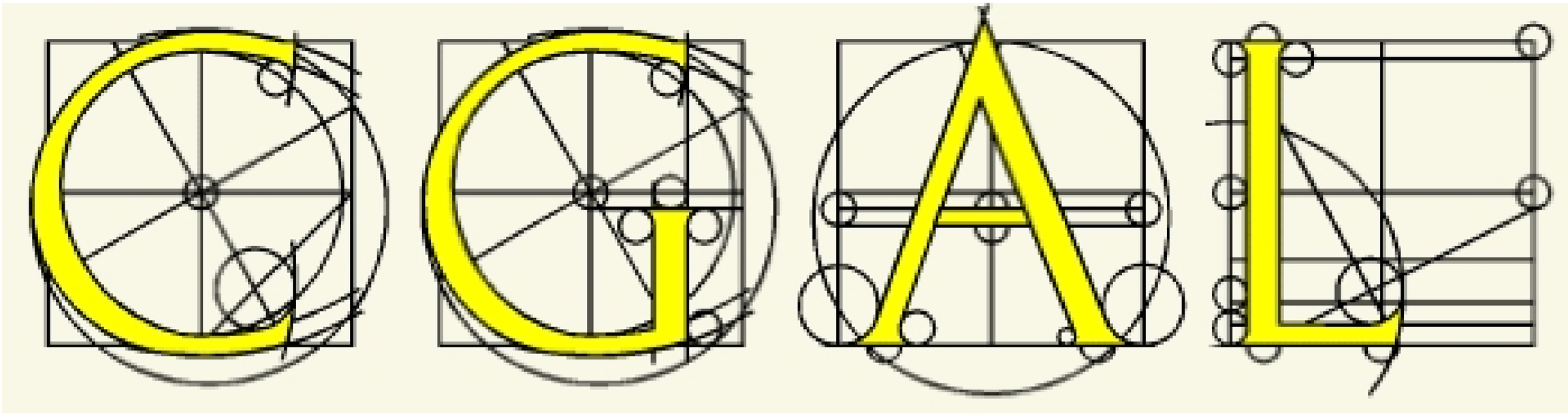

# Introduction to CGAL

Constantinos Tsirogiannis

**TU/Eindhoven**

# CGAL ?

- CGAL = Computational Geometry Algorithms Library:

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  - A library of Geometric algorithms and data structures.

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  - A library of Geometric algorithms and data structures.
  - Written in C++
  - Uses template programming

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- Traditional C code:
- ```
  int a=5;
  int b=3;
  add_function(a,b);
  ```
  ```

- C++ code:

```
int a=5;
int b=3;
Example_class foo;
foo.add(a,b);
```

Here follow few basic concepts of C++

# Classes/Structures

- Class:

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- Class:

- ```
  class Example_class
  {
     public:
          int add( int a, int b)
          { return a+b; }
          ...
    private:
          int k;
  };
  ```
  ```

# Classes/ Structures (cont'd)

- Structures: same as classes, yet everything is by default visible ("public")

# Namespaces

- Namespace: Can be seen as a “big bag” containing declarations of class types and functions.

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- Example:

```
namespace FOO
{
    class something{...};
    class another_class{...};
    struct whatever{...};
    int add(int a, int b){a+b;}
}
```

# Namespace `std`

- To access the type `something` from a namespace `FOO` try:

  `FOO::something` or `typename FOO::something`

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  `FOO::something` or `typename FOO::something`

- Namespace `std` contains many helpfull classes and functions of the Standard Library of C++.

# Containers

- Nice and easy classes to insert and manipulate sets of objects.

