Chapter 14

Drawing in a Window

The Window Client Area

- A coordinate system that is local to the window.
- It always uses the upper-left corner of the client area as its reference point.

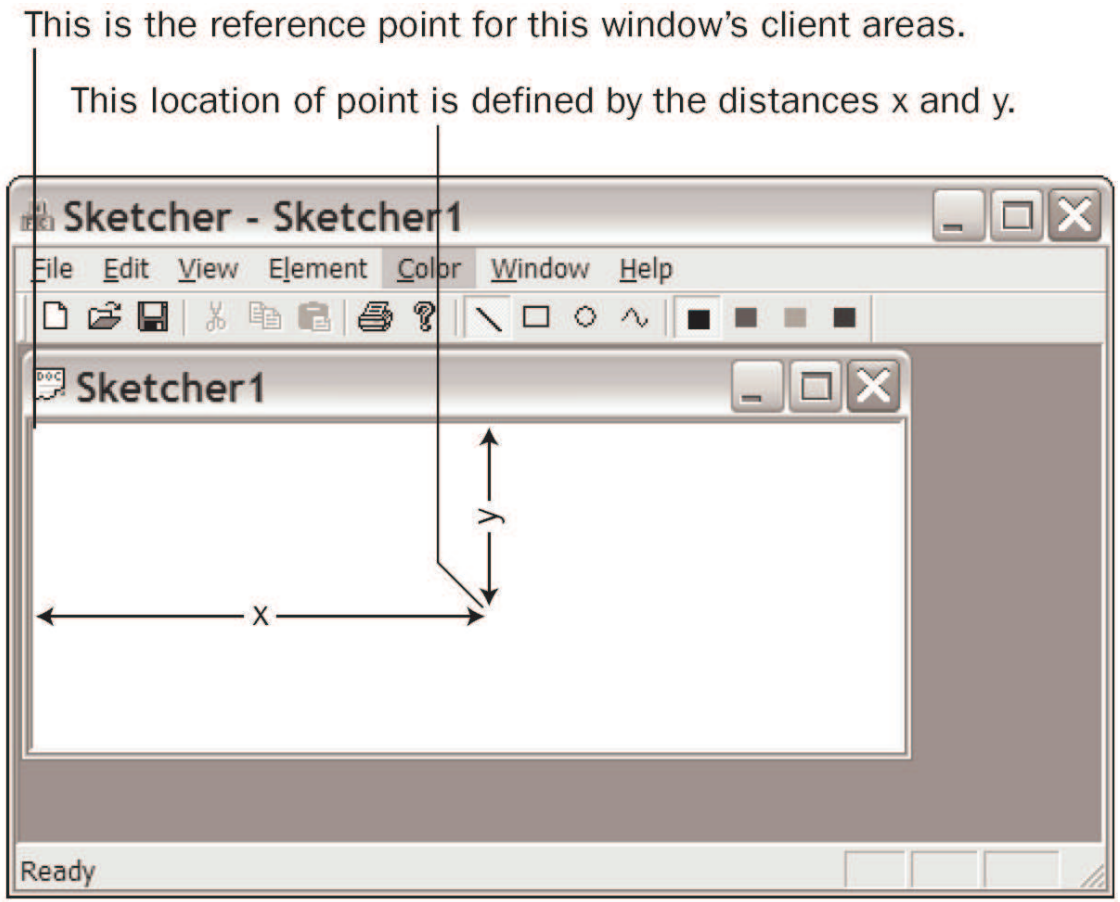


Figure 14-1

Graphical Device Interface (GDI)

- You don't draw pictures directly to the screen.
- You must define the graphical output (lines, circles, text) using the Graphical Device Interface.
- The GDI enables you to program graphical output independently of the hardware
  - Such as the display screen, printers, plotters

What Is a Device Context?

- You must use a device context to draw anything on a graphical output device.
- In a word, a device context is a data structure defined by Windows.
  - A device context contains attributes such as
    - Drawing color
    - Background color
    - Line thickness
    - Font
    - Mapping mode
- Your output requests are specified by device-independent GDI function calls.
  - A device context contains information that allows Windows to translate those requests into actions on the particular physical output device.

Mapping Modes

- MM_TEXT
  - A logical unit is one device pixel with positive x from left to right, and positive y from top to bottom of the window client area.

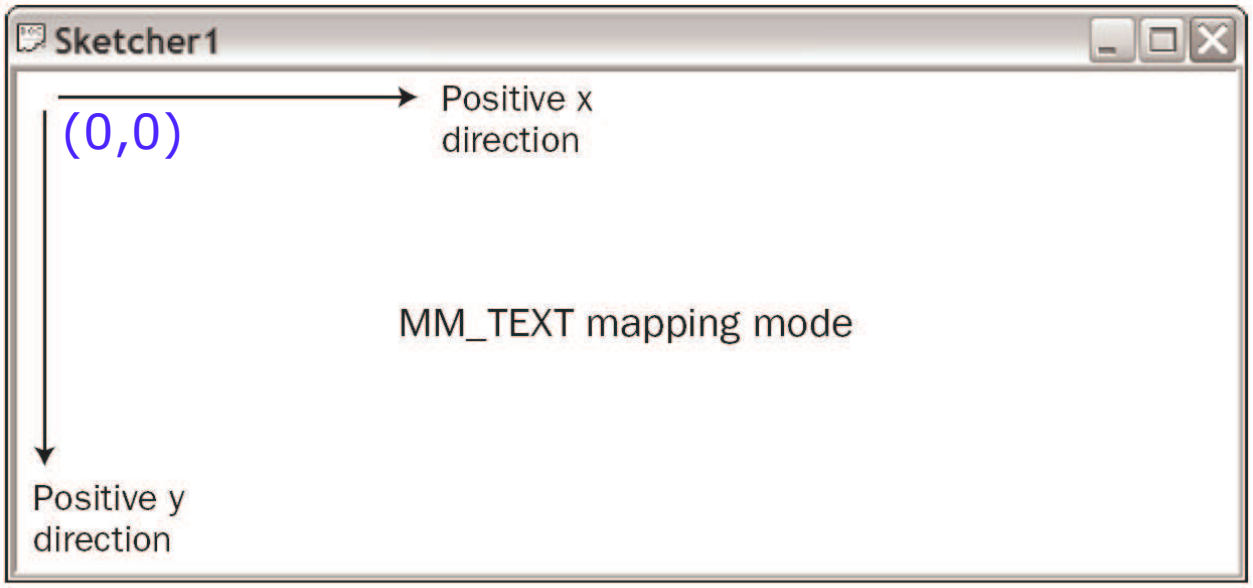


Figure 14-2

Mapping Modes (2)

- MM_LOENGLISH
  - A logical unit is 0.01 inches with positive x from left to right, and positive y from the top of the client area upwards.
    - Consistent with what we learned in high school.
  - By default, the point at the upper-left corner has the coordinates (0,0) in every mapping mode.
  - Coordinate are always 32-bit signed integers.

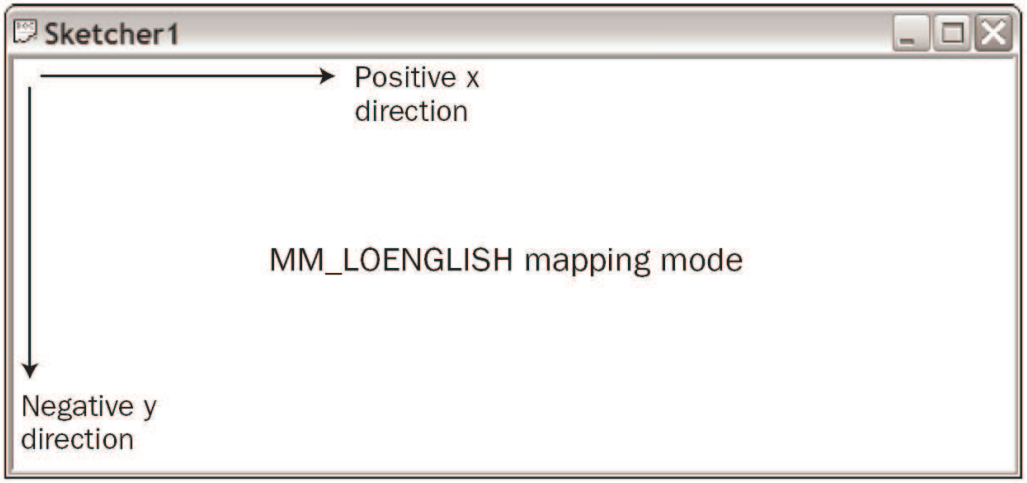


Figure 14-3

The View Class in Your Application

- In the class CSketcherView, the function OnDraw() is called when a WM_PAINT message is received in your program.
  - Windows sends this message to your program whenever it requires the client area to be redrawn.
    - The user resizes the window
    - Part of your window was previously “covered” by another window

The OnDraw( ) Member Function

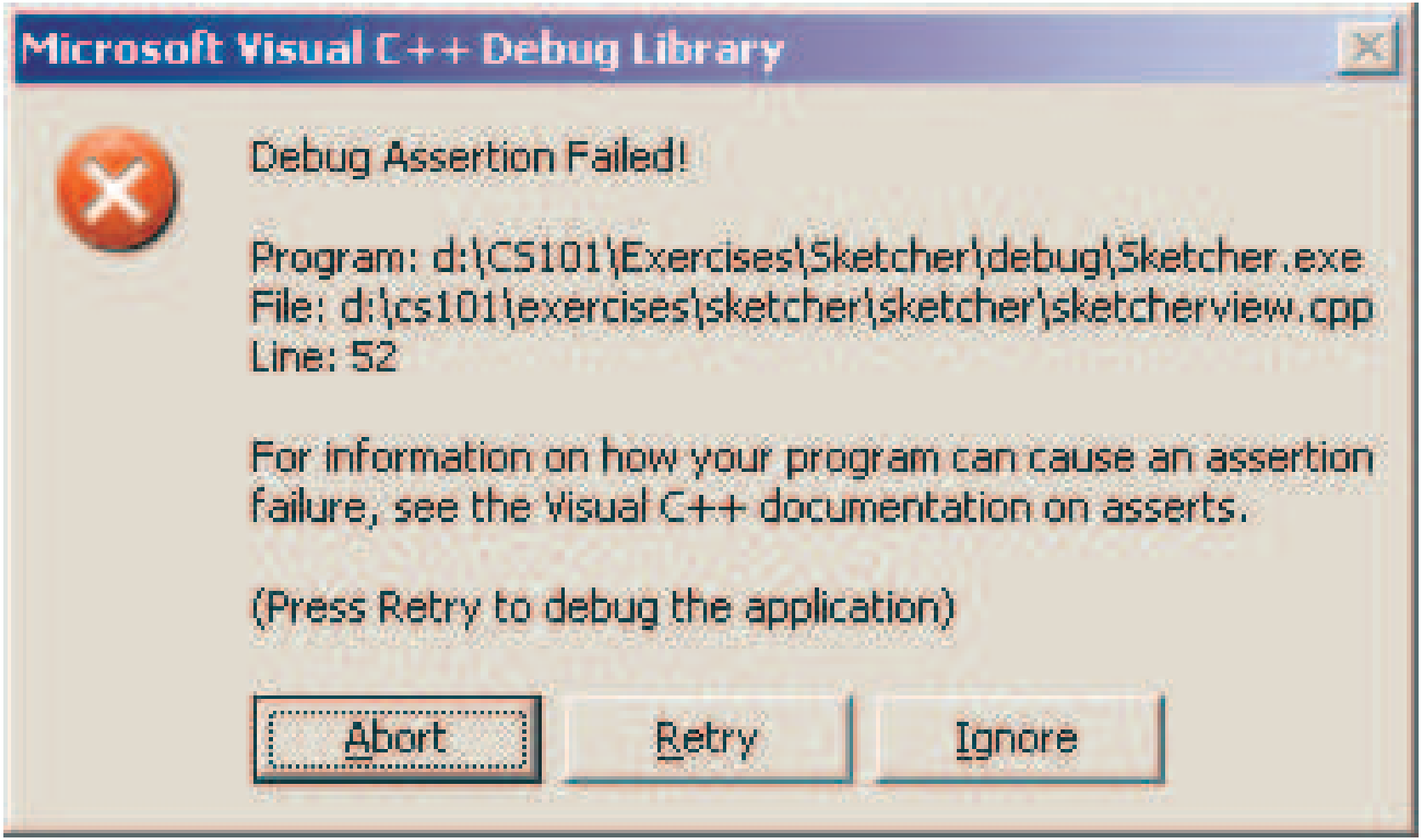
```
void CSketcherView::OnDraw(CDC* pDC)
{
  CSketcherDoc* pDoc = GetDocument();
  ASSERT_VALID(pDoc);
  if (!pDoc)
     return;
// TODO: add draw code for native data here
}
```

Returns the address of the document object related to the current view (P.652)

Make sure the pointer pDoc contains a valid address.

