  - LEDA - combinatorial and generic data types and algorithms
  - CGAL - computational geometry generic data types and algorithms
  - GMP & CORE - Numerical types
  - Other
- Visualization
  - OpenGl, Direct3d
  - GLUT
  - QT
  - Geomview

Generic Programming

- STL - Standard Template Library
  - first example of generic programming, 1994
- A simple example

```
int main() {
  vector<string> V;
  string tmp;

  while (getline(cin, tmp))
    V.push_back(tmp);

  sort(V.begin(), V.end());
  copy(V.begin(), V.end(), ostream_iterator<string>(cout, "\n"));
}
```

CGAL - Computational Geometry Algorithm and Database

- A Computational Geometry Algorithms Library
- A collection of Data Structure and Operations
- Conists ot 3 major parts:

kernel constant-size non-modifiable geometric primitive objects and operations on these objects

basic library - a collection of basic geometric data structures and algorithms

other facilities - non-geometric support facilities, such as circulators, random sources, I/O support for debugging and for interfacing CGAL to various visualization tools

CGAL - Technical Information

- Written in C++
- Follows the Generic Programming paradigm
- Developed by a consortium consisting of
  - ETH Zürich (Switzerland)
  - Freie Universität Berlin (Germany)
  - Martin-Luther-Universität Halle-Wittenberg
  - Max-Planck Institut für Informatik, Saarbrücken
  - INRIA Sophia-Antipolis (France)
  - Tel-Aviv University (Israel)
  - Utrecht University (The Netherlands)
- CGAL home page - `http://www.cgal.org`
- CGAL at TAU - `http://www.cs.tau.ac.il/CGAL`

CGAL - Kernel

- Contains objects of constant size
  - point, vector, direction, line, ray, segment, triangle, iso-oriented rectangle and tetrahedron.
  - Each type comes with a set of functions that can be applied to an object of this type.
- Access functions, tests of the position of a point relative to the object, a function returning the bounding box, the length, or the area of an object, etc..
  - More basic operations
- Affine transformations, detection and computation of intersections, and distance computations.

CGAL - Basic Library

- The collection of basic geometric algorithms and data structures
  - polygons, half-edge data structures, polyhedral surfaces, planar maps, triangulations, convex hulls, alpha shapes, optimisation algorithms, dynamic point sets for geometric queries, and multidimensional search trees.
- Tel-Aviv Planar Map Packages:

Topological map - combinatorial information and no geometric information

Planar Map - embedding of a topological map into the plane

Arrangement - A structure that supports 2D arrangements. Maintains a planar map and curve hierarchy trees.

Robustness

- Most geometric algorithms assume exact computation with real numbers
- Implementation of geometric algorithms becomes problematic
- Often the exact real arithmetic is replaced by inexact floating-point arithmetic in the implementation
- Rounding errors introduced by an inaccurate arithmetic may lead to inconsistent decisions, causing unexpected failures

CGAL Robustness handling

- In CGAL you can choose the underlying number types and arithmetic.
- You can use different types of arithmetic simultaneously
- The choice can be easily changed
- You can choose between implementations with fast but occasionally inexact arithmetic and exact computation

LEDA - Efficient Data types and Algorithms

- A C++ class library
- Provides algorithmic in-depth knowledge in the field of graph and network problems, geometric computations, combinatorial opimization and other.
- Used in application areas such as GIS, VLSI design, telecommunication, scheduling, traffic planning, computational biology, and computer-aided design.
- Offers algorithm building blocks such as graphs, sequences, dictionaries, trees, points, flows, matchings, segments, shortest paths, and more.
- Follows object-oriented generic prog. paradigm
- CGAL & LEDA are independent, but work well together
- LEDA - `http://www.algorithmic-solutions.de/redirected.htm`

GMP - GNU Multiple Precision

- GNU MP is a library for arbitrary precision arithmetic
- Operating on signed integers, rational numbers, and floating point numbers
- It has a rich set of functions, and the functions have a regular interface
- GNU MP is designed to be as fast as possible for small and huge operands
- Gmp home page - `http://www.gnu.org/software/gmp/gmp.html`
- Online Manual - `http://www.gnu.org/manual/gmp/index.html`

CORE - Robust Numerical and Geometric computation

- based on a novel number core, an API that defines four levels of numerical accuracies:
  - Machine Accuracy (IEEE standard)
  - Arbitrary Accuracy
  - Guaranteed Accuracy
  - Mixed Accuracy
- Core home page - `http://www.cs.nyu.edu/exact/core`

GLUT & GLUI - Graphics Library Utility Toolkits

- GLUT
  - The OpenGL Utility Toolkit
  - An ANSI C implementation of GLUT for the X Window System -