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- Example: Vectors

```
std::vector<int> integers;
integers.push_back(4);
integers.push_back(-2);
integers.push_back(9);
integers.push_back(3);
for( int i=0; i< integers.size(); i++ )
  std::cout << integers[i] << std::endl;
```

# Iterators

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- Example:

```
std::vector<int> integers;
integers.push_back(4);
integers.push_back(-2);
integers.push_back(9);
integers.push_back(3);
for( typename std::vector<int>::iterator
  it=integers.begin();
   it< integers.end(); it++ )
     std::cout << *it << std::endl;
```

# Input from file

- In the beginning of your .cpp file put:

```
# include<fstream>
```

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- To read a set of integers from a file:

```
std::ifstream in(‘‘filename.txt’’);
std::istream_iterator<int> begin(in);
std::istream_iterator<int> end;
std::vector<int> integers;

integers.insert(integers.begin(),begin,end);
```

# Output to file

- Example:

```
std::ofstream os("filename.cout");
std::vector<int> integers;
integers.push_back(4);
integers.push_back(-2);
integers.push_back(9);
integers.push_back(3);
for( typename std::vector<int>::iterator
    it=integers.begin();
     it< integers.end(); it++ )
  os << *it << std::endl;
```

# Template

- A template is a class or function that one can choose the types that it contains/manipulates.

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- Example: A function that computes a power of a given integer.

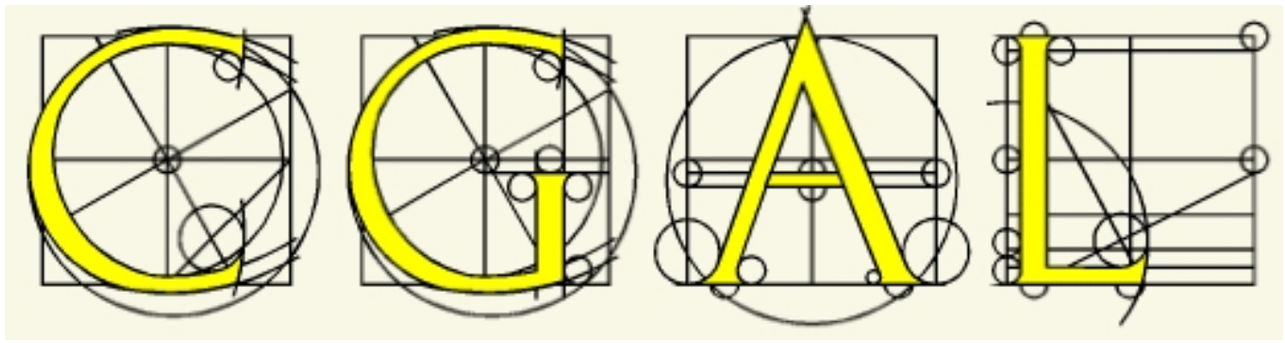
```
int power (int base, int exponent)
{
    int res=1;
    for( int i=1; i<=exponent; i++ )
    res = res * base;
    return res;
}
```

# Templates

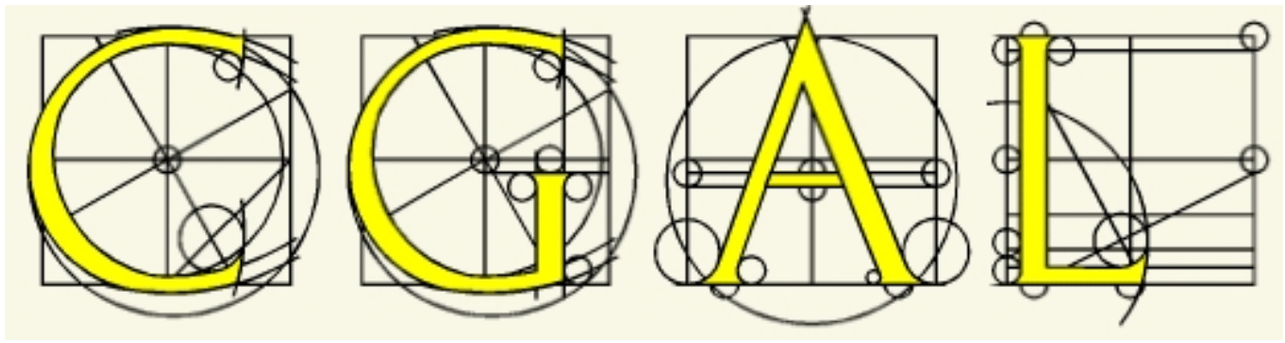
- Example: A function that computes a power of a given object of type Type.

```
template <class Type>
Type power ( Type base, int exponent)
{
    Type res=1;
     for( int i=1; i<=exponent; i++ )
     res = res * base;
     return res;
}
```

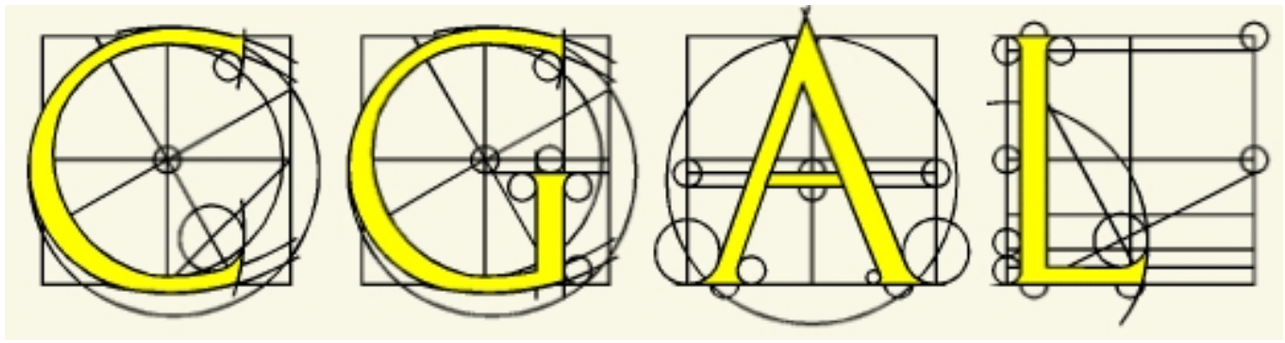
# CGAL



- CGAL provides implementations of:



- CGAL provides implementations of:
- Triangulations.



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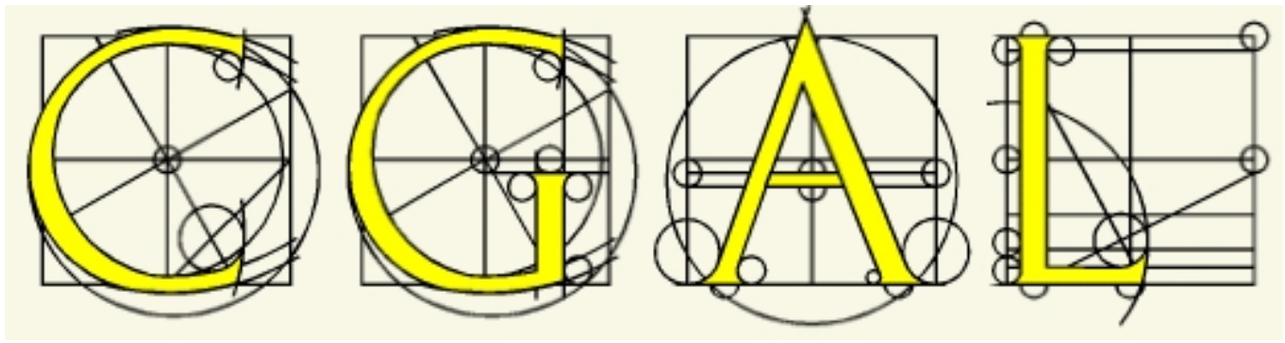
- Triangulations.
- Voronoi diagrams.



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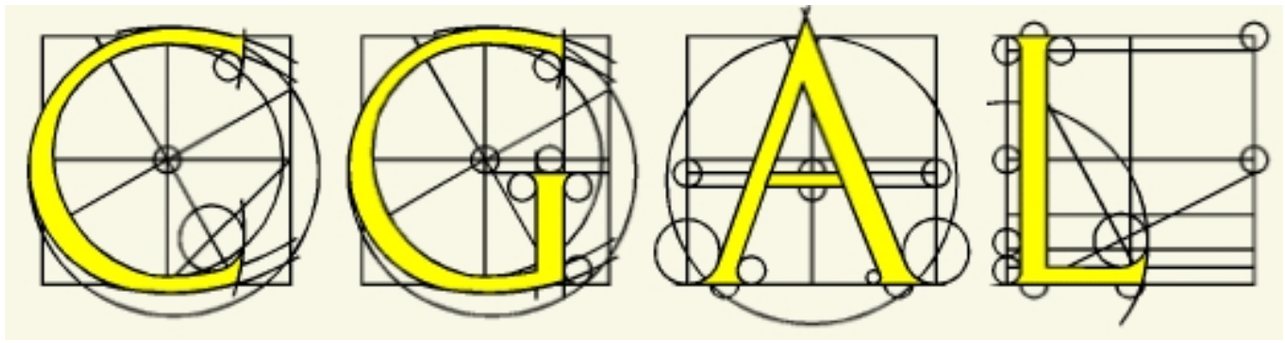
- Arrangements.



- CGAL provides implementations of:
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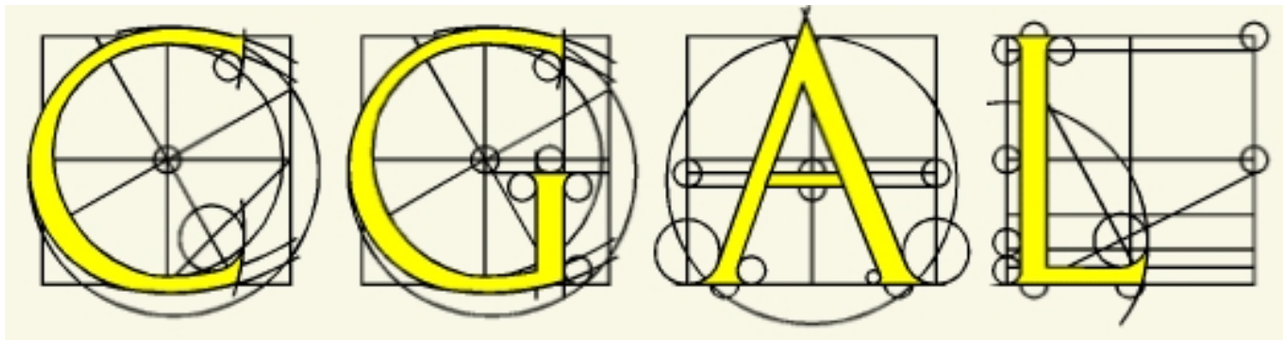
- Arrangements.
- Kinetic Data Structures.



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# CGAL Concepts

The concepts provided by CGAL are categorized as:

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- Geometric Predicates/Constructions
- Geometric Algorithms/Data-Structures

# Kernel

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- A kernel is more or less a large class the encapsulates objects and predicates that fall in the same general category.
- ```
  struct Cartesian_kernel
  {
      class Point {...};
      class Segment {...};
      class Triangle {...};
      ...
      class Do_intersect_predicate {...};
  };
  ```
  ```

# Kernel

- A kernel is in fact a template.
  The template parameter is a number type.

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- A kernel is in fact a template.
  The template parameter is a number type.

- ```
  template <typename Num_type>
  struct Cartesian_kernel
  {
      class Point<Num_type> {...};
      class Segment<Num_type> {...};
      class Triangle<Num_type> {...};
      ...
      class Do_intersect_pred<Num_type> {...};
  };
  ```
  ```

# CGAL Number types

CGAL provides many different number types:

- Built in: `int`,`double`.

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CGAL provides many different number types:

- Built in: `int`,`double`.
- Arbitrary precision rationals: `Gmpq`,`MP_Float`.
- Algebraic numbers: `Root_of_2<Type>`.

# Kernels

- You can use kernels with fixed number types such as Cartesian<double>.

# Kernels

- Or you can use predefined "Filtered Kernels" that provide exact predicates, and even exact constructions, if desired.
- Filtered Kernels use less computationally intensive number types as default, and fall back to exact computation when required.
- Exact_predicates_exact_constructions_kernel
- Exact_predicates_inexact_constructions_kernel

# Algorithms and Data Structures

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- The main algorithms and data-structures appear outside the kernels.
- They are also templates.
- Example:

```
template <typename Kernel>
struct Triangulation_2
{
  typedef typename Kernel::Point     Point;
  typedef typename Kernel::Segment   Segment;
  typedef typename Kernel::Triangle Triangle;
  ...
};
```

- Let's have a close look on the example program.

```
#include <CGAL/basic.h>
#include <CGAL/intersections.h>
#include <CGAL/Exact_predicates_exact_constructions_kernel.h>

#include <qapplication.h>
#include <qmainwindow.h>

#include <CGAL/IO/Qt_widget.h>
#include <CGAL/IO/Qt_widget_standard_toolbar.h>
```

```
typedef CGAL::Exact_predicates_exact_constructions_kernel Kernel;
typedef Kernel::Point_2          Point;
typedef Kernel::Segment_2        Segment;
typedef Kernel::Line_2           Line;
```

```
Point a, b, c, d;

Segment s;

Line l;

CGAL::Object o;
```

```
class My_window : public QMainWindow {
  Q_OBJECT
public:
  My_window()
  {
  ..............
  }

  private slots: //functions
  void redraw_win()
  {
  ..............
  }

private:  //members
  CGAL::Qt_widget *widget;
  CGAL::Qt_widget_standard_toolbar *std_toolbar;
};
```

```
My_window()
{
    widget = new CGAL::Qt_widget(this);
    setCentralWidget(widget);
    resize(3,3);
    widget->show();
    widget->set_window(-1, 2, -1, 2);

    a = Point(0,0);
    b = Point(1,0);
    c = Point(1,1);
    d = Point(0,1);

    s = Segment(a,c);
    l = Line(b,d);

    o = CGAL::intersection(s, l);

    //How to attach the standard toolbar
    std_toolbar = new CGAL::Qt_widget_standard_toolbar(widget, this,
                                        "Standard Toolbar");

    connect(widget, SIGNAL(redraw_on_back()),
         this, SLOT(redraw_win()) );
}
```

```
void redraw_win()
{
    *widget << a << b << c << d << CGAL::BLUE << s << l << CGAL::RED;
    if (const Point *ipoint = CGAL::object_cast<Point>(&o)) {
       // handle the point intersection case with *ipoint.
       *widget << *ipoint;
    } else if (const Segment *iseg = CGAL::object_cast<Segment>(&o)) {
       // handle the segment intersection case with *iseg.
       *widget << *iseg;
    } else {
       // handle the no intersection case.
    }
}
```

```
int main( int argc, char **argv )
{
    QApplication app( argc, argv );
    My_window W();
    app.setMainWidget( &W );
    W.show();
    W.setCaption("Using the Standard Toolbar");
    return app.exec();
}
```

# Version of the program using new framework:

```
#include <CGAL/basic.h>
#include <CGAL/intersections.h>
#include <CGAL/Exact_predicates_exact_constructions_kernel.h>
#include <CGAL/number_utils.h>

#include <iostream>
#include <boost/format.hpp>
#include <QtGui>
#include <CGAL/Qt/GraphicsViewNavigation.h>
```

```
typedef CGAL::Exact_predicates_exact_constructions_kernel Kernel;
typedef Kernel::Point_2          Point;
typedef Kernel::Segment_2        Segment;
typedef Kernel::Line_2           Line;
```

```
int main(int argc, char **argv)
{
    QApplication app(argc, argv);


    QGraphicsScene scene;

   Point a(0,0), b(1,0), c(1,1), d(0,1);
   Segment s(a,c);
   Line l(b,d);

   CGAL::Object o = CGAL::intersection(s,l);

    scene.setSceneRect(-1, -1, 2, 2);

   scene.addEllipse(CGAL::to_double(a.x()) - 0.01, CGAL::to_double(a.y()) - 0.01, 0.02, 0.02);
   scene.addEllipse(CGAL::to_double(b.x()) - 0.01, CGAL::to_double(b.y()) - 0.01, 0.02, 0.02);
   scene.addEllipse(CGAL::to_double(c.x()) - 0.01, CGAL::to_double(c.y()) - 0.01, 0.02, 0.02);
   scene.addEllipse(CGAL::to_double(d.x()) - 0.01, CGAL::to_double(d.y()) - 0.01, 0.02, 0.02);

   scene.addLine(CGAL::to_double(s.source().x()), CGAL::to_double(s.source().y()),
                 CGAL::to_double(s.target().x()), CGAL::to_double(s.target().y()), QPen(Qt::blue));


   scene.addLine(-2, CGAL::to_double(l.y_at_x(-2)),
                 3, CGAL::to_double(l.y_at_x(3)), QPen(Qt::blue));

    if (const Point *ipoint = CGAL::object_cast<Point>(&o)) {
        // handle the point intersection case with *ipoint.
        scene.addEllipse(CGAL::to_double(ipoint->x()) - 0.01, CGAL::to_double(ipoint->y()) - 0.01, 0.02, 0.02, QPen(),
QBrush(Qt::red));
   } else if (const Segment *iseg = CGAL::object_cast<Segment>(&o)) {
        // handle the segment intersection case with *iseg.
        scene.addLine(CGAL::to_double(iseg->source().x()), CGAL::to_double(iseg->source().y()),
                      CGAL::to_double(iseg->target().x()), CGAL::to_double(iseg->target().y()), QPen(Qt::red));
   } else {
        // handle the no intersection case.
   }

    QGraphicsView* view = new QGraphicsView(&scene);
    CGAL::Qt::GraphicsViewNavigation navigation;
    view->installEventFilter(&navigation);
    view->viewport()->installEventFilter(&navigation);
    view->setRenderHint(QPainter::Antialiasing);

    view->show();
    return app.exec();
}
```

# Arrangement DCEL

```
#include <CGAL/Exact_predicates_exact_constructions_kernel.h>
#include <CGAL/Arr_segment_traits_2.h>
#include <CGAL/Arrangement_2.h>
#include <CGAL/Arr_default_dcel.h>

typedef CGAL::Exact_predicates_exact_constructions_kernel    Kernel;
typedef CGAL::Arr_segment_traits_2<Kernel>
Traits_2;
typedef CGAL::Arr_default_dcel<Traits_2>                     ArrangementDcel;
```

http://www.cgal.org/Manual/latest/doc_html/cgal_manual/Arrangement_on_surface_2_ref/Concept_ArrangementDcel.html

# Installing CGAL

- Prerequisites: cmake, boost, GMP, MPFR, Qt3 and/or Qt4.
- cmake-gui .
- make
- sudo make install

# Tips on using CGAL

- Use predefined filtered kernels: These define your geometric objects and predicates.
- Documentation can be a hit or a miss, when in doubt, look at example code, which is provided in the CGAL directory.

# Further Reference

- http://www.cgal.org/Manual/3.4/doc_html/cgal_manual/contents.html
- http://www.cgal.org/mailing_list.html