Make sure the pointer pDoc is not null.

Assertion Failed



The CDC Class

- You should do all the drawing in your program using members of the CDC class.
  - C – Class
  - DC – Device Context
- There are over a hundred member functions of this class.
- Sometimes you use objects of CClientDC
  - It is derived from CDC, and thus contains all the members we will discuss.
  - Its advantage is that CClientDC always contains a device context that represents only the client area of a window.

Current Position

- In a device context, you draw entities such as lines, and text relative to a current position.
- You may set the current position by calling the MoveTo() function.

MoveTo()

- The CDC class overloads the MoveTo() function in two versions to provide flexibility.
  - CPoint MoveTo(int x, int y);
  - CPoint MoveTo(POINT aPoint);
- POINT is a structure defined as:
  - typedef struct tagPOINT
  - {
  - LONG x;
  - LONG y;
  - } POINT;
- CPoint is a class with data members x and y of type LONG.
- The return value from the MoveTo() function is a CPoint object that specifies the position before the move.
  - This allows you to move back easily.

Drawing Lines

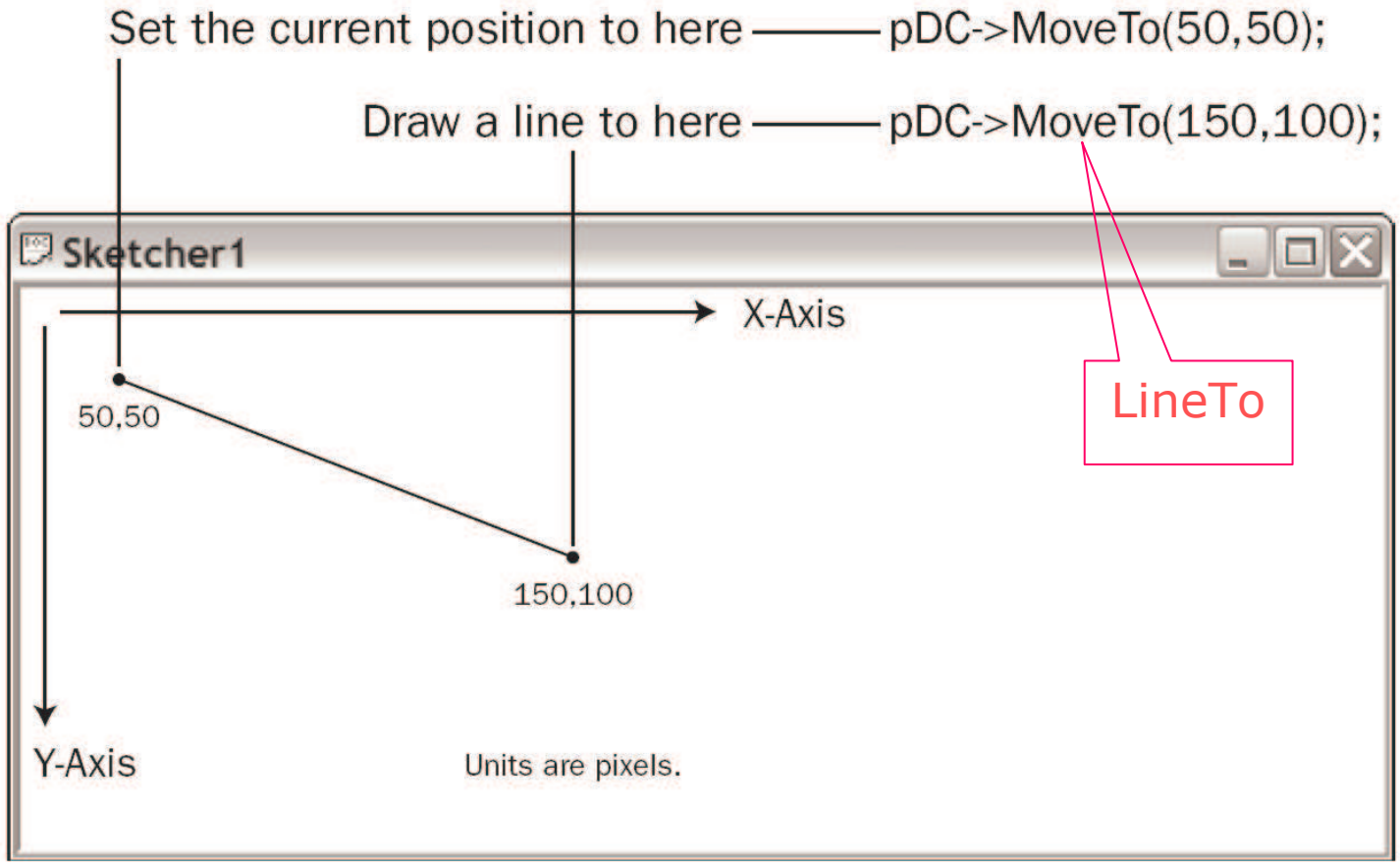


Figure 14-4

LineTo()

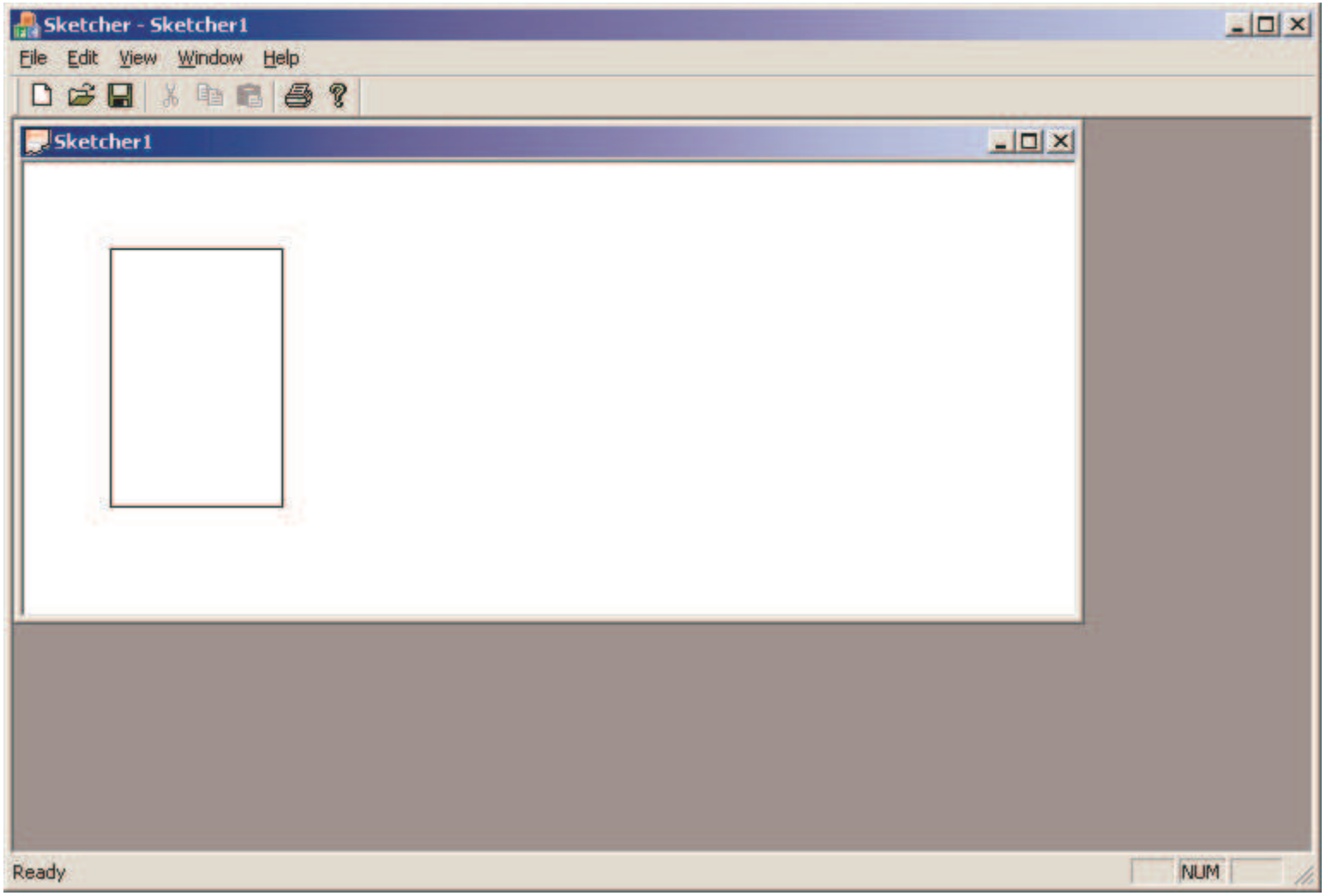
- The CDC class also defines two versions of the LineTo() function
  - BOOL LineTo(int x, int y);
  - BOOL LineTo(POINT aPoint);
    - You may use either a POINT struct or a CPoint object as the argument.

Ex14_1 (P.715)

- When the LineTo() function is executed, the current position is changed to the point specifying the end of the line.

```
void CSketcherView::OnDraw(CDC* pDC)
{
   CSketcherDoc* pDoc = GetDocument();
   ASSERT_VALID(pDoc);
   if (!pDoc)
     return;

   pDC->MoveTo(50,50);
   pDC->LineTo(50,200);
   pDC->LineTo(150,200);
   pDC->LineTo(150,50);
   pDC->LineTo(50,50);
}
```

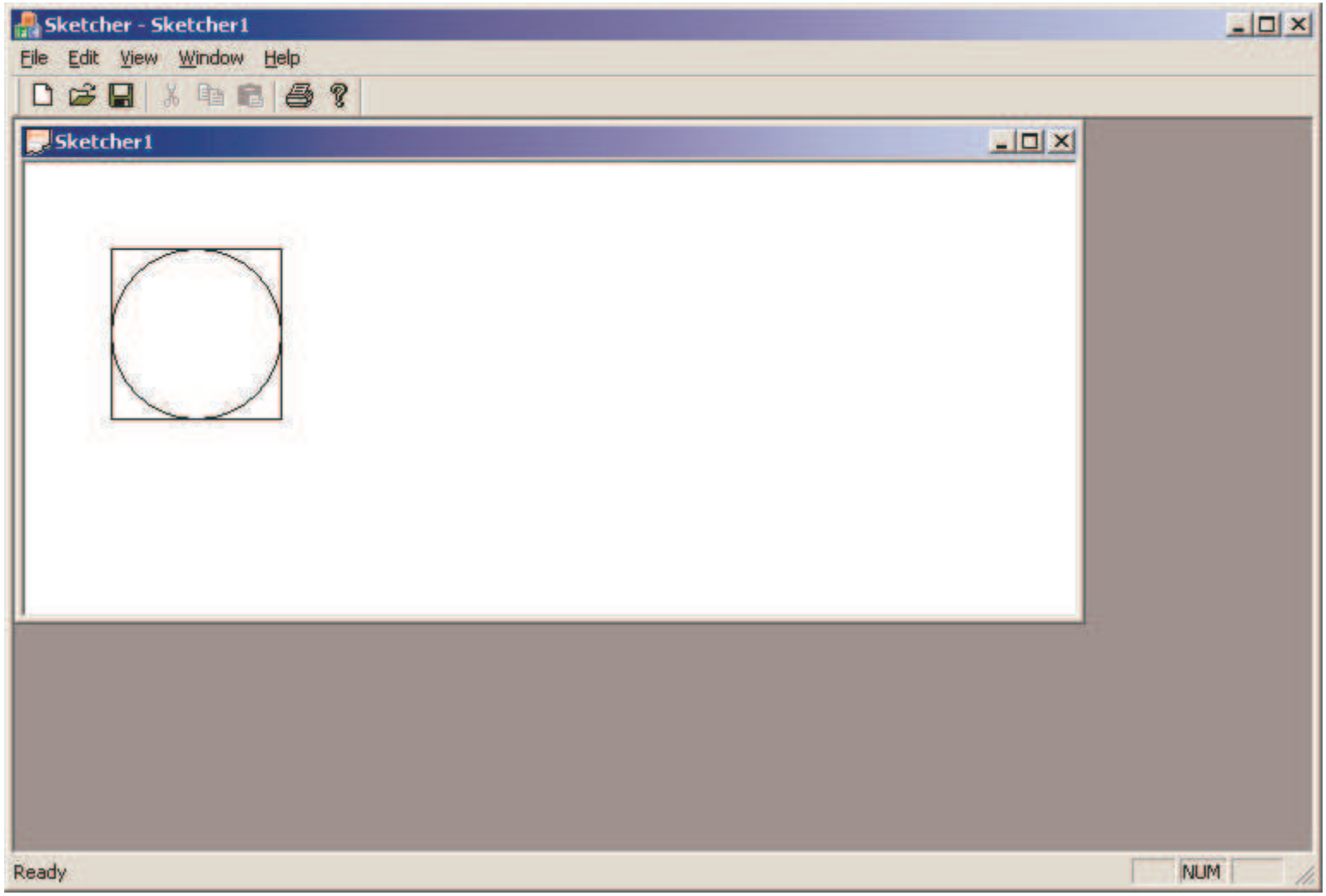
Figure 14-5


Sketcher - Sketcher1
File Edit View Window Help
Sketcher1
Ready
NUM

Drawing Rectangles & Circles

```
void CSketcherView::OnDraw(CDC* pDC)
{
  CSketcherDoc* pDoc = GetDocument();
  ASSERT_VALID(pDoc);
  if (!pDoc)
     return;

  pDC->Rectangle(50,50, 150, 150);
  pDC->Ellipse(50,50, 150,150);

}
```

