23

GUI with Windows Presentation Foundation

Objectives

In this chapter you'll:

- Define a WPF GUI with Extensible Application Markup Language (XAML).
- Handle WPF user-interface events.
- Use WPF's commands feature to handle common tasks such as cut, copy and paste.
- Customize the look-and-feel of WPF GUIs using styles and control templates.
- Use data binding to display data in WPF controls.

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23.1 Introduction

Microsoft has three active GUI technologies—Windows Forms, Windows Presentation Foundation (WPF) and the Universal Windows Platform (UWP). In Chapters 14–15, you built GUIs using Windows `Forms`. In this chapter, you'll build GUIs using **Windows Presentation Foundation** (**WPF**), which—unlike Windows `Forms`—is completely customizable. In Chapter 24, WPF Graphics and Multimedia, you'll learn how to incorporate 2D graphics, 3D graphics, animation, audio and video in WPF apps. Microsoft's current and future direction is the Universal Windows Platform (UWP), which is designed to provide a common platform and user experience across all Windows devices, including personal computers, smartphones, tablets, Xbox and even Microsoft's new HoloLens virtual reality and augmented reality holographic headset—all using nearly identical code. We're moving to UWP as well and will provide two online UWP chapters. For that reason, we've included our WPF chapters *as is* from this book's previous edition and we will no longer be updating our WPF treatment.

We begin with an introduction to WPF. Next, we discuss an important tool for creating WPF apps called **XAML** (pronounced "zammel")—**Extensible Application Markup Language**. XAML is an XML vocabulary for defining and arranging GUI controls without any C# code. Because XAML is an XML vocabulary, you should understand the basics of XML before learning XAML and WPF. We introduce XML in Sections 22.2–22.4.

Section 23.3 demonstrates how to define a WPF GUI with XAML. Sections 23.4–23.7 demonstrate the basics of creating a WPF GUI—layout, controls and events. You'll also learn capabilities of WPF controls and event handling that are different from those in Windows `Forms`. WPF allows you to easily customize the look-and-feel of a GUI beyond what is possible in Windows `Forms`. Sections 23.8–23.11 demonstrate several techniques for manipulating the appearance of your GUIs. WPF also allows you to create data-driven GUIs that interact with many types of data. We demonstrate this in Section 23.12.

23.2 Windows Presentation Foundation (WPF)

Before WPF, you often had to use multiple technologies to build client apps. If a Windows `Forms` app required video and audio capabilities, you needed to incorporate an additional technology such as Windows Media Player. Likewise, if your app required 3D graphics capabilities, you had to incorporate a separate technology such as Direct3D. WPF provides a single platform capable of handling both of these requirements, and more. It enables you to use one technology to build apps containing GUI, images, animation, 2D or 3D graphics, audio and video capabilities. In this chapter and Chapter 24, we demonstrate each of these capabilities.

WPF can interoperate with existing technologies. For example, you can include WPF controls in Windows `Forms` apps to incorporate multimedia content (such as audio or video) without converting the entire app to WPF, which could be a costly and time-consuming process. You also can use Windows `Forms` controls in WPF apps.

WPF can use your computer's graphics hardware acceleration capabilities to increase your apps' performance. In addition, WPF generates **vector-based graphics** and is **resolution independent**. Vector-based graphics are defined not by a grid of pixels as **raster-based graphics** are, but rather by mathematical models. An advantage of vector-based graphics is that when you change the resolution, there's no loss of quality. Hence, the graphics become portable to a great variety of devices. Moreover, your apps won't appear smaller on higher-resolution screens. Instead, they'll remain the same size and display sharper. Chapter 24 presents more information about vector-based graphics and resolution independence.

Building a GUI with WPF is similar to building a GUI with Windows `Forms`—you drag-and-drop predefined controls from the **Toolbox** onto the design area. Many WPF controls correspond directly to those in Windows `Forms`. Just as in a Windows `Forms` app, the functionality is event driven. Many of the Windows `Forms` events you're familiar with are also in WPF. A WPF `Button`, for example, is similar to a Windows `Forms` `Button`, and both raise `Click` events.