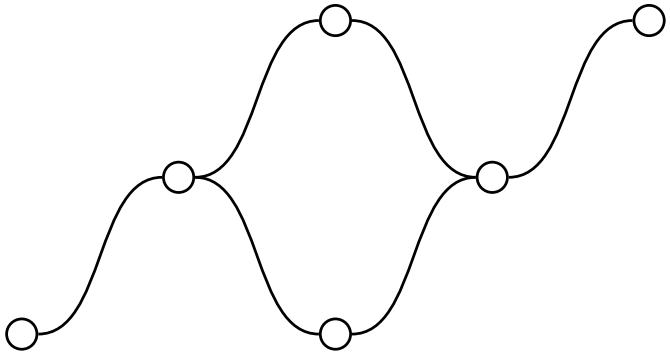
    `http://www.xmission.com/ nate/glut.html`
- GLUI
  - GLUT-based C++ user interface library
    - Window-system independent
  - provides controls (e.g., buttons, checkboxes, radio buttons, and spinners) to OpenGL applications.
  - Home page - `http://www.nigels.com/glt/glui`

Qt - GUI software toolkit/widget-kit

- Multiplatform - Windows, Linux/Unix, Mac OS X, and embedded Linux
- Object-oriented C++ application framework
- KDE is based on Qt

Planar Maps

- Planar graphs that are embedded in the plane



Planar Arrangements

- Given a collection Γ of planar curves, the arrangement $\mathcal{A}(\Gamma)$ is the partition of the plane into vertices, edges and faces induced by the curves of Γ

The Package in Brief

- Goal: construct, maintain, modify, traverse, query and present subdivisions of the plane
- Robust
- Generic
- Handles all degeneracies
- Efficient
- Easy to interface

Hierarchy

- Topological_map
  - Maintains topological maps of finite edges
- Planar_map_2
  - Maintains planar maps of interior-disjoint x-monotone curves
- Planar_map_with_intersections_2
  - Maintains planar maps of general curves (may intersect, may be non-x-monotone)
- Arrangement_2
  - Maintains planar maps of intersecting curves along with curve history

Planar Map Functionality

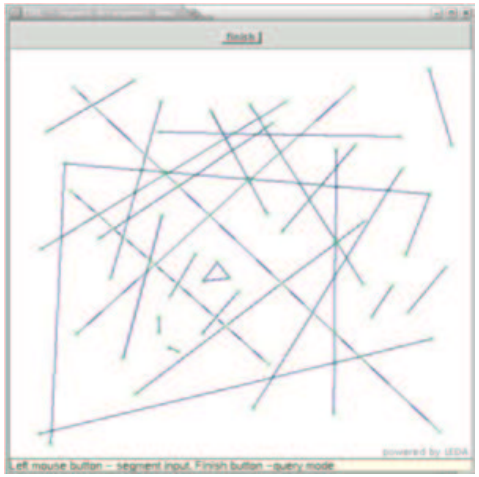
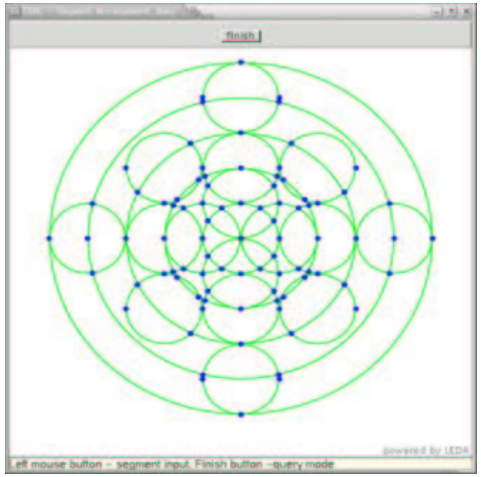
- Creation and Destruction
- I/O
  - Save, load, print (ASCII streams)
  - Draw (graphic streams)
- Modification
  - Insertion, removal, split, merge
- Traversal
- Queries
  - Number of vertices, halfedges, and faces
  - Is Point in Face
  - Point location - various strategies
  - Vertical ray shoot

Planar Map Traits

- Geometric interface
- Parameter of package
  - Defines the family of curves in interest
  - Package can be used with any family of curves for which a traits class is supplied
- Aggregate
  - geometric types (points, curves)
  - Operations over types (accessors, predicates, constructors)

Planar Map Supplied Traits

- Segments
  - Standard
  - Cached contains the underline line and flags
- Polylines
- Conic arcs (segments of circles, ellipses, parabolas, hyperbolas, and lines)


Planar Map Insertion Operations

- Incremental insert
- Aggregate insert
- Often information is known in advance
  - Containing face
    - Insert in face interior
  - Incident vertices
    - Insert from vertex, between vertices
  - Order around vertex
    - Insert from halfedge target, between halfedge targets

Planar Map Aggregate Insertion Operations

- Inserts a container into the map

```
template <class curve_iterator>
Halfedge_iterator
insert(const curve_iterator & begin,
       const curve_iterator & end,
       Change_notification * en = NULL);
```

- Two versions
  - Simplified - planar map no intersections
  - General - planar map with intersections
- Sweep based