A circle is a special ellipse

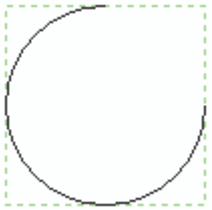


Arc

- Another way to draw circles is to use the Arc() function.
  - BOOL Arc(int x1, int y1, int x2, int y2, int x3, int y3, int x4, int y4);
    - (x1, y1) and (x2, y2) define the upper-left and lower-right corners of a rectangle enclosing the circle (ellipse).
    - The points (x3, y3) and (x4, y4) define the start and end points of the arc, which is drawn counterclockwise.
    - If (x4, y4) is identical to (x3, y3), you get a circle.
  - BOOL Arc(LPCRECT lpRect, POINT Startpt, POINT Endpt);
    - lpRect points to an object of the class CRect, which has four public data members: left , top, right, bottom.

Drawing with the `Arc()` Function

```
void CSketcherView::OnDraw(CDC* pDC)
{
   CSketcherDoc* pDoc = GetDocument();
   ASSERT_VALID(pDoc);
   if (!pDoc)
     return;

   pDC->Arc(50,50,150,150,100,75,150,100);

   CRect* pRect = new CRect(250,50,300,100);
   CPoint Start(275,100);
   CPoint End(250,75);
   pDC->Arc(pRect, Start, End);
   delete pRect;
}
```



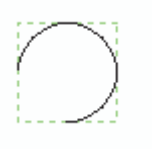
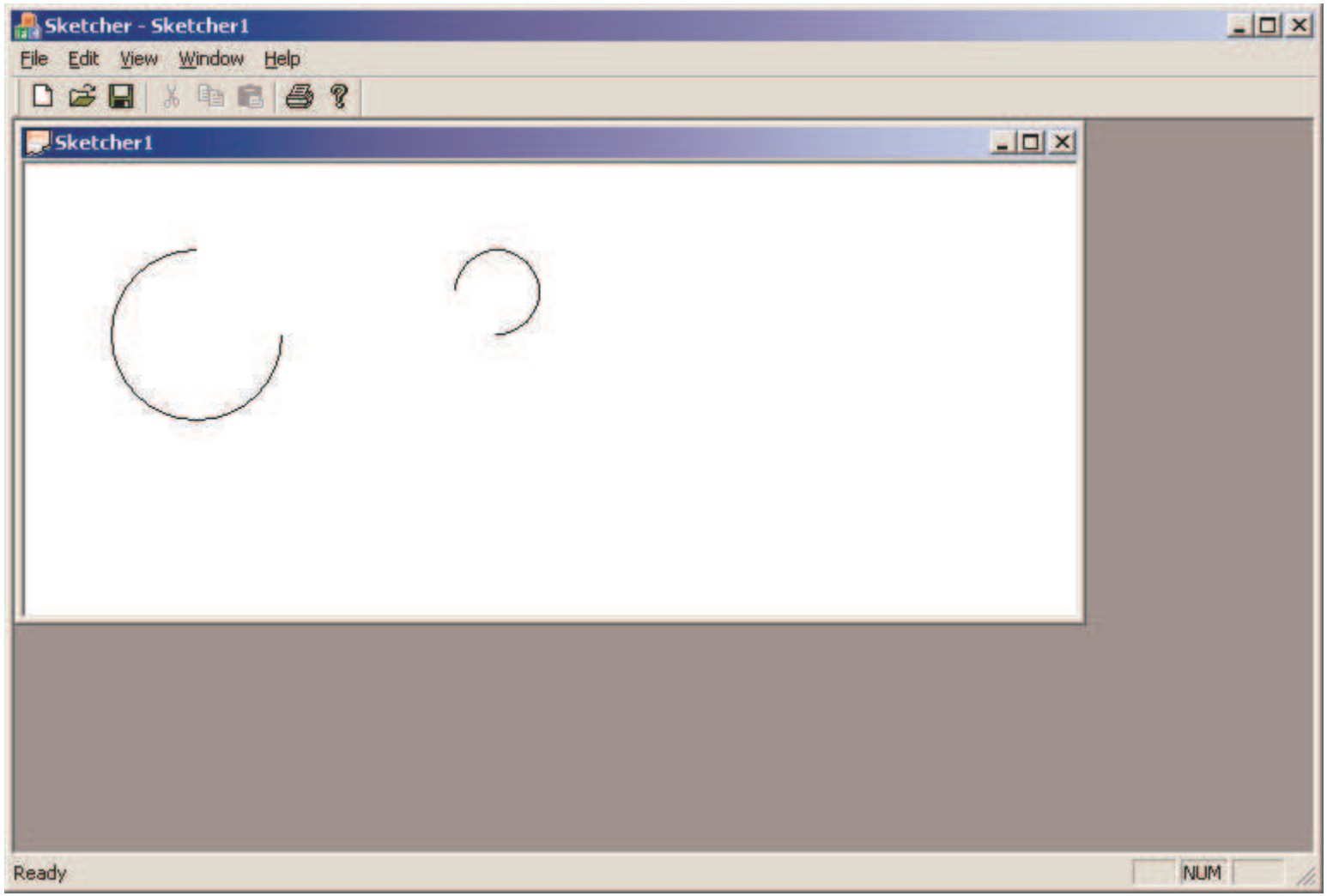
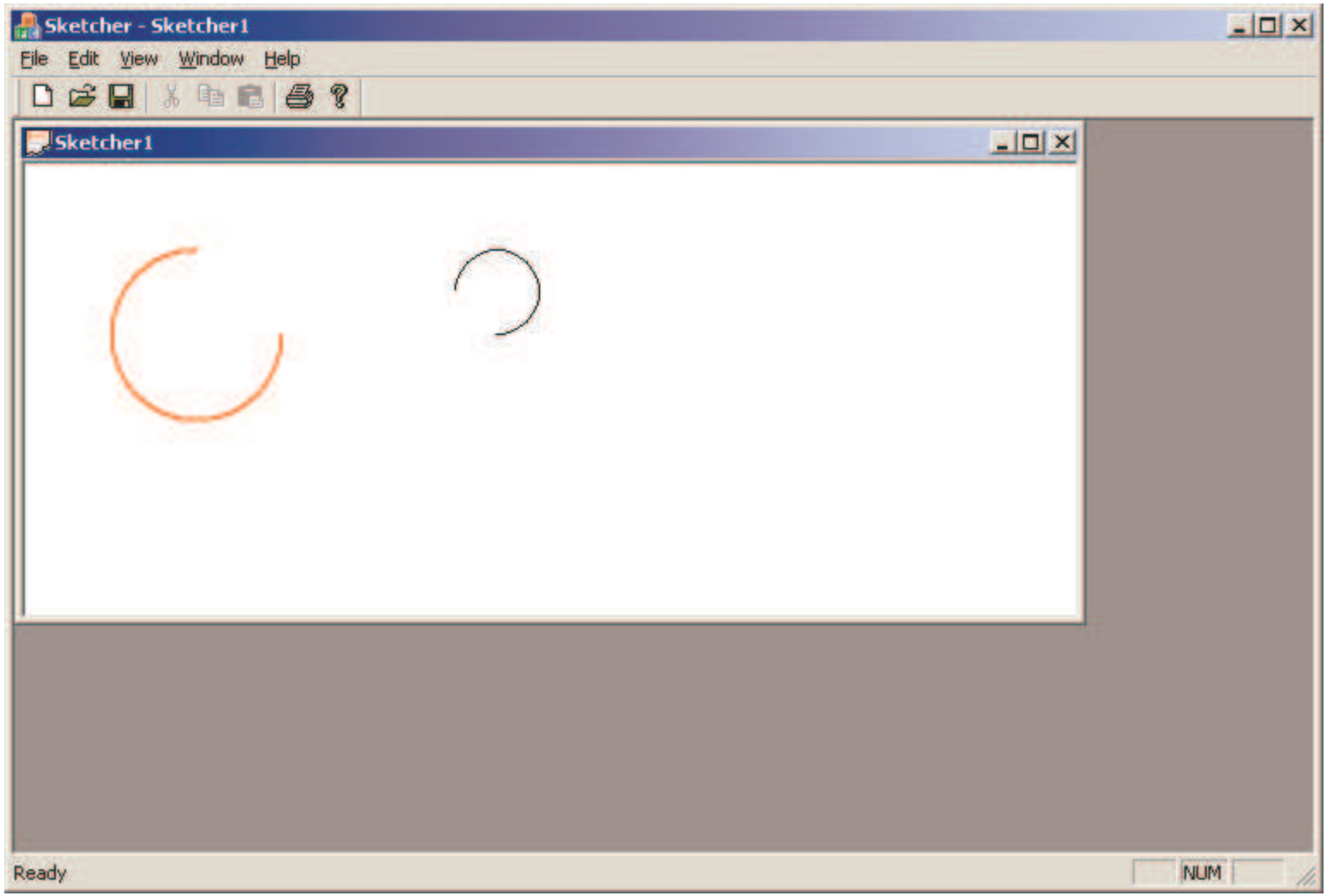


Figure 14-6


Sketcher - Sketcher1
File Edit View Window Help
Sketcher1
Ready
NUM

Drawing in Color



Using a Pen

- Declare a pen object and initialize it as a red solid pen drawing a line 2 pixels wide (P.719)
  - CPen aPen;
  - aPen.CreatePen(PS_SOLID, 2, RGB(255, 0, 0));
  - CPen* pOldPen = pDC->SelectObject(&aPen);
  - pDC->Arc(50,50,150,150,100,75,150,100);
  - pDC->SelectObject(pOldPen);
  - CRect* pRect = new CRect(250,50,300,100);
  - CPoint Start(275,100);
  - CPoint End(250,75);
  - pDC->Arc(pRect, Start, End);
  - delete pRect;