There are several important differences between the two technologies, though. The WPF layout scheme is different. WPF properties and events have more capabilities. Most notably, WPF allows designers to define the appearance and content of a GUI without any C# code by defining it in XAML, a descriptive **markup** language (that is, a text-based notation for describing something).

Introduction to XAML

In Windows `Forms`, when you use the designer to create a GUI, the IDE generates code statements that create and configure the controls. In WPF, it generates XAML markup. Because XML is designed to be readable by both humans and computers, you also can manually write XAML markup to define GUI controls. When you compile your WPF app, a XAML compiler generates code to create and configure controls based on your XAML markup. This technique of defining *what* the GUI should contain without specifying *how* to generate it is an example of **declarative programming**.

XAML allows designers and programmers to work together more efficiently. Without writing any code, a graphic designer can edit the look-and-feel of an app using a design tool, such as Microsoft's **Blend for Visual Studio**—a XAML graphic design program that's installed with Visual Studio Community edition. A programmer can import the XAML markup into Visual Studio and focus on coding the logic that gives an app its functionality. Even if you're working alone, however, this separation of front-end appearance from back-end logic improves your program's organization and makes it easier to maintain. XAML is an essential component of WPF programming.

23.3 Declarative GUI Programming Using XAML

A XAML document defines the appearance of a WPF app. Figure 23.1 is a simple XAML document that defines a window that displays `Welcome to WPF!` A XAML document consists of many nested elements, delimited by start tags and end tags. As with any other XML document, each XAML document must contain a single root element. Just as in XML, data is placed as nested content or in attributes.

```
 1  <!-- Fig. 23.1: MainWindow.xaml -->
 2  <!-- A simple XAML document. -->
 3
 4  <!-- the Window control is the root element of the GUI -->
 5  <Window x:Class="XAMLIntroduction.MainWindow"
 6     xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
 7     xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
 8     Title="A Simple Window" Height="150" Width="250">
 9
10     <!-- a layout container -->
11     <Grid Background="Gold">
12        <!-- a Label control -->
13        <Label Content="Welcome to WPF!" HorizontalAlignment="Center"
14           VerticalAlignment="Center"/>
15     </Grid>
16  </Window>
```

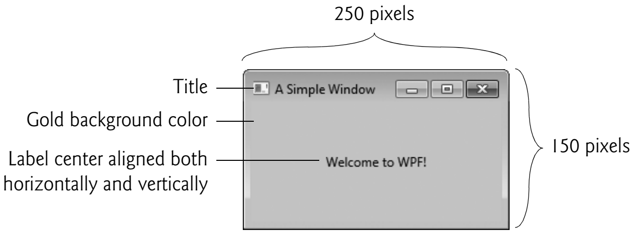


Fig. 23.1 | A simple XAML document.

Presentation XAML Namespace and Standard XAML Namespace

Two standard namespaces must be defined in every XAML document so that the XAML compiler can interpret your markup—the **presentation XAML namespace**, which defines WPF-specific elements and attributes, and the **standard XAML namespace**, which defines elements and attributes that are standard to all types of XAML documents. Usually, the presentation XAML namespace (`http://schemas.microsoft.com/winfx/2006/xaml/presentation`) is defined as the default namespace (line 6), and the standard XAML namespace (`http://schemas.microsoft.com/winfx/2006/xaml`) is mapped to the namespace prefix `x` (line 7). These are both automatically included in the `Window` element's start tag when you create a WPF app.

`Window` Control

WPF **controls** are represented by XAML elements. The root element of the XAML document in Fig. 23.1 is a **`Window`** control (lines 5–16), which defines the app's window—this corresponds to a `Form` in Windows `Forms`. The `Window` start tag **`x:Class`** attribute (line 5) specifies the name of the associated *code-behind* class that provides the GUI's functionality. The `x:` signifies that the `Class` attribute is located in the standard XAML namespace. A XAML document must have an associated code-behind file to handle events.

Using attributes, you can define a control's properties in XAML. For example, the `Window`'s `Title`, `Width` and `Height` properties are set in line 8. A `Window`'s `Title` specifies the text that's displayed in the title bar. The `Width` and `Height` properties specify a control's width and height, respectively, using machine-independent pixels.

Content Controls

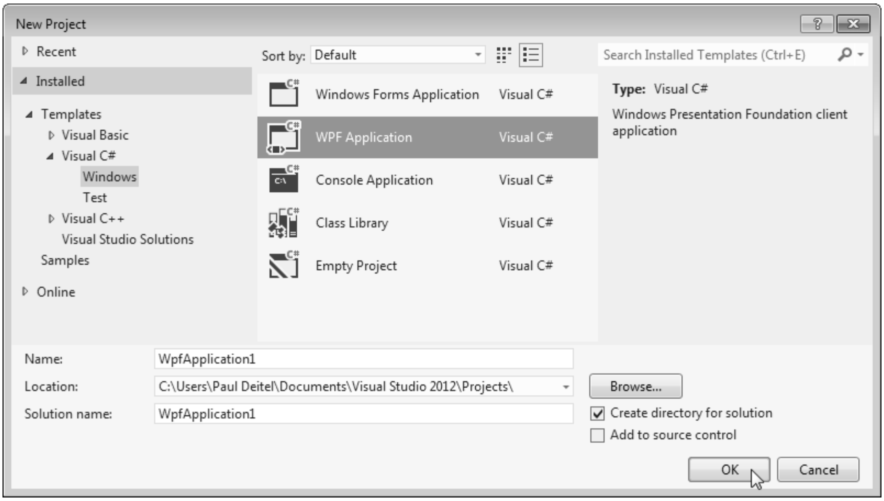
`Window` is a **content control** (a control derived from class **`ContentControl`**), meaning it can have exactly one child element or text content. You'll almost always set a **layout container** (a control derived from the **`Panel`** class) as the child element so that you can host multiple controls in a `Window`. A layout container such as a `Grid` (lines 11–15) can have many child elements, allowing it to contain many controls. In Section 23.5, you'll use content controls and layout containers to arrange a GUI.

`Label` Control

Like `Window`, a **`Label`** (lines 13–14) is also a `ContentControl`. `Label`s are generally used to display text.

23.4 Creating a WPF App

To create a new WPF app, select **File > New > Project...** to display the **New Project** dialog (Fig. 23.2) and select **WPF Application** from the list of template types under **Visual C# > Windows**. Specify a name and location for your app, then click **OK** to create the project. The IDE for a WPF app looks nearly identical to that of a Windows `Forms` app. You'll recognize the familiar **Toolbox**, **Design** view, **Solution Explorer** and **Properties** window.



Sort by: Default

Type: Visual C#

Windows Presentation Foundation client application

Name: WpfApplication1

Location: C:\Users\Paul Deitel\Documents\Visual Studio 2012\Projects\

Solution name: WpfApplication1

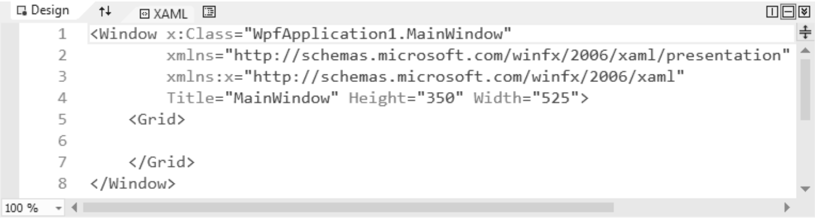
☑ Create directory for solution

☐ Add to source control

Fig. 23.2 | **New Project** dialog.

XAML View[1]

There are differences in the IDE, however. One is the new **XAML view** (Fig. 23.3) that appears below the design area when you open a XAML document that represents a window. The **XAML** view is linked to the **Design** view and the **Properties** window. When you edit content in the **Design** view, the **XAML** view automatically updates, and vice versa. Likewise, when you edit properties in the **Properties** window, the **XAML** view automatically updates, and vice versa.



```
<Window x:Class="WpfApplication1.MainWindow"
        xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
        xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
        Title="MainWindow" Height="350" Width="525">
    <Grid>

    </Grid>
</Window>
```

Fig. 23.3 | **XAML** view.

Generated Files

When you create a WPF app, several files are generated and can be viewed in the **Solution Explorer**. **`App.xaml`** defines the `Application` object and its settings. The most noteworthy setting is the `Application` element's **`StartupUri`** attribute, which defines the XAML document that executes first when the app loads (`MainWindow.xaml` by default). **`App.xaml.cs`** contains `App.xaml`'s code-behind class and handles application-level events. `MainWindow.xaml` defines the app's window, and `MainWindow.xaml.cs` contains its code-behind class, which handles the window's events. The file name of the code-behind class is always the file name of the associated XAML document followed by the `.cs` file-name extension.

Setting XAML Indent Size and Displaying Line Numbers

We use three-space indents in our code. To ensure that your code appears the same as the book's examples, change the tab spacing for XAML documents to three spaces (the default is four). Select **Tools > Options…** to display the **Options** dialog, then in **Text Editor > XAML > Tabs** change the **Tab size** and **Indent size** to 3. You should also configure the **XAML** editor to display line numbers by checking the **Line numbers** checkbox in **Text Editor > XAML > General**.

GUI Design

Creating a WPF app is similar to creating a Windows `Forms` app. You can drag-and-drop controls onto the **Design** view of your WPF GUI. A control's properties can be edited in the **Properties** window. Because XAML is easy to understand and edit, some programmers manually edit their GUIs' XAML markup directly rather than doing everything through the IDE's drag-and-drop GUI designer and **Properties** window.

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[1] Visual-Studio-generated XAML can vary between editions—elements may appear in a different order from what we show or with additional items that we do not discuss.

23.5 Laying Out Controls

In Windows `Forms`, a control's size and location are specified explicitly. In WPF, a control's size should be specified as a *range* of possible values rather than fixed values, and its location specified *relative* to those of other controls. This scheme, in which you specify how controls share the available space, is called **flow-based layout**. Its advantage is that it enables your GUIs, if designed properly, to be aesthetically pleasing, no matter how a user might *resize* the app. Likewise, it enables your GUIs to be resolution independent.

23.5.1 General Layout Principles

Layout refers to the *size* and *positioning* of controls. The WPF layout scheme addresses both of these in a flow-based fashion and can be summarized by two fundamental principles with regard to a control's size and position.

Size of a Control

Unless necessary, a control's size should *not* be defined *explicitly*. Doing so often creates a design that looks pleasing when it first loads, but deteriorates when the app is resized or the content updates. In addition to the `Width` and `Height` properties associated with every control, all WPF controls have the **`MinWidth`**, **`MinHeight`**, **`MaxHeight`** and **`MaxWidth`** properties. If the `Width` and `Height` properties are both `Auto` (which is the default when they are not specified in the XAML code), you can use `MinWidth`, `MinHeight`, `MaxWidth` and `MaxHeight` to specify a *range* of acceptable sizes for a control as it's resized with its container.

Position of a Control

A control's position should *not* be defined in absolute terms. Instead, it should be specified based on its position *relative* to the layout container in which it's included and the other controls in the same container. All controls have three properties for this purpose—`Margin`, `HorizontalAlignment` and `VerticalAlignment`. **`Margin`** specifies how much space to put around a control's edges. The value of `Margin` is a comma-separated list of four integers, representing the left, top, right and bottom margins. Additionally, you can specify two integers—the first represents the value for the left and right margins and the second for the top and bottom margins. If you specify just one integer, it uses the same margin on all four sides.

`HorizontalAlignment` and **`VerticalAlignment`** specify how to align a control within its layout container. Valid options of `HorizontalAlignment` are `Left`, `Center`, `Right` and `Stretch`. Valid options of `VerticalAlignment` are `Top`, `Center`, `Bottom` and `Stretch`. `Stretch` means that the object will occupy as much space as possible.

Other Layout Properties

A control can have other layout properties specific to the layout container in which it's contained. We'll discuss these as we examine the specific layout containers. WPF provides many controls for laying out a GUI. Figure 23.4 lists several of them.

Control	Description
Layout containers (derived from `Panel`*)*	
`Grid`	Layout is defined by a *grid of rows and columns*, depending on the `RowDefinitions` and `ColumnDefinitions` properties. Elements are placed into *cells*.
`Canvas`	Layout is *coordinate based*. Element positions are defined explicitly by their distance from the *top* and *left* edges of the `Canvas`.
`StackPanel`	Elements are arranged in a *single row or column*, depending on the `Orientation` property.
`DockPanel`	Elements are positioned based on which edge they're *docked* to. If the `LastChildFill` property is `True`, the last element gets the remaining space in the middle.
`WrapPanel`	A wrapping `StackPanel`. Elements are arranged *sequentially in rows or columns* (depending on the `Orientation`), each row or column wrapping to start a new one when it reaches the `WrapPanel`'s right or bottom edge, respectively.
Content controls (derived from `ContentControl`*)*	
`Border`	Adds a background or a border to the child element.
`GroupBox`	Surrounds the child element with a titled box.
`Window`	The app's window. Also the root element.
`Expander`	Puts the child element in a titled area that collapses to display just the header and expands to display the header and the content.

Fig. 23.4 | Common controls used for layout.

23.5.2 Layout in Action

Figure 23.5 shows the XAML document and the GUI display of a painter app. Note the use of `Margin`, `HorizontalAlignment` and `VerticalAlignment` throughout the markup. This example introduces several WPF controls that are commonly used for layout, as well as a few other basic controls like `Buttons` and `RadioButtons`.

```
<!-- Fig. 23.5: MainWindow.xaml -->
<!-- XAML of a painter app. -->
<Window x:Class="Painter.MainWindow"
   xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
   xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
   Title="Painter" Height="340" Width="350" Background="Beige">

   <!-- creates a Grid -->
   <Grid>
      <Grid.ColumnDefinitions>
         <ColumnDefinition Width="Auto" /> <!-- defines a column -->
         <ColumnDefinition Width="*" />
      </Grid.ColumnDefinitions>
```

Fig. 23.5 | XAML of a painter app. (Part 1 of 3.)

```

      <!-- creates a Canvas -->
      <Canvas x:Name="paintCanvas" Grid.Column="1" Background="White"
         Margin="0" MouseMove="paintCanvas_MouseMove"
         MouseLeftButtonDown="paintCanvas_MouseLeftButtonDown"
         MouseLeftButtonUp="paintCanvas_MouseLeftButtonUp"
         MouseRightButtonDown="paintCanvas_MouseRightButtonDown"
         MouseRightButtonUp="paintCanvas_MouseRightButtonUp" />

      <!-- creates a StackPanel-->
      <StackPanel Margin="3">
         <!-- creates a GroupBox for color options -->
         <GroupBox Header="Color" Margin="3">
            <StackPanel Margin="3" HorizontalAlignment="Left"
               VerticalAlignment="Top">

               <!-- creates RadioButtons for selecting color -->
               <RadioButton x:Name="redRadioButton" Content="Red"
                  Margin="3" Checked="redRadioButton_Checked" />
               <RadioButton x:Name="blueRadioButton" Content="Blue"
                  Margin="3" Checked="blueRadioButton_Checked" />
               <RadioButton x:Name="greenRadioButton" Content="Green"
                  Margin="3" Checked="greenRadioButton_Checked" />
               <RadioButton x:Name="blackRadioButton" Content="Black"
                  IsChecked="True" Margin="3"
                  Checked="blackRadioButton_Checked" />
            </StackPanel>
         </GroupBox>

         <!-- creates GroupBox for size options -->
         <GroupBox Header="Size" Margin="3">
            <StackPanel Margin="3" HorizontalAlignment="Left"
               VerticalAlignment="Top">
               <RadioButton x:Name="smallRadioButton" Content="Small"
                  Margin="3" Checked="smallRadioButton_Checked" />
               <RadioButton x:Name="mediumRadioButton" IsChecked="True"
                  Checked="mediumRadioButton_Checked" Content="Medium"
                  Margin="3" />
               <RadioButton x:Name="largeRadioButton" Content="Large"
                  Margin="3" Checked="largeRadioButton_Checked" />
            </StackPanel>
         </GroupBox>

         <!-- creates a Button-->
         <Button x:Name="undoButton" Content="Undo" Width="75"
            Margin="3,10,3,3" Click="undoButton_Click"/>

         <!-- creates a Button-->
         <Button x:Name="clearButton" Content="Clear" Width="75"
            Margin="3,10,3,3" Click="clearButton_Click"/>
      </StackPanel>
   </Grid>
</Window>
```

Fig. 23.5 | XAML of a painter app. (Part 2 of 3.)

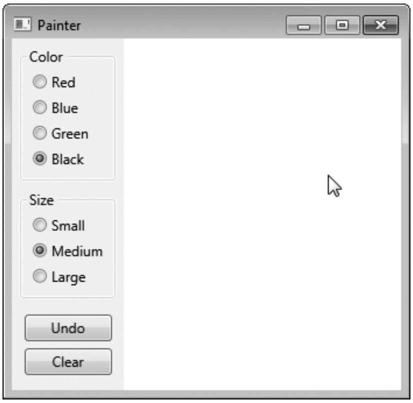


Fig. 23.5 | XAML of a painter app. (Part 3 of 3.)

This app's controls look similar to Windows `Forms` controls. WPF **`RadioButton`**s function as *mutually exclusive* options, just like their Windows `Forms` counterparts. However, a WPF `RadioButton` does not have a `Text` property. Instead, it's a `ContentControl`, meaning it can have *exactly one child* or *text content*. This makes the control more versatile, enabling it to be labeled by an image or other item. In this example, each `RadioButton` is labeled by plain text specified with the `Content` attribute (for example, lines 31, 33, 35 and 37). A WPF **`Button`** behaves like a Windows `Forms` `Button` but is a `ContentControl`. As such, a WPF `Button` can display any single element as its content, not just text. Lines 58–59 and 62–63 define the two buttons seen in the `Painter` app. You can drag and drop controls onto the WPF designer and create their event handlers, just as you do in the Windows `Forms` designer.

`GroupBox` Control

A WPF **`GroupBox`** arranges controls and displays just as a Windows `Forms` `GroupBox` would, but using one is slightly different. The **`Header`** property replaces the Windows `Forms` version's `Text` property. Also, a `GroupBox` is a `ContentControl`, so to place *multiple* controls in it, you must place them in a layout container such as a `StackPanel` (lines 27–40).

`StackPanel` Control

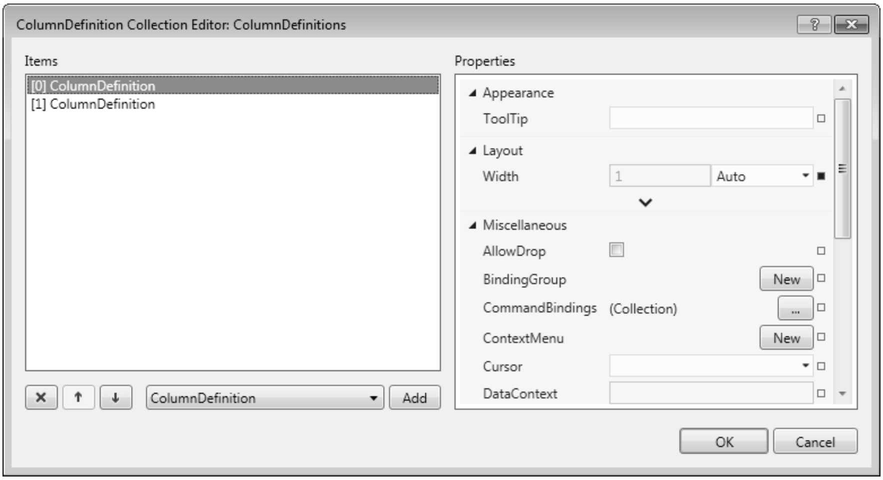
In the `Painter` app, we organized each `GroupBox`'s `RadioButtons` by placing them in **`StackPanel`**s (for example, lines 27–40). A `StackPanel` is the *simplest* of layout containers. It arranges its content either *vertically* or *horizontally*, depending on its **`Orientation`** property's setting. The default `Orientation` is `Vertical`, which is used by every `StackPanel` in the `Painter` example.

`Grid` Control

The `Painter` `Window`'s contents are contained within a **`Grid`**—a flexible, all-purpose layout container. A `Grid` organizes controls into a user-defined number of *rows* and *columns* (one row and one column by default). You can define a `Grid`'s rows and columns by setting its **`RowDefinitions`** and **`ColumnDefinitions`** properties, whose values are a collection of **`RowDefinition`** and **`ColumnDefinition`** objects, respectively. Because these properties do not take `string` values, they cannot be specified as attributes in the `Grid` tag. Another syntax is used instead. A class's property can be defined in XAML as a *nested* element with the name *ClassName.PropertyName*. For example, the `Grid.ColumnDefinitions` element in lines 10–13 sets the `Grid`'s `ColumnDefinitions` property and defines two columns, which separate the options from the painting area, as shown in Fig. 23.5.

You can specify the `Width` of a `ColumnDefinition` and the `Height` of a `RowDefinition` with an *explicit size*, a *relative size* (using `*`) or `Auto`. `Auto` makes the row or column only as big as it needs to be to fit its contents. The setting `*` specifies the size of a row or column with respect to the `Grid`'s other rows and columns. For example, a column with a `Height` of `2*` would be twice the size of a column that's `1*` (or just `*`). A `Grid` first allocates its space to the rows and columns whose sizes are defined explicitly or determined automatically. The remaining space is divided among the other rows and columns. By default, all `Width`s and `Height`s are set to `*`, so every cell in the grid is of equal size. In the `Painter` app, the first column is just wide enough to fit the controls, and the rest of the space is allotted to the painting area (lines 11–12). If you resize the `Painter` window, you'll notice that only the width of the paintable area increases or decreases.

If you click the ellipsis button next to the `RowDefinitions` or `ColumnDefinitions` property in the **Properties** window, the **Collection Editor** window will appear. (If you cannot find a property, type its name in the **Search Properties** text box at the top of the **Properties** window or view the properties by **Name** rather than **Category**.) This tool can be used to add, remove, reorder, and edit the properties of rows and columns in a `Grid`. In fact, any property that takes a collection as a value can be edited in a version of the **Collection Editor** specific to that collection. For example, you could edit the `Items` property of a `ComboBox` (that is, drop-down list) in such a way. The `ColumnDefinitions` **Collection Editor** is shown in Fig. 23.6.



[0] ColumnDefinition
[1] ColumnDefinition

ToolTip
Width 1 Auto
AllowDrop ☐
BindingGroup
CommandBindings (Collection)
ContextMenu
Cursor
DataContext

Fig. 23.6 | Using the **Collection Editor**.

The control properties we've introduced so far look and function just like their Windows `Forms` counterparts. To indicate which cell of a `Grid` a control belongs in, however, you use the **`Grid.Row`** and **`Grid.Column`** properties. These are known as **attached properties**—they're defined by a *different* control than that to which they're applied. In this case, `Row` and `Column` are defined by the `Grid` itself but applied to the controls contained in the `Grid` (for example, line 16 in Fig. 23.5). To specify the number of rows or columns that a control spans, you can use the **`Grid.RowSpan`** or **`Grid.ColumnSpan`** attached properties, respectively. By default, a control spans the entire `Grid`, unless the `Grid.Row` or `Grid.Column` property is set, in which case the control spans only the specified row or column by default.

`Canvas` Control

The painting area of the `Painter` app is a **`Canvas`** (lines 16–21), another layout container. A `Canvas` allows users to position controls by defining explicit coordinates. Controls in a `Canvas` have the attached properties, **`Canvas.Left`** and **`Canvas.Top`**, which specify the control's coordinate position based on its distance from the `Canvas`'s *left* and *top* borders, respectively. If two controls *overlap*, the one with the *greater* **`Canