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# Chapter 13
# Graphics classes

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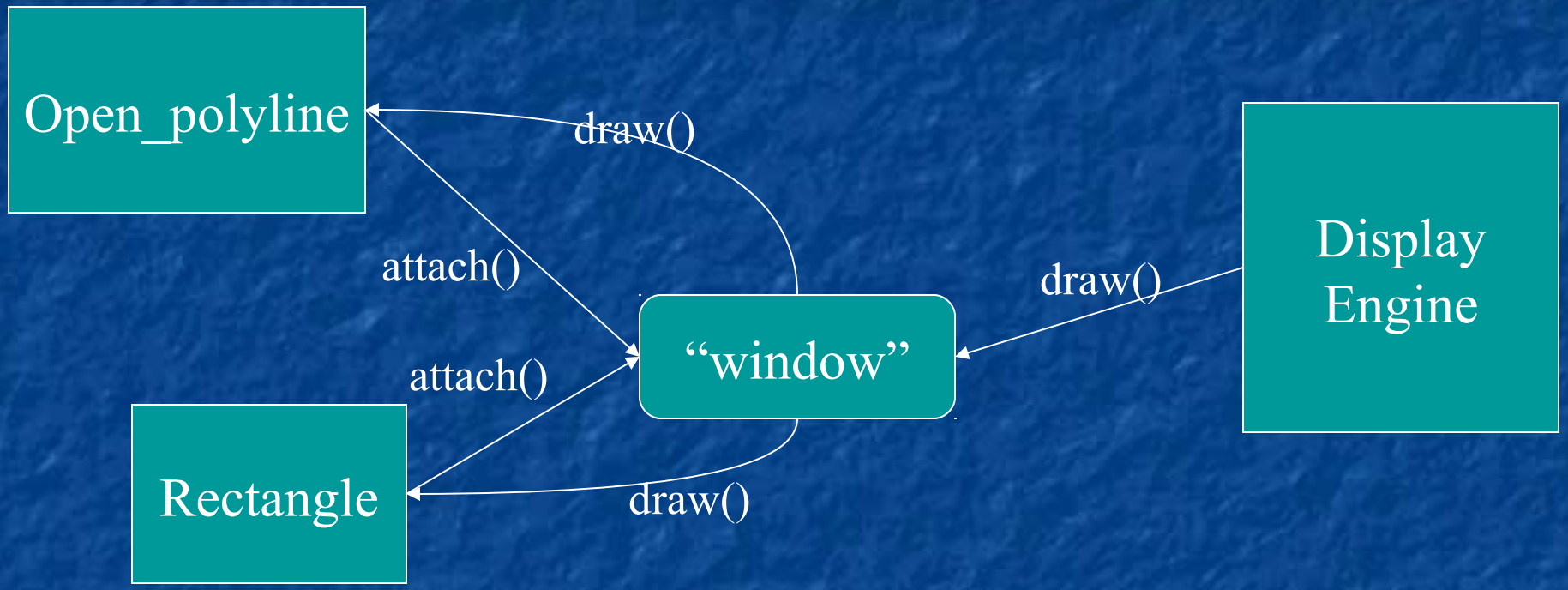
# Abstract

- Chapter 12 demonstrated how to create simple windows and display basic shapes: rectangle, circle, triangle, and ellipse. It showed how to manipulate such shapes: change colors and line style, add text, etc.
- Chapter 13 shows how these shapes and operations are implemented, and shows a few more examples. In Chapter 12, we were basically tool users; here we become tool builders.

# Overview

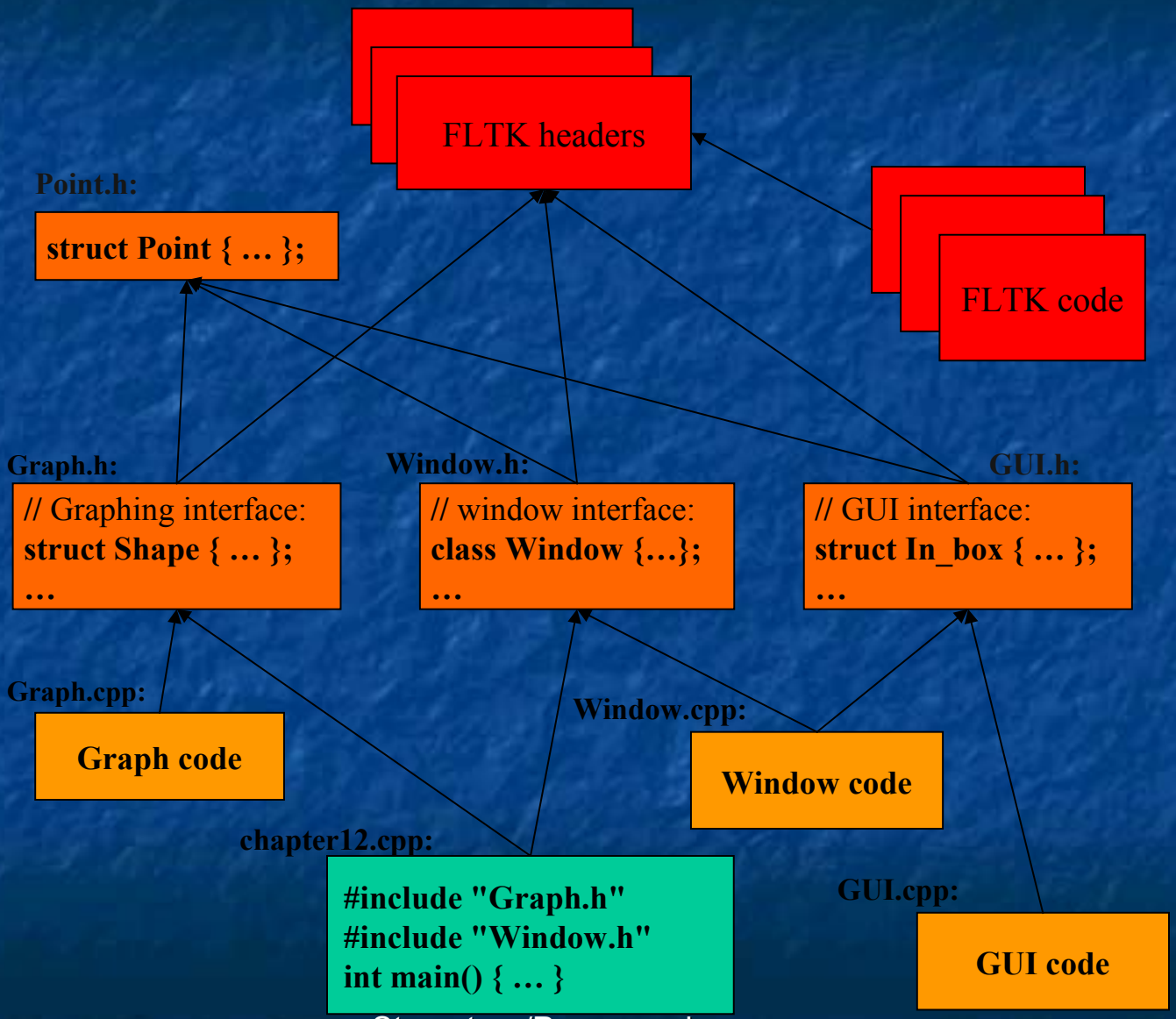
- Graphing
  - Model
  - Code organization
- Interface classes
  - Point
  - Line
  - Lines
  - Grid
  - Open Polylines
  - Closed Polylines
  - Color
  - Text
  - Unnamed objects

# Display model




- Objects (such as graphs) are "attached to" ("placed in") a window.
- The "display engine" invokes display commands (such as "draw line from x to y") for the objects in a window
- Objects such as Rectangle add vectors of lines to the window to draw

# Code organization



# Source files

- Header
  - File that contains interface information (declarations)
  - **#include** in user and implementer
- .cpp ("code file" / "implementation file")
  - File that contains code implementing interfaces defined in headers and/or uses such interfaces
  - **#include**s headers
- Read the **Graph.h** header
  - And later the **Graph.cpp** implementation file
- Don't read the **Window.h** header or the **Window.cpp** implementation file
  - Naturally, some of you will take a peek
  - Beware: heavy use of yet unexplained C++ features

# Design note



- The ideal of program design is to represent concepts directly in code
  - We take this ideal very seriously
- For example:
  - **Window** – a window as we see it on the screen
    - Will look different on different operating systems (not our business)
  - **Line** – a line as you see it in a window on the screen
  - **Point** – a coordinate point
  - **Shape** – what's common to shapes
    - (imperfectly explained for now; all details in Chapter 14)
  - **Color** – as you see it on the screen

# Point

```
namespace Graph_lib      // our graphics interface is in Graph_lib
{
    struct Point         // a Point is simply a pair of ints (the coordinates)
    {
        int x, y;
        Point(int xx, int yy) : x(xx), y(yy) { }
    };                   // Note the ';'
}
```

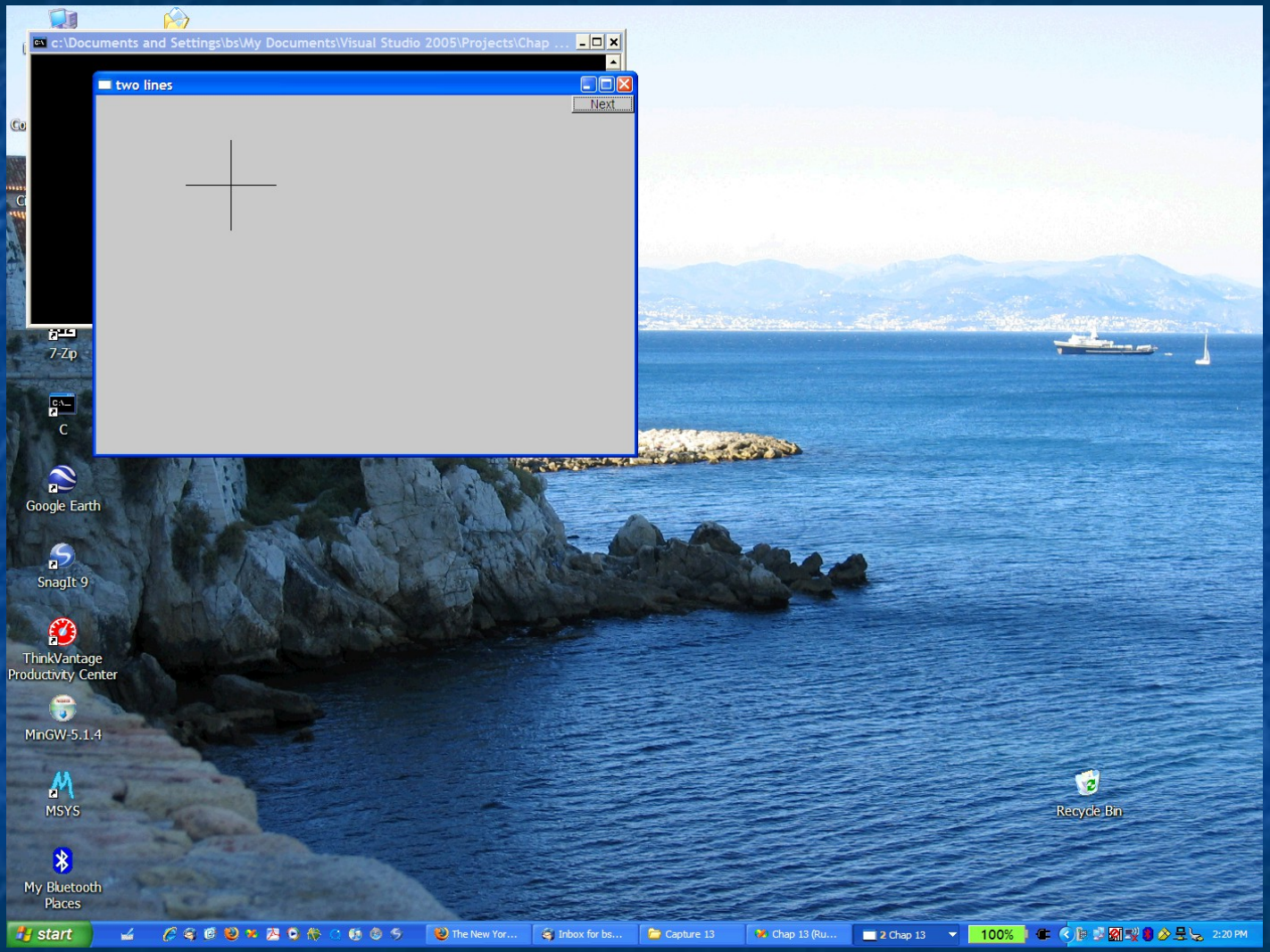
# Line

```
struct Shape {
    // hold lines represented as pairs of points
    // knows how to display lines
};

struct Line : Shape          // a Line is a Shape defined by just two Points
{
    Line(Point p1, Point p2);
};

Line::Line(Point p1, Point p2)      // construct a line from p1 to p2
{
    add(p1);        // add p1 to this shape (add() is provided by Shape)
    add(p2);        // add p2 to this shape
}
```

# Line example

```
// draw two lines:
using namespace Graph_lib;

Simple_window win(Point(100,100),600,400,"Canvas");     // make a window

Line horizontal(Point(100,100),Point(200,100));     // make a horizontal line
Line vertical(Point(150,50),Point(150,150));        // make a vertical line

win.attach(horizontal);    // attach the lines to the window
win.attach(vertical);

win.wait_for_button();    // Display!
```

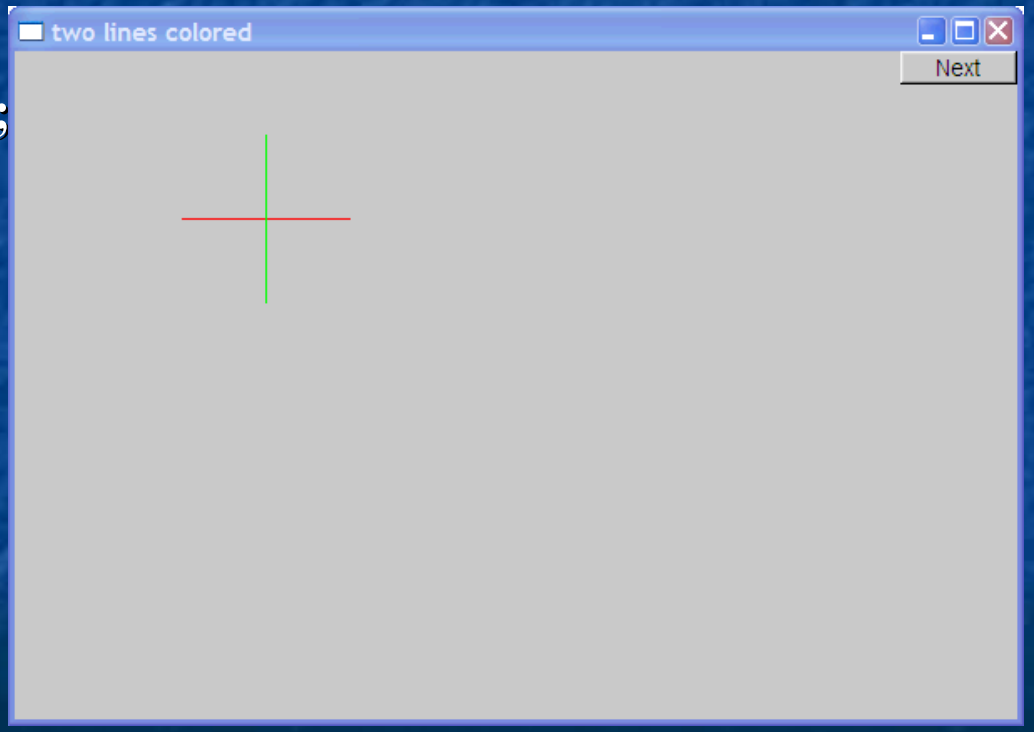
# Line example



# Line example

- Individual lines are independent

```
horizontal.set_color(Color::red);
vertical.set_color(Color::green);
```



# Lines

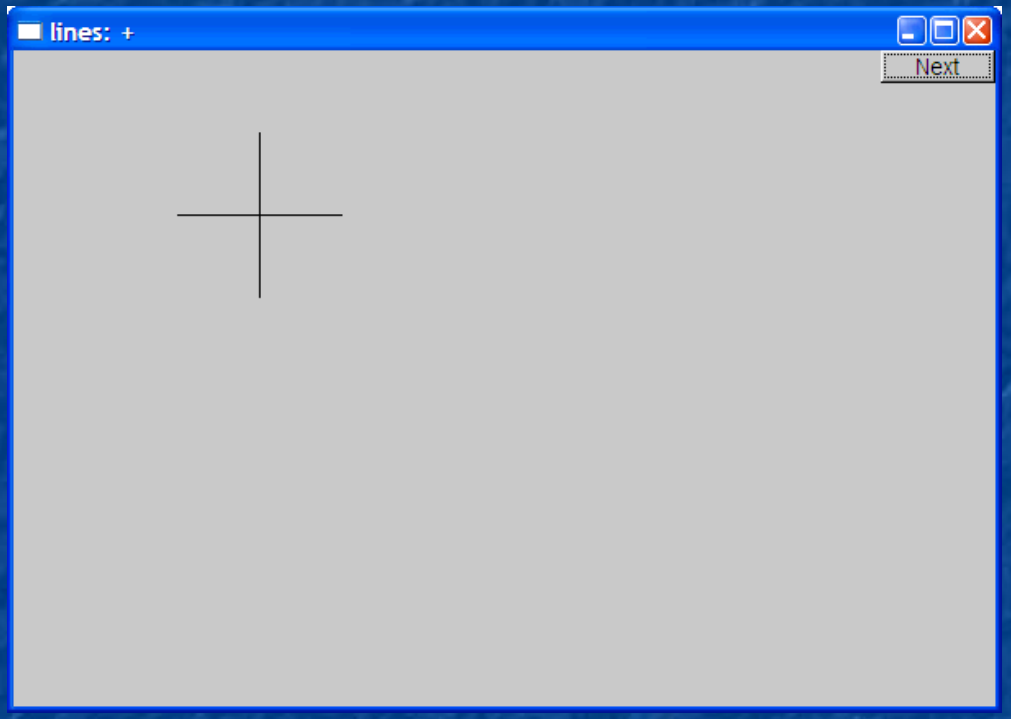
```
struct Lines : Shape {      // a Lines object is a set of lines
    // We use Lines when we want to manipulate
    // all the lines as one shape, e.g. move them all
    // together with one move statement
    void add(Point p1, Point p2);   // add line from p1 to p2
    void draw_lines() const;        // to be called by Window to draw Lines
};
```

- Terminology:
  - Lines "is derived from" Shape
  - Lines "inherits from" Shape
  - Lines "is a kind of" Shape
  - Shape "is the base" of Lines
- This is the key to what is called "object-oriented programming"
  - We'll get back to this in Chapter 14

# Lines Example

```
Lines x;
x.add(Point(100,100), Point(200,100));      // horizontal line
x.add(Point(150,50), Point(150,150));       // vertical line

win.attach(x);              // attach Lines object x to Window win
win.wait_for_button();      // Draw!
```

# Lines example




- Looks exactly like the two **Lines** example

# Implementation: Lines

```
void Lines::add(Point p1, Point p2)          // use Shape's add()
{
    Shape::add(p1);
    Shape::add(p2);
}

void Lines::draw_lines() const      // to somehow be called from Shape
{
    for (int i=1; i<number_of_points(); i+=2)
    fl_line(point(i-1).x, point(i-1).y, point(i).x, point(i).y);
}
```

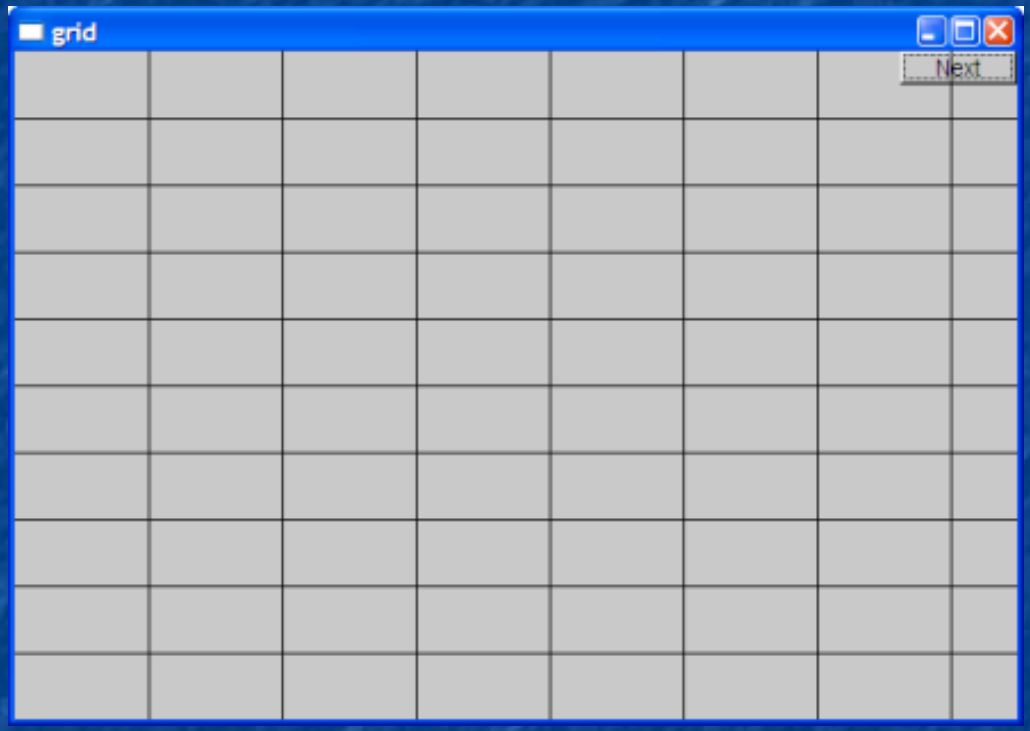
- Note
  - fl_line is a basic line drawing function from FLTK
  - FLTK is used in the *implementation*, not in the *interface* to our classes
  - We could replace FLTK with another graphics library

# Draw Grid

## (Why bother with **Lines** when we have **Line**?)

```
// A Lines object may hold many related lines
// Here we construct a grid:

int x_size = win.x_max();
int y_size = win.y_max();
int x_grid = 80;            // make cells 80 pixels wide
int y_grid = 40;            // make cells 40 pixels high

Lines grid;

for (int x=x_grid; x<x_size; x+=x_grid)     // veritcal lines
    grid.add(Point(x,0),Point(x,y_size));
for (int y = y_grid; y<y_size; y+=y_grid)   // horizontal lines
    grid.add(Point(0,y),Point(x_size,y));

win.attach(grid);  // attach our grid to our window (note grid is one object)
```

# Grid



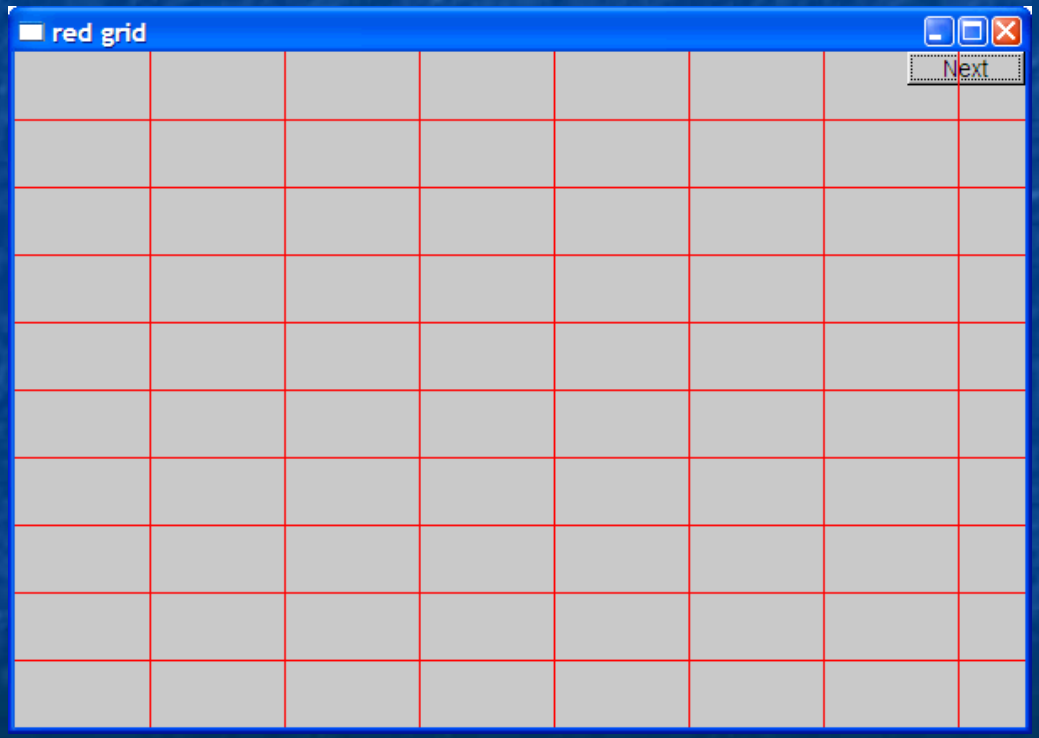

- Oops! Last column is narrow, there's a grid line on top of the Next button, etc.—tweaking required (as usual)

# Color

```
struct Color {     // Map FLTK colors and scope them;
                   // deal with visibility/transparency
    enum Color_type { red=FL_RED, blue=FL_BLUE, /* ... */ };

    enum Transparency { invisible=0, visible=255 };  // also called Alpha

    Color(Color_type cc) :c(Fl_Color(cc)), v(visible) { }
    Color(int cc) :c(Fl_Color(cc)), v(visible) { }
    Color(Color_type cc, Transparency t) :c(Fl_Color(cc)), v(t) { }

    int as_int() const { return c; }

    Transparency visibility() { return v; }
    void set_visibility(Transparency t) { v = t; }
private:
    Fl_Color c;
    char v;
};
```

# Draw red grid

```
grid.set_color(Color::red);
```

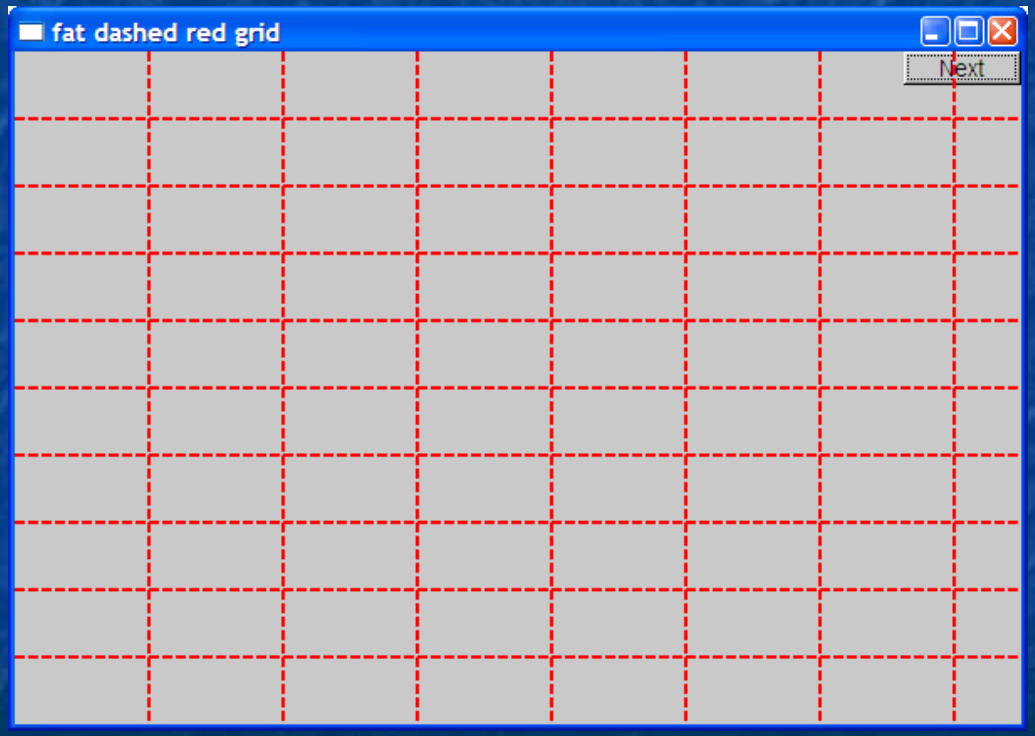


# Line_style

```
struct Line_style {
    enum Line_style_type {
        solid=FL_SOLID,              // -------
        dash=FL_DASH,                // - - - -
        dot=FL_DOT,                  // .......
        dashdot=FL_DASHDOT,          // - . - .
        dashdotdot=FL_DASHDOTDOT,    // -..-..
    };

    Line_style(Line_style_type ss) :s(ss), w(0) { }
    Line_style(Line_style_type lst, int ww) :s(lst), w(ww) { }
    Line_style(int ss) :s(ss), w(0) { }

    int width() const { return w; }
    int style() const { return s; }
private:
    int s;
    int w;
};
```

# Example: colored fat dash grid

```
grid.set_style(Line_style(Line_style::dash,2));
```



# Polylines

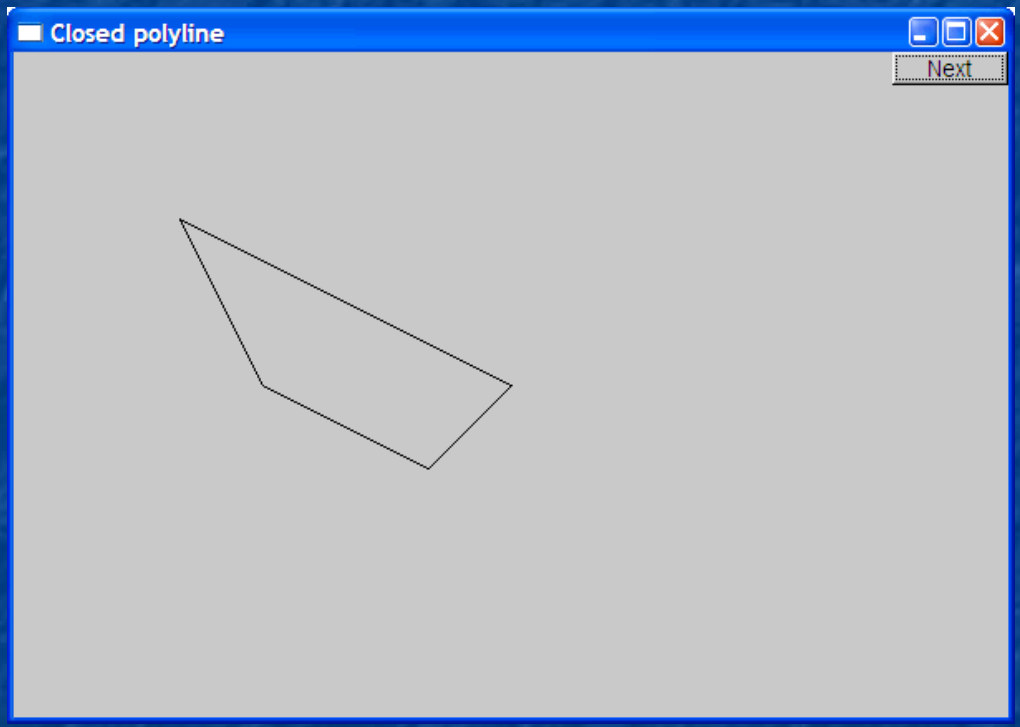
```
struct Open_polyline : Shape {     // open sequence of lines
    void add(Point p) { Shape::add(p); }
};

struct Closed_polyline : Open_polyline {   // closed sequence of lines
    void draw_lines() const
    {
    Open_polyline::draw_lines(); // draw lines (except the closing one)
    // draw the closing line:
    fl_line(          point(number_of_points()-1).x,
    point(number_of_points()-1).y,
    point(0).x,
    point(0).y
              );
    }
    void add(Point p) { Shape::add(p); }     // not needed (why?)
};
```

# Open_polyline

```
Open_polyline opl;
opl.add(Point(100,100));
opl.add(Point(150,200));
opl.add(Point(250,250));
opl.add(Point(300,200));
```

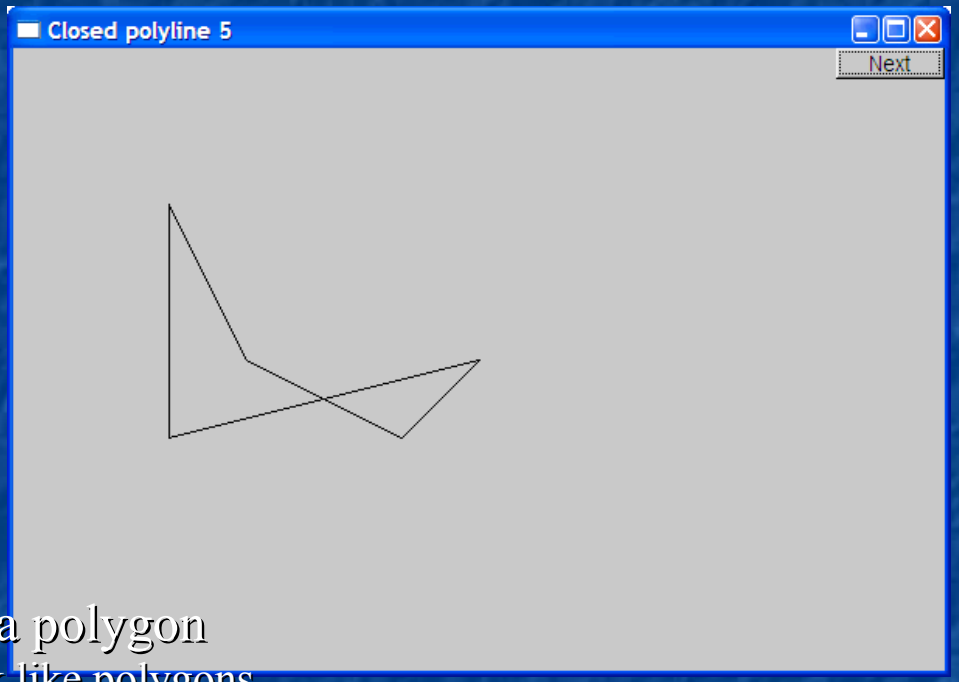
# Closed_polyline

```
Closed_polyline cpl;
cpl.add(Point(100,100));
cpl.add(Point(150,200));
cpl.add(Point(250,250));
cpl.add(Point(300,200));
```



# Closed_polyline

```
cpl.add(Point(100,250));
```



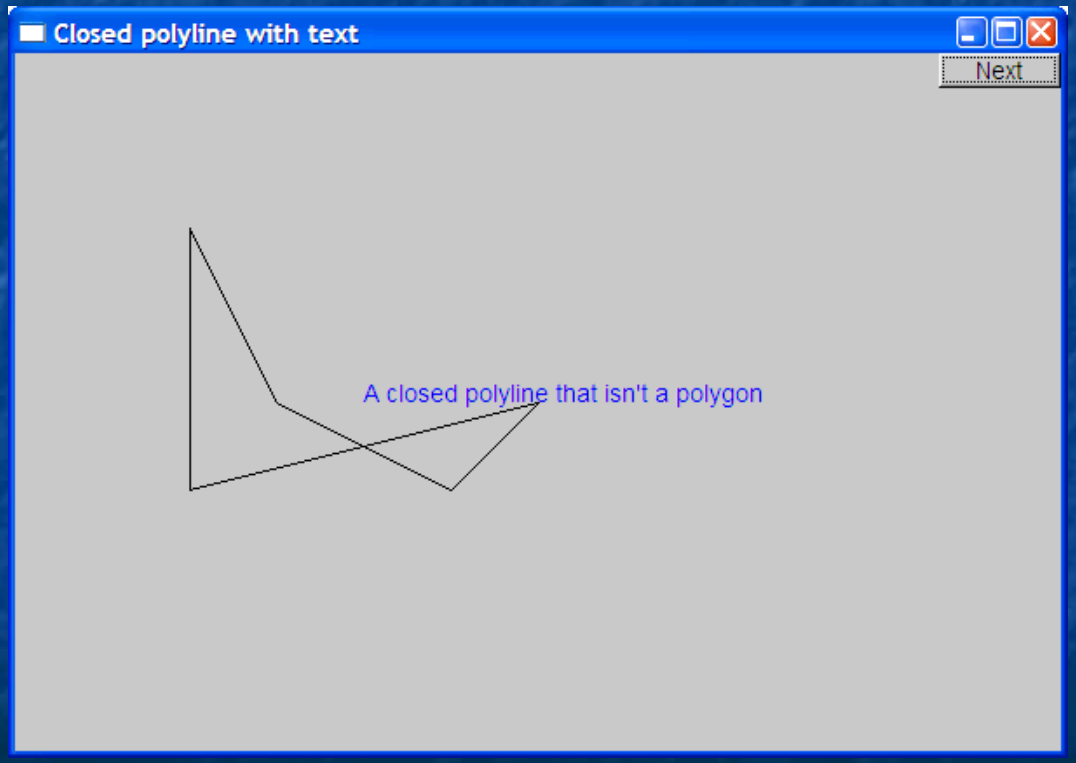

- A **Closed_polyline** is not a polygon
  - some closed_polylines look like polygons
  - A **Polygon** is a **Closed_polyline** where no lines cross
    - A **Polygon** has a stronger invariant than a **Closed_polyline**

# Text

```
struct Text : Shape {
    Text(Point x, const string& s)  // x is the bottom left of the first letter
    : lab(s),
      fnt(fl_font()),           // default character font
      fnt_sz(fl_size())         // default character size
    { add(x); }     // store x in the Shape part of the Text object

    void draw_lines() const;

    // ... the usual "getter and setter" member functions ...
private:
    string lab;     // label
    Font fnt;       // character font of label
    int fnt_sz;     // size of characters in pixels
};
```

# Add text

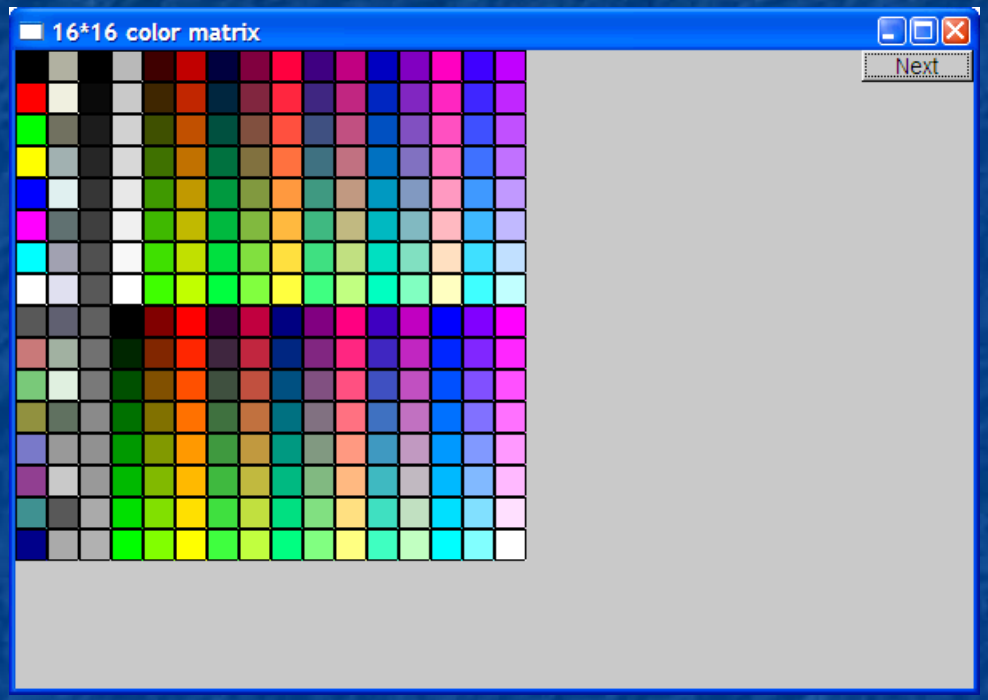
```
Text t(Point(200,200), "A closed polyline that isn’t a polygon");
t.set_color(Color::blue);
```



# Implementation: Text

```
void Text::draw_lines() const
{
    fl_draw(lab.c_str(), point(0).x, point(0).y);
}

// fl_draw() is a basic text drawing function from FLTK
```

# Color matrix

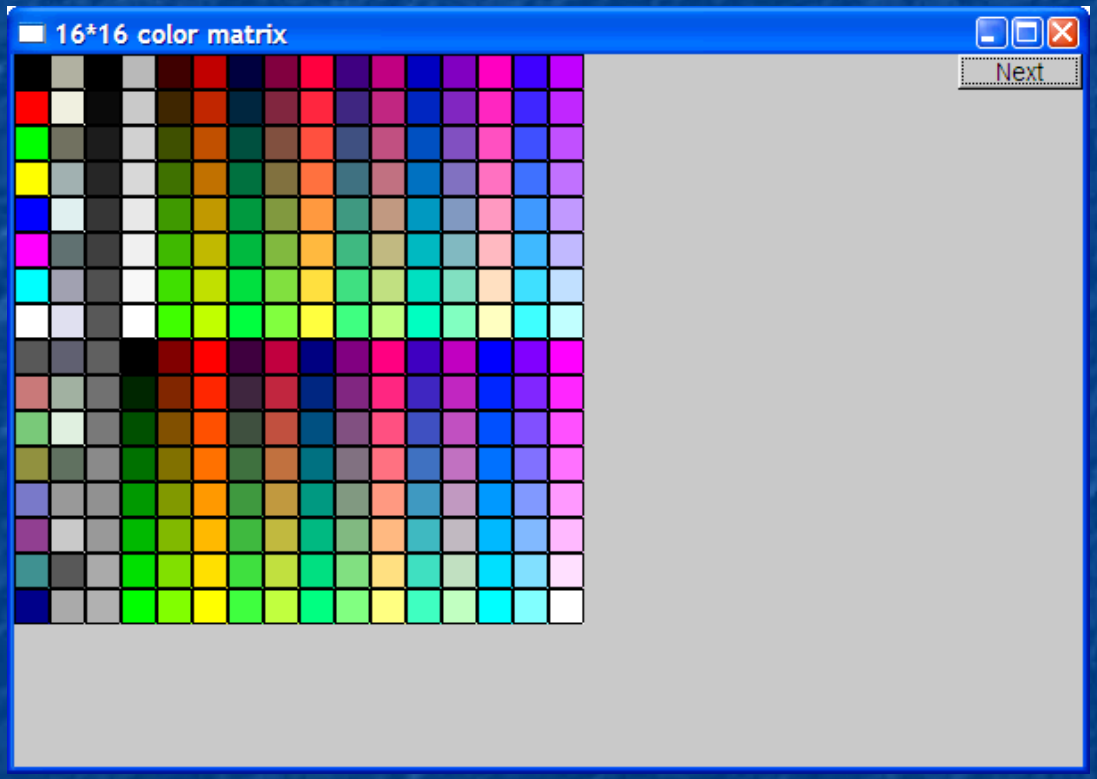



- Let's draw a color matrix
  - To see some of the colors we have to work with
  - To see how messy two-dimensional addressing can be
    - See Chapter 24 for real matrices
  - To see how to avoid inventing names for hundreds of objects

# Color Matrix (16*16)

```
Simple_window win20(pt,600,400,"16*16 color matrix");

Vector_ref<Rectangle> vr;  // use like vector
        // but imagine that it holds references to objects
for (int i = 0; i<16; ++i) { // i is the horizontal coordinate
    for (int j = 0; j<16; ++j) {        // j is the vertical coordinate
    vr.push_back(new Rectangle(Point(i*20,j*20),20,20));
    vr[vr.size()-1].set_fill_color(i*16+j);
    win20.attach(vr[vr.size()-1]);
    }

// new makes an object that you can give to a Vector_ref to hold
// Vector_ref is built using std::vector, but is not in the standard library
```

# Color matrix (16*16)




More examples and graphics classes in the book (chapter 13)

# Next lecture

- What is class Shape?
- Introduction to object-oriented programming