Pen Style

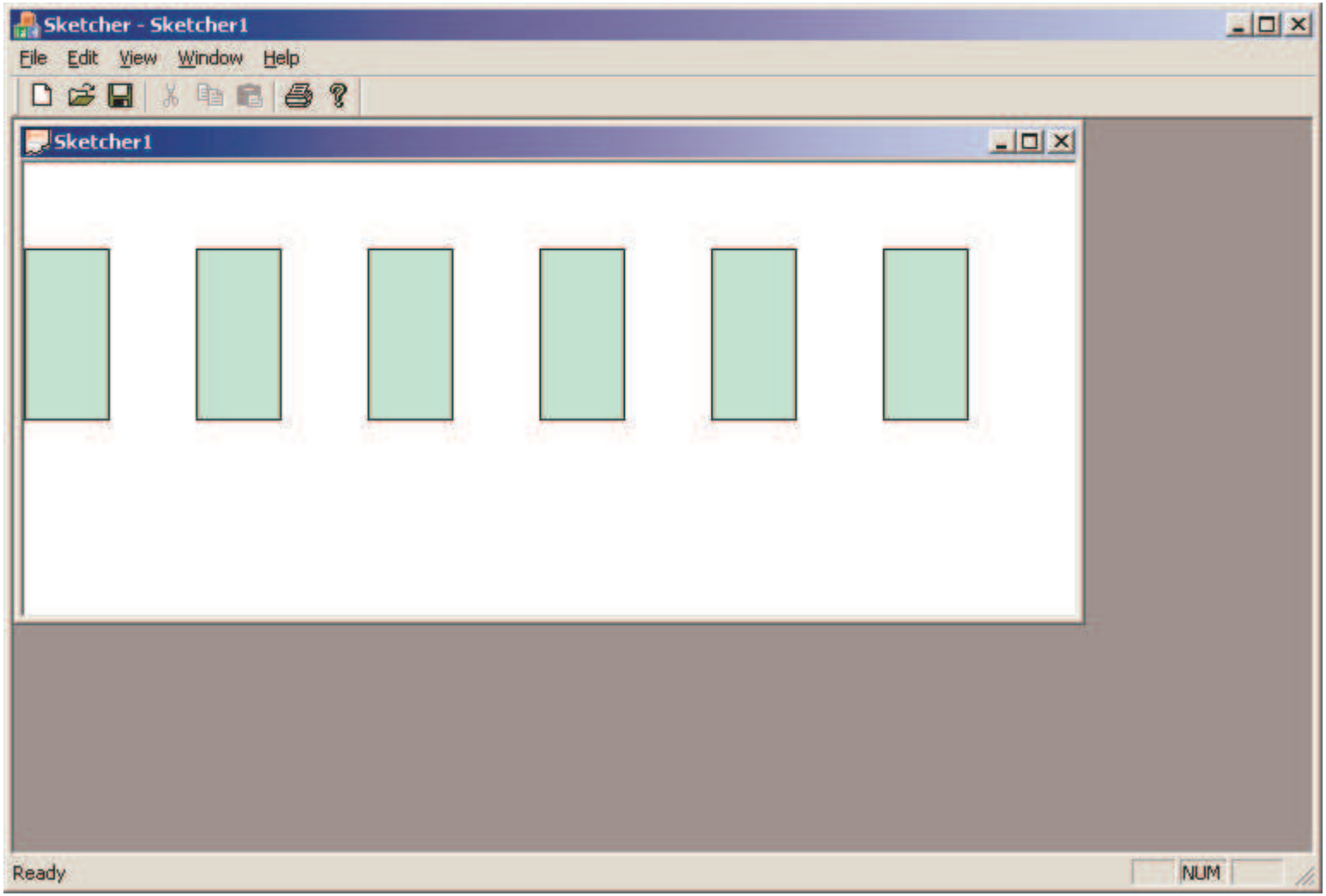
- `BOOL CreatePen(int aPenStyle, int aWidth, COLORREF aColor);`
  - PS_SOLID – solid line
  - PS_DASH – dashed line
  - PS_DOT – dotted line
  - PS_DASHDOT – alternating dashes and dots
  - PS_DASHDOTDOT – alternating dashes and double dots.
  - PS_NULL – draw nothing

Creating a Brush

- A brush is actually an 8x8 block of patterns that's repeated over the region to be filled.
- All closed shapes in CDC will be filled with a brush (and a color).
- Select the brush into the device context by calling the `SelectObject()` member (similar to selecting a pen).

```
CBrush aBrush;
aBrush.CreateSolidBrush(RGB(0,255,255));
CBrush* pOldBrush =
  static_cast<CBrush*> (pDC->SelectObject(&aBrush));

const int width = 50;
const int height = 50;
int i;
for (i=0; i<6; i++)
  pDC->Rectangle(i*2*width, 50,i*2*width+50, 150);

pDC->SelectObject(pOldBrush);
```

Solid Brush


Sketcher - Sketcher1
File Edit View Window Help
Sketcher1
Ready
NUM

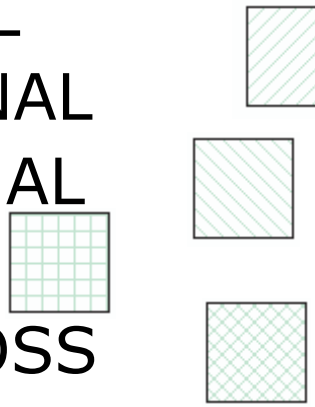
OnMouseMove()

```
void CSketcherView::OnMouseMove(UINT nFlags, CPoint point)
{
   // TODO: Add your message handler code here and/or call default

   if (nFlags & MK_LBUTTON)
   {
        m_SecondPoint = point;
        // Test for a previous temporary element
        {
        // We get to here if there was a previous mouse move
        // so add code to delete the old element
        }

        // Add code to create new element
        // and cause it to be drawn
   }
}
```

Verify the left mouse button is down

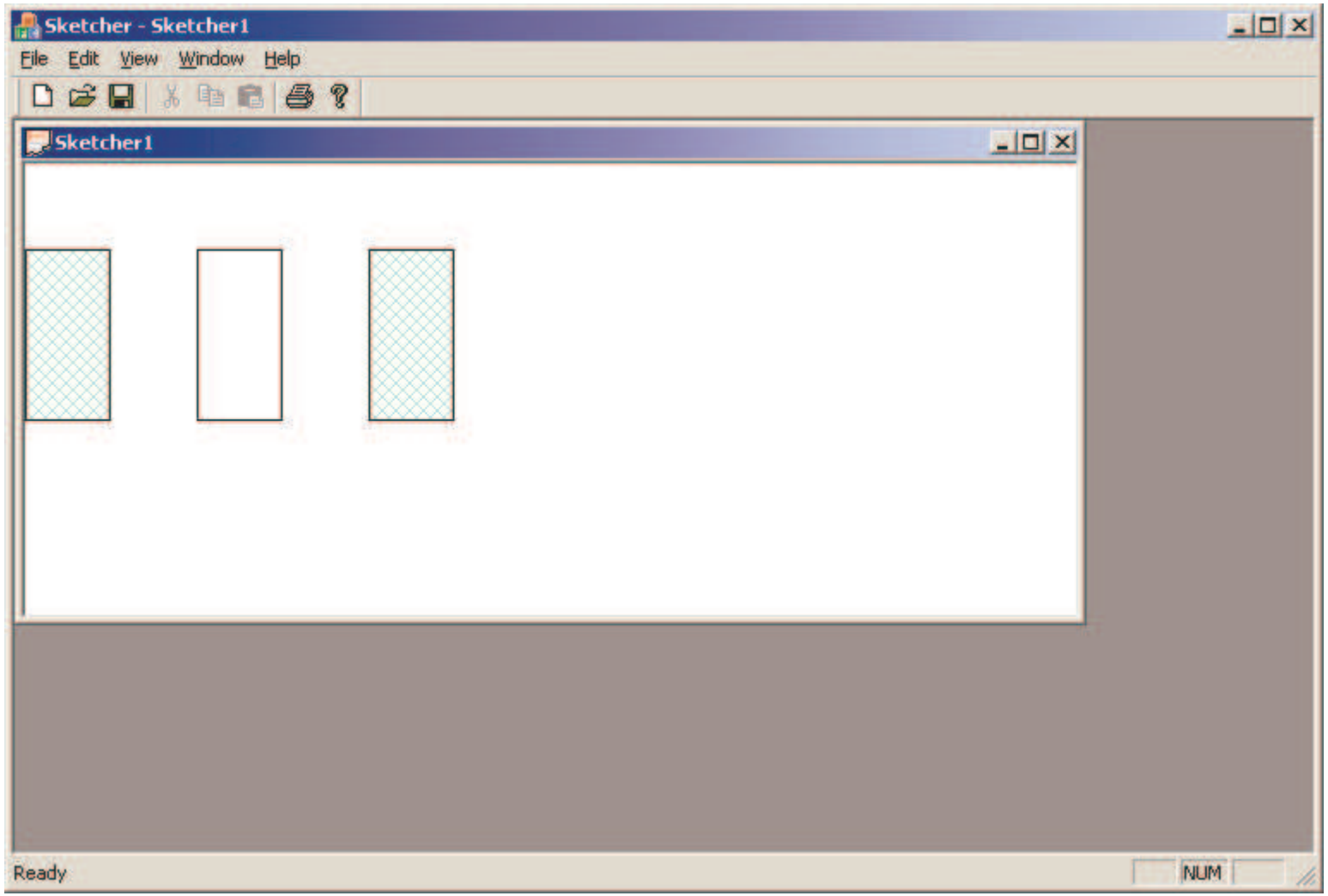
Hatching Style

- HS_HORIZONTAL
- HS_VERTICAL
- HS_BDIAGONAL
- HS_FDIAGONAL
- HS_CROSS
- HS_DIAGCROSS



```
CBrush aBrush;
aBrush.CreateHatchBrush(HS_DIAGCROSS,
  RGB(0,255,255));
CBrush* pOldBrush =
  static_cast<CBrush*> (pDC->SelectObject(&aBrush));
```

A Hatched Brush



Drawing Graphics in Practice

- The easiest mechanism for drawing is using just the mouse.

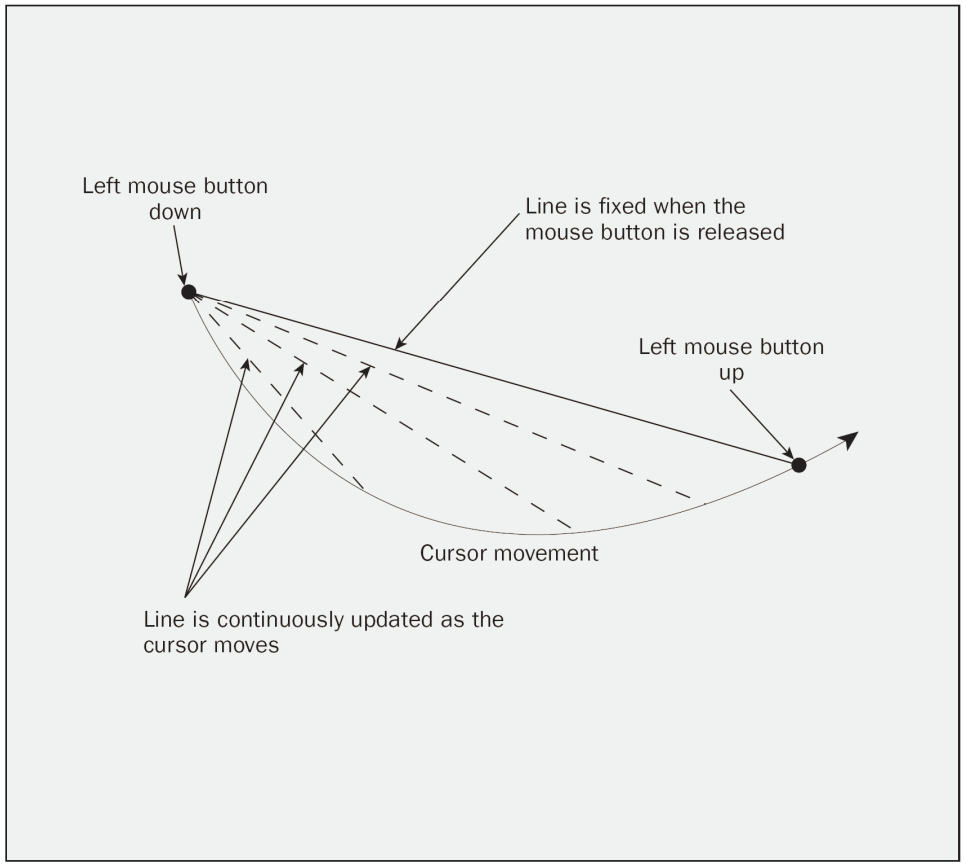


Figure 14-7

Circle

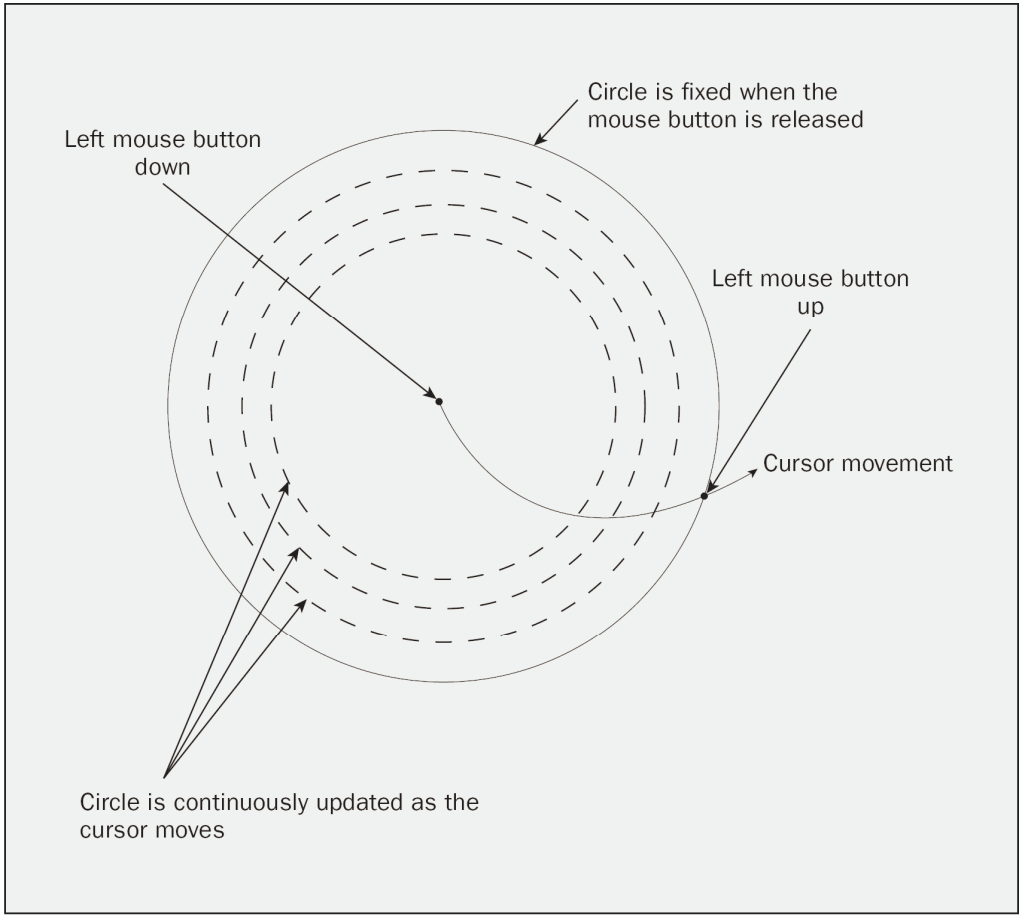


Figure 14-8

Rectangle

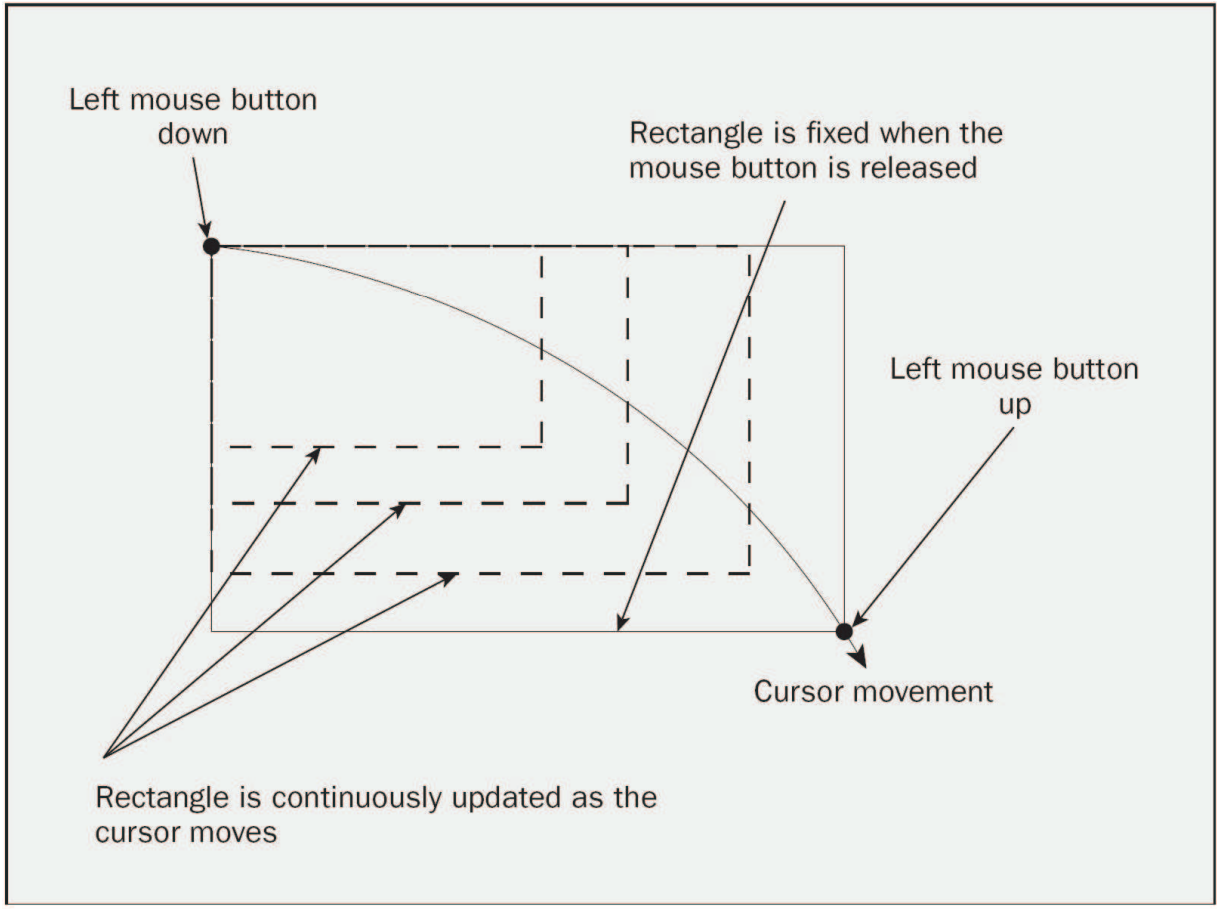


Figure 14-9

Curve

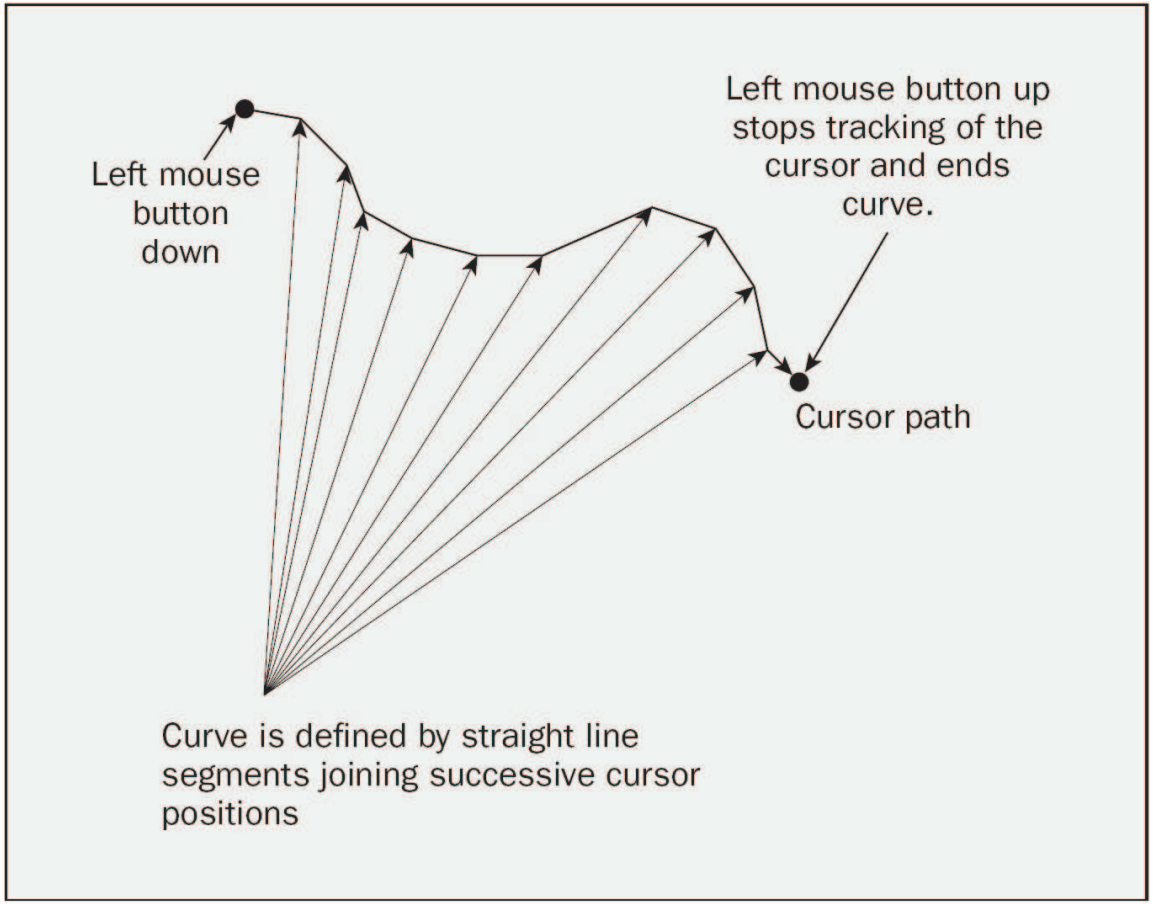


Figure 14-10

Message from the Mouse

- WM_LBUTTONDOWN
  - Left mouse button is pressed
- WM_LBUTTONUP
  - Left mouse button is released
- WM_MOUSEMOVE
  - The mouse is moved.

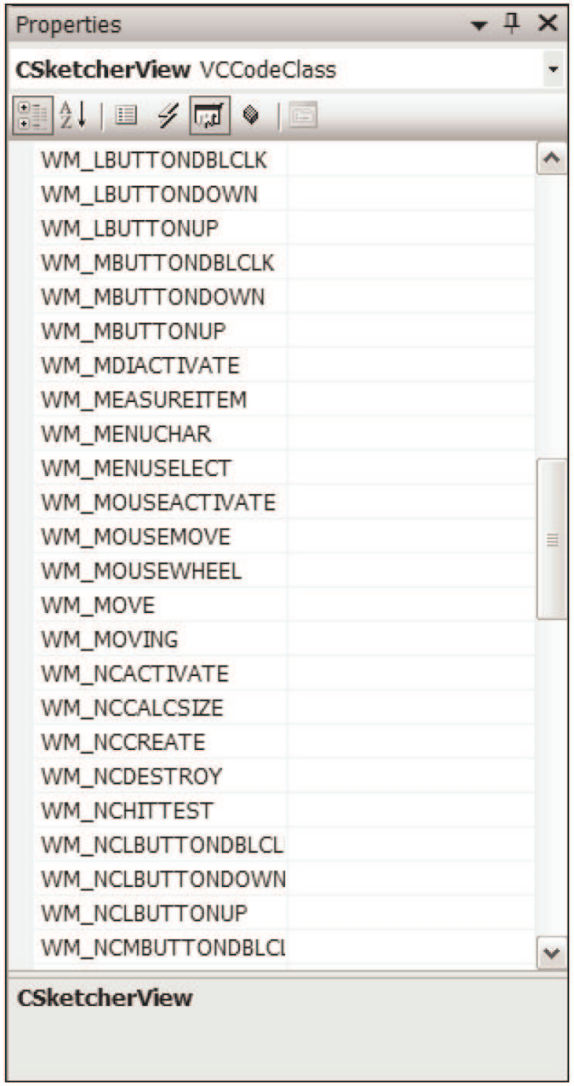


Figure 14-11

Mouse Message Handlers

- Create a handler by clicking on the ID of a mouse message.
- Then select the down arrow in its right column.
  - For example, select <add> OnLButtonUp for the WM_LBUTTONUP message.
  - The wizard generates the WM_LBUTTONUP message handler:

```
void CSketcherView::OnLButtonUp(UINT nFlags, CPoint point)
{
   // TODO: Add your message handler code here and/or call default

   CView::OnLButtonUp(nFlags, point);
}
```

nFlags

- MK_CONTROL
  - Ctrl key being pressed
- MK_LBUTTON
  - Left mouse button being down
- MK_MBUTTON
  - Middle mouse button being down
- MK_RBUTTON
  - Right mouse button being down
- MK_SHIFT
  - Shift key being pressed

- To test for the Ctrl key being pressed

```
if (nFlags & MK_CONTROL)
// Do something
```

bitwise AND operator (P.82)

Storing the Position of the Cursor

- You may store the position of the cursor in the CSketcherView class.

Figure 14-12

m_FirstPoint & m_SecondPoint

- Initialization in the constructor,

```
CSketcherView::CSketcherView(): m_FirstPoint(CPoint(0,0)),
   m_SecondPoint(CPoint(0,0))
```

- Assigning values in the message handler,

```
void CSketcherView::OnLButtonDown(UINT nFlags, CPoint point)
{
   // TODO: Add your message handler code here and/or call default
   m_FirstPoint = point;          // Record the cursor position
}
```

Defining Classes for Elements

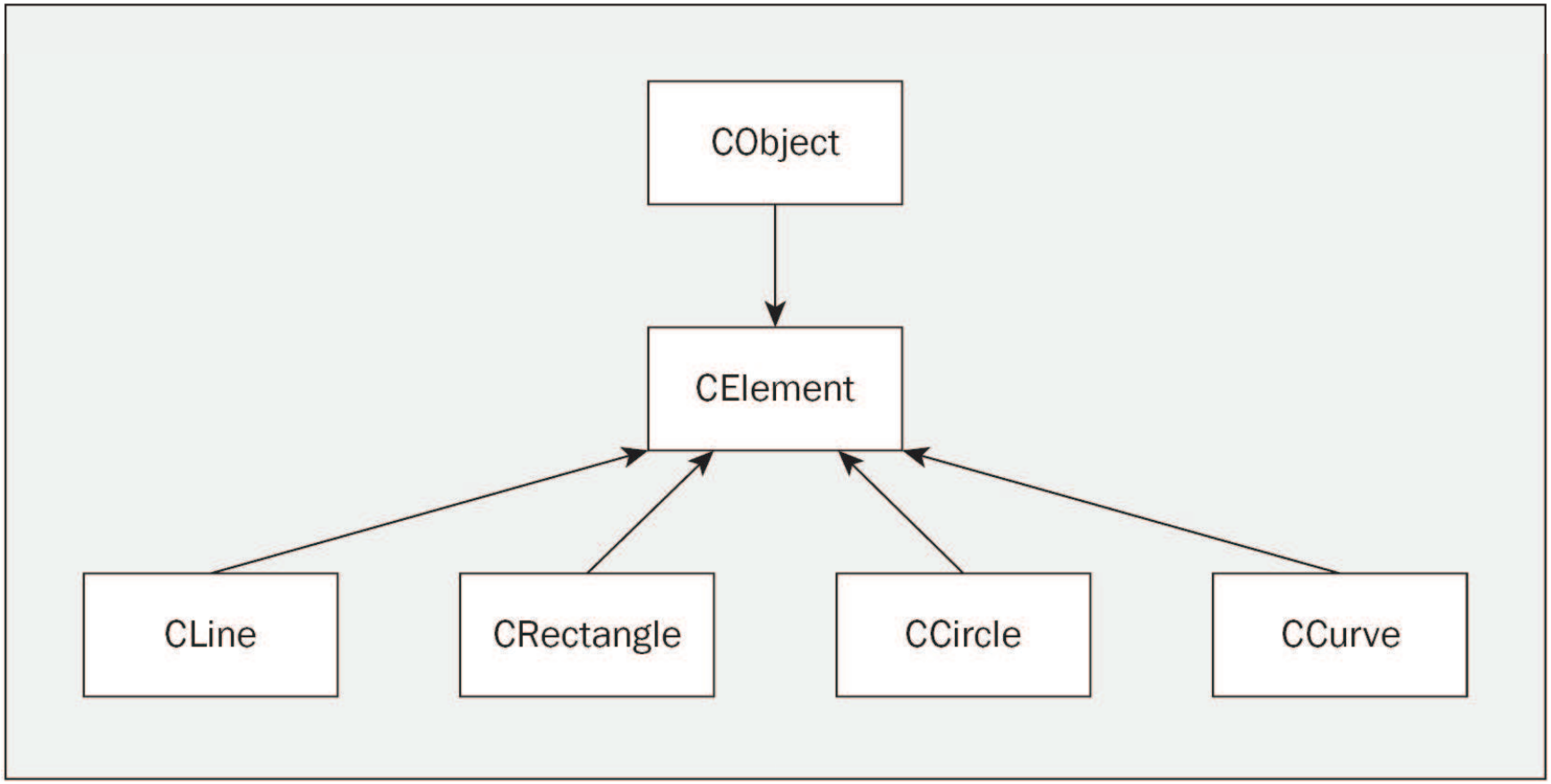


Figure 14-13

Creating the CElement Class

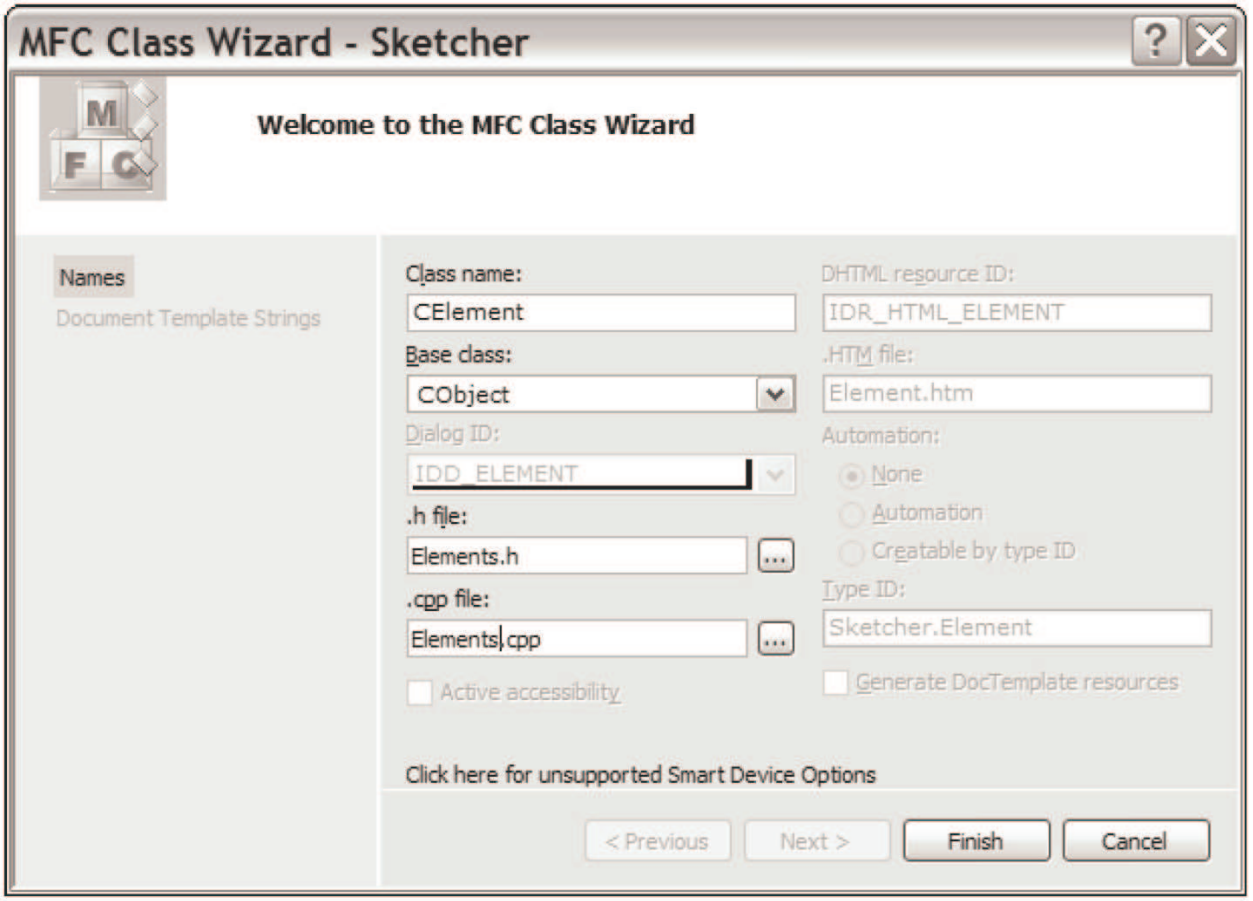
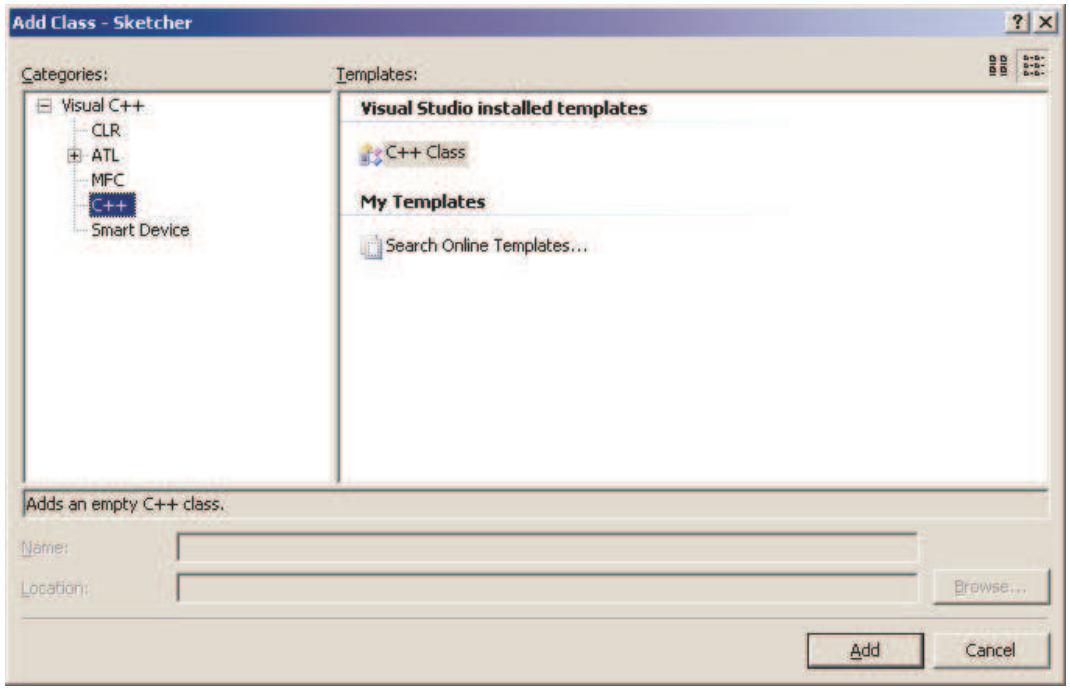


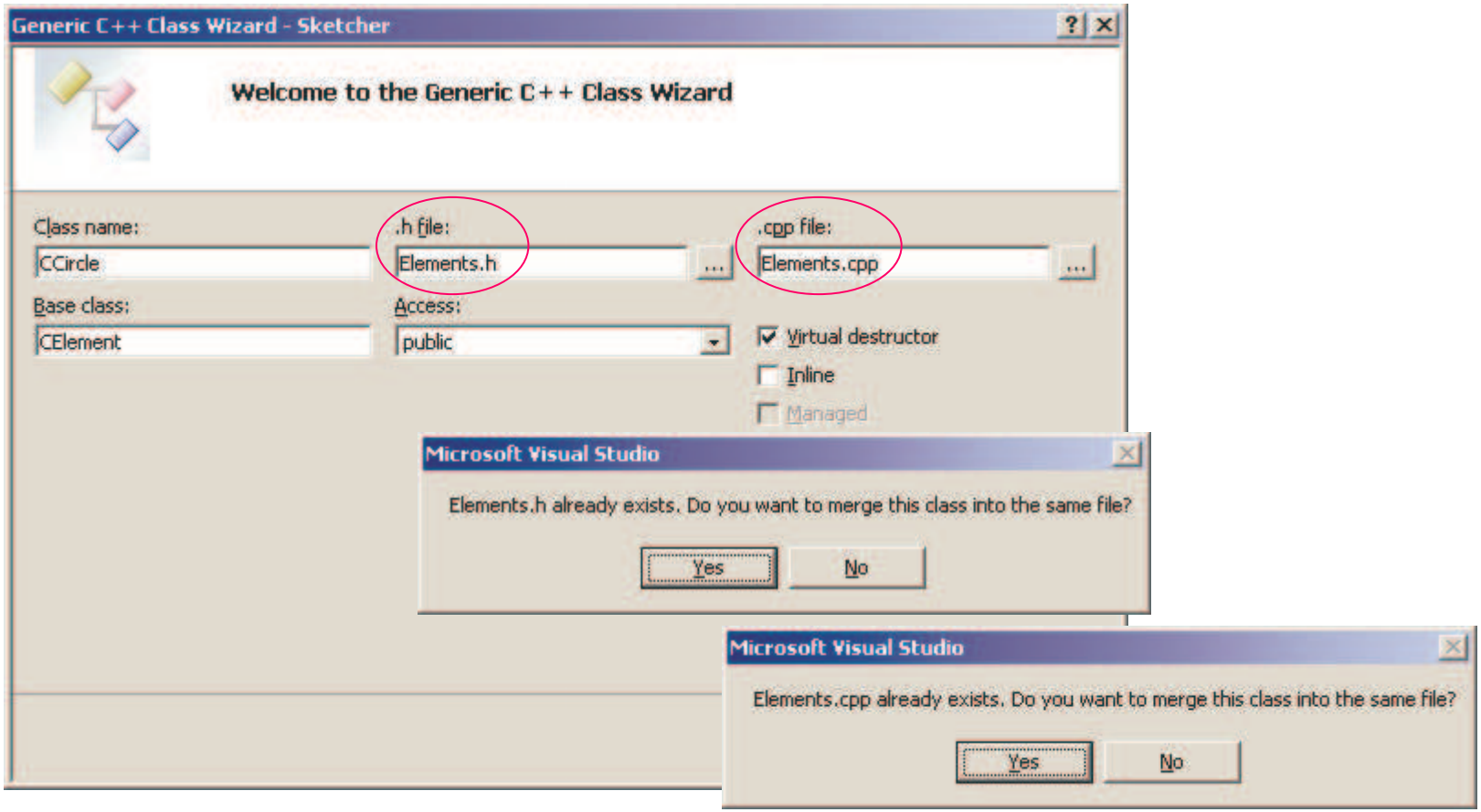
Figure 14-14

Creating the CCircle Class

- Create element classes using CElement as the base class
  - Choose the class category to be C++
  - Choose the template as C++ class

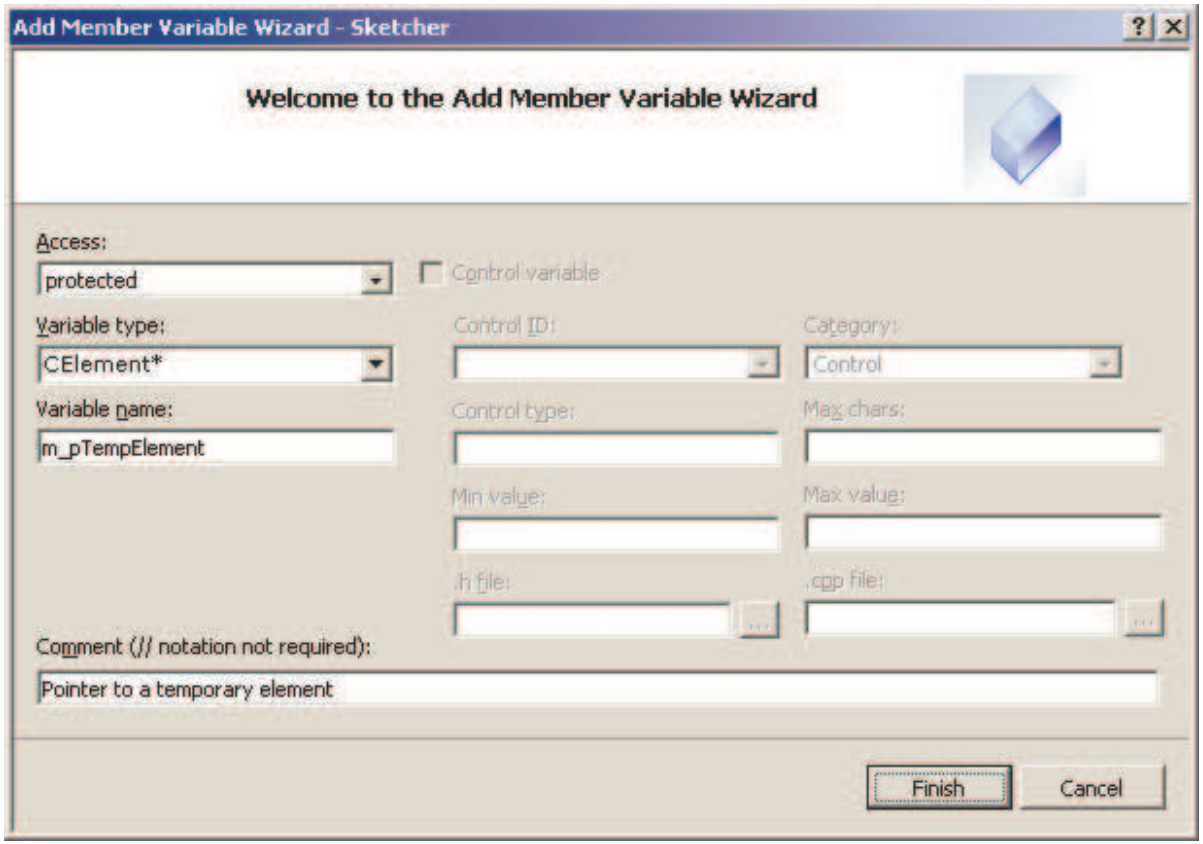


- Create CLine, CRectangle, CCircle, CCurve



Storing a Temporary Element in the View

- In the view class, add a pointer to a CElement
  - Right-click the CSketcherView class
  - Add > Add Variable



- The Add Member Variable Wizard adds some code to initialized the new variable.
  - NULL fits nicely for us!

```
CSketcherView::CSketcherView()
: m_FirstPoint(CPoint(0,0))
, m_SecondPoint(CPoint(0,0))
, m_pTempElement(NULL)
{
  // TODO: add construction code here

}
```

Check SketcherView.h

- At the beginning, there is a line:
  - `#include “atltypes.h”`
    - The wizard assumed the CElement type is an ATL (Active Template Library) type.
- Delete this line and add the following statement:
  - `class CElement;`
    - Forward class declaration

SketcherView.cpp

- `#include “Elements.h”`
  - before `#include SketcherView.h`

- Ensure that the definition of the CElement class is included before the CSketcherView class definition.

The CElement Class

```
class CElement : public CObject
{
protected:
   COLORREF m_Color;              // Color of an element
   CElement();

public:
   virtual ~CElement();
   virtual void Draw(CDC* pDC) {}
       // Virtula draw operation

   CRect GetBoundRect();
       // Get the bounding rectangle for an element
};
```

The constructor is changed from public to protected.

The CLine Class

```
class CLine : public CElement
{
protected:
   CLine(void);      // Default constructor (should not be
   used)
   CPoint m_StartPoint;
   CPoint m_EndPoint;

public:
   ~CLine(void);
   virtual void Draw(CDC* pDC); // Function to display a
   line

   // Constructor for a line object
   CLine(CPoint Start, CPoint End, COLORREF aColor);
};
```

Implementation of the CLine Constructor

```
CLine::CLine(CPoint Start, CPoint End,
  COLORREF aColor)
{
  m_StartPoint = Start;
  m_EndPoint = End;
  m_Color = aColor;
}
```

Drawing a Line

```
// Draw a CLine object
void CLine::Draw(CDC* pDC)
{
   // Create a pen for this object and
   // initialize it to the object color and line width of 1 pixel
   CPen aPen;
   if(!aPen.CreatePen(PS_SOLID, m_Pen, m_Color))
   {
      // Pen creation failed. Abort the program
      AfxMessageBox(_T("Pen creation failed drawing a line"), MB_OK);
      AfxAbort();
   }

   CPen* pOldPen = pDC->SelectObject(&aPen);  // Select the pen

   // Now draw the line
   pDC->MoveTo(m_StartPoint);
   pDC->LineTo(m_EndPoint);

   pDC->SelectObject(pOldPen);                // Restore the old pen
}
```

Pen Width (set in P.740)

defined in CElement

If the pen cannot be created, display a message box and abort the program.

Bounding Rectangles

- Not exactly coincide with the enclosing rectangles which are used to draw the elements.
- Thickness must be taken into account.

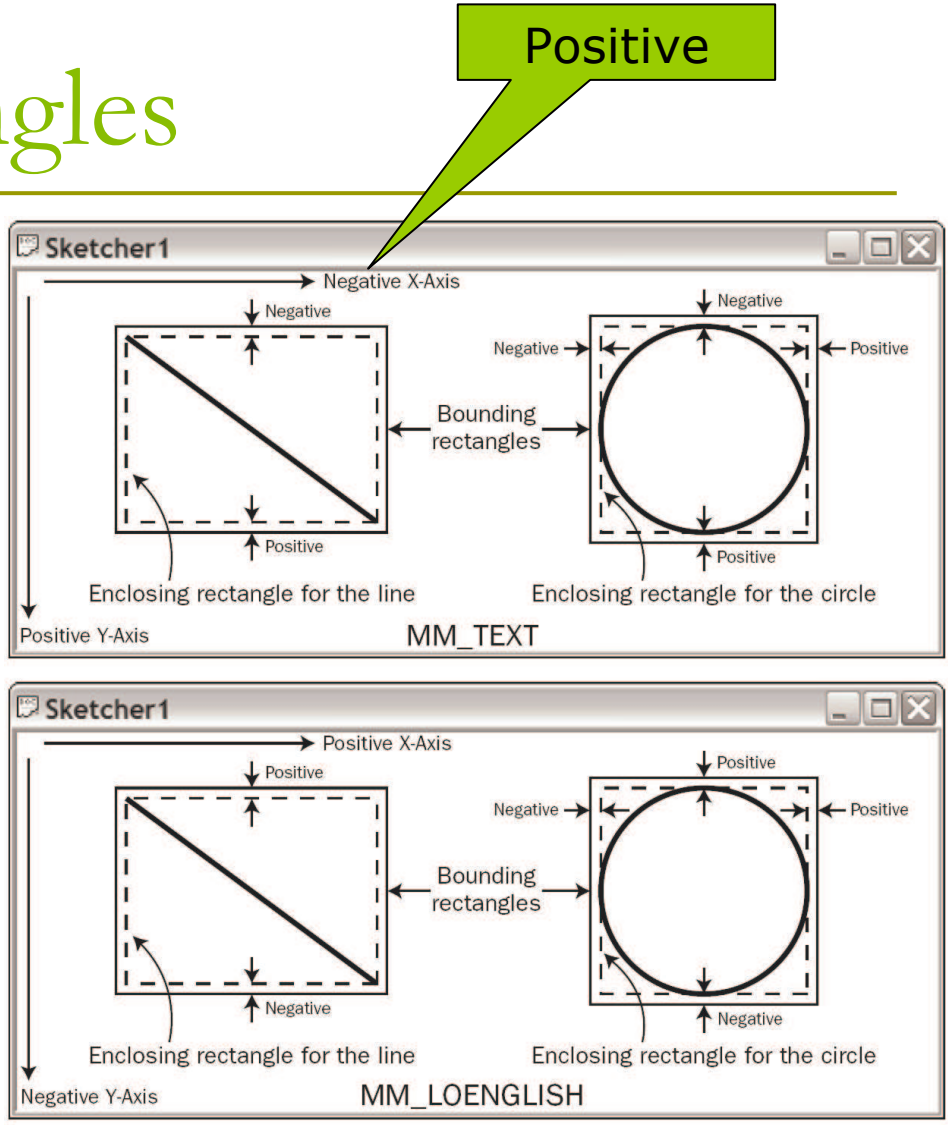


Figure 14-17

Modify the CElement Class Definition

```
class CElement : public CObject
{
protected:
    COLORREF m_Color;           // Color of an element
    CRect m_EnclosingRect;      // Rectangle enclosing an element
    int m_Pen;                  // Pen width

   CElement();

public:
   virtual ~CElement();
   virtual void Draw(CDC* pDC) {}     // Virtula draw operation

   CRect GetBoundRect();
        // Get the bounding rectangle for an element
};
```

Update the CLine Constructor

```
CLine::CLine(CPoint Start, CPoint End,
  COLORREF aColor)
{
  m_StartPoint = Start;
  m_EndPoint = End;
  m_Color = aColor;
  m_Pen = 1;
}
```

GetBoundRect()

- Assuming the MM_TEXT mapping mode:

```
// Get the bounding rectangle for an element
CRect CElement::GetBoundRect()
{
   CRect BoundingRect;
         // Object to store bounding rectangle
   BoundingRect = m_EnclosingRect;
          // Store the enclosing rectangle

   // Increase the rectangle by the pen width
   BoundingRect.InflateRect(m_Pen, m_Pen);
   return BoundingRect;
          // Return the bounding rectangle
}
```

Enlarge the Enclosing Rectangle by the Pen Width

- `BoundingRect.InflateRect(m_Pen, m_Pen);`
- `BoundingRect = m_EnclosingRect + CRect(m_Pen, m_Pen, m_Pen, m_Pen);`
- `BoundingRect = m_EnclosingRect;`
- `BoundingRect.top -= m_Pen;`
- `BoundingRect.left -= m_Pen;`
- `BoundingRect.bottom += m_Pen;`
- `BoundingRect.right += m_Pen;`

Calculating the Enclosing Rectangle for a Line

```
CLine::CLine(CPoint Start, CPoint End,
  COLORREF aColor)
{
  m_StartPoint = Start;
  m_EndPoint = End;
  m_Color = aColor;
  m_Pen = 1;

  // Define the enclosing rectangle
  m_EnclosingRect = CRect(Start, End);
}
```

The CRectangle Class

```
class CRectangle :
   public CElement
{
public:
   ~CRectangle(void);
   virtual void Draw(CDC* pDC);
       // Function to display a rectangle

       // Constructor for a rectangle object
  CRectangle(CPoint Start, CPoint End, COLORREF aColor);

protected:
  CRectangle(void);
        // Default constructor - should not be used
};
```

The CRectangle Class Constructor

- Similar to that for a CLine constructor

```
// CRectangle class constructor
CRectangle:: CRectangle(CPoint Start, CPoint End,
  COLORREF aColor)
{
   m_Color = aColor;       // Set rectangle color
   m_Pen = 1;              // Set pen width

   // Define the enclosing rectangle
   m_EnclosingRect = CRect(Start, End);
}
```

Drawing a Rectangle

```
void CRectangle::Draw(CDC* pDC)
{
   // Create a pen for this object and
   // initialize it to the object color and line width of 1 pixel
   CPen aPen;
   if(!aPen.CreatePen(PS_SOLID, m_Pen, m_Color))
   {
      // Pen creation failed
      AfxMessageBox(_T("Pen creation failed drawing a rectangle"), MB_OK);
      AfxAbort();
   }

   // Select the pen
    CPen* pOldPen = pDC->SelectObject(&aPen);
   // Select the brush
   CBrush* pOldBrush = (CBrush*)pDC->SelectStockObject(NULL_BRUSH);

   // Now draw the rectangle
   pDC->Rectangle(m_EnclosingRect);

   pDC->SelectObject(pOldBrush);       // Restore the old brush
   pDC->SelectObject(pOldPen);         // Restore the old pen
}
```

The CCircle Class

- Similar to the CRectangle class

```
class CCircle :  public CElement
{
public:
  ~CCircle(void);
    virtual void Draw(CDC* pDC);
     // Function to display a circle

    // Constructor for a circle object
    CCircle(CPoint Start, CPoint End, COLORREF aColor);

protected:
    CCircle(void);
    // Default constructor - should not be used
};
```

Implementing the CCircle Class

- The point you press the left mouse button is the center
- The point you release the left mouse button is a point on the circumference.
- We need to design the constructor to convert this to the enclosing rectangle of a circle.

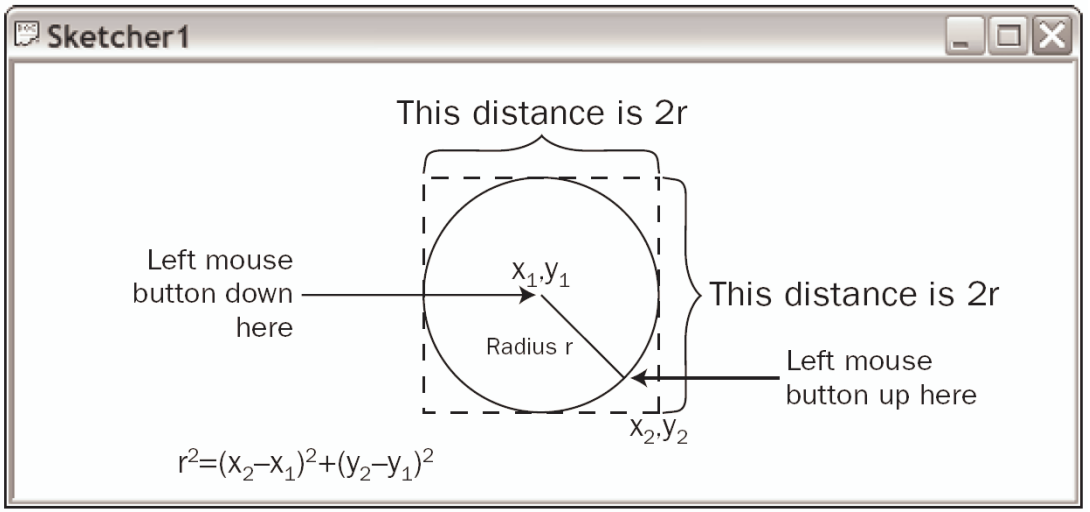


Figure 14-18

The CCircle Class Constructor

#include <math.h> in Elements.cpp

```
CCircle::CCircle(CPoint Start, CPoint End, COLORREF aColor)
{
   // First calculate the radius
   // We use floating point because that is required by the
   // library function (in math.h) for calculating a square root.
   long Radius = static_cast<long> (sqrt(
           static_cast<double>((End.x-Start.x)*(End.x-Start.x)+
                               (End.y-Start.y)*(End.y-Start.y))));

   // Now calculate the rectangle enclosing
   // the circle assuming the MM_TEXT mapping mode
   m_EnclosingRect = CRect(Start.x-Radius, Start.y-Radius,
                           Start.x+Radius, Start.y+Radius);

   m_Color = aColor;           // Set the color for the circle
   m_Pen = 1;                  // Set pen width to 1
}
```

Drawing a Circle

```
void CCircle::Draw(CDC* pDC)
{
   // Create a pen for this object and
   // initialize it to the object color and line width of 1 pixel
   CPen aPen;
   if(!aPen.CreatePen(PS_SOLID, m_Pen, m_Color))
   {
      // Pen creation failed
      AfxMessageBox(_T("Pen creation failed drawing a circle"), MB_OK);
      AfxAbort();
   }

   CPen* pOldPen = pDC->SelectObject(&aPen);  // Select the pen

   // Select a null brush
    CBrush* pOldBrush = (CBrush*)pDC->SelectStockObject(NULL_BRUSH);

   // Now draw the circle
   pDC->Ellipse(m_EnclosingRect);

   pDC->SelectObject(pOldPen);                  // Restore the old pen
   pDC->SelectObject(pOldBrush);                // Restore the old brush
}
```

Setting the Drawing Mode

- SetROP2()
  - **Set R**aster **OP**eration **to**
- R2_BLACK
  - All drawing is in black
- R2_WHITE
  - All drawing is in white
- R2_NOP
  - Drawing operations do nothing
- R2_COPYPEN
  - Drawing is in the pen color. This is the default.
- R2_XORPEN
  - Drawing is in the color produced by exclusive ORing the pen color and the background color.
- R2_NOTXORPEN
  - Drawing is in the color that is the inverse of the R2_XORPEN color.

R2_NOTXORPEN

- If you draw the same shape again, the shape disappears.

	R	G	B
Background – white	1	1	1
Pen – red	1	0	0
XORed	0	1	1
NOT XOR – produces red	1	0	0

	R	G	B
Background – red	1	0	0
Pen – red	1	0	0
XORed	0	0	0
NOT XOR – produces white	1	1	1

Coding the OnMouseMove() Handler

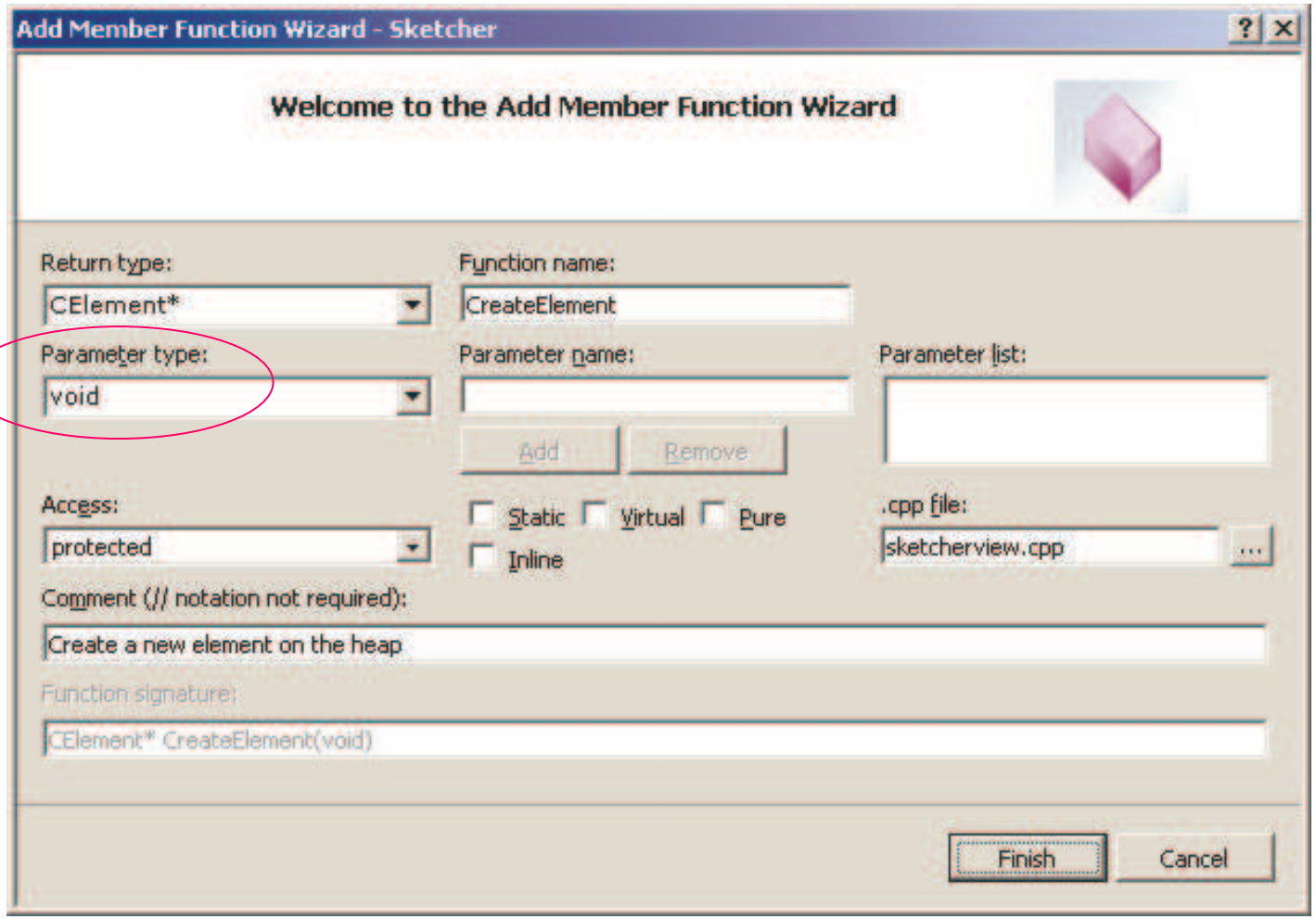
- Using the CClientDC class rather than CDC
  - It automatically destroys the device context when you are done.

```
void CSketcherView::OnMouseMove(UINT nFlags, CPoint point)
{  // Define a Device Context object for the view
   CClientDC aDC(this);                  // DC is for this view
   aDC.SetROP2(R2_NOTXORPEN);            // Set the drawing mode
   if((nFlags & MK_LBUTTON) && (this == GetCapture()))
   {  m_SecondPoint = point;
      if(m_pTempElement)
      {  // Redraw the old element so it disappears from the view
         m_pTempElement->Draw(&aDC);
         delete m_pTempElement;          // Delete the old element
         m_pTempElement = 0;             // Reset the pointer to 0
      }
      // Create a temporary element of the type and color that
      // is recorded in the document object, and draw it
      m_pTempElement = CreateElement();// Create a new element
      m_pTempElement->Draw(&aDC);        // Draw the element
   }
}
```

defined in CSketcherView (P.735)

will be defined on P.751

CreateElement()



Implementing CreateElement()

```
CElement* CSketcherView::CreateElement(void)
{  // Get a pointer to the document for this view
   CSketcherDoc* pDoc = GetDocument();

   // Now select the element using the type stored in the document
   switch(pDoc->GetElementType())
   {
      case RECTANGLE:
         return new CRectangle(m_FirstPoint, m_SecondPoint,
                 pDoc->GetElementColor());

      case CIRCLE:
         return new CCircle(m_FirstPoint, m_SecondPoint,
                 pDoc->GetElementColor());

      case LINE:
         return new CLine(m_FirstPoint, m_SecondPoint,
                 pDoc->GetElementColor());

      default:
         // Something's gone wrong
         AfxMessageBox(_T("Bad Element code"), MB_OK);
        AfxAbort();
         return NULL;
   }
}
```

will be defined on P.753

GetElementType()

```
class CSketcherDoc : public CDocument
{
   // Rest of the class definition as before …

// Operations
public:
       // Get the element type
      unsigned int GetElementType() { return m_Element; }

       // Get the element color
      COLORREF GetElementColor() { return m_Color; }

   // Rest of the class definition as before

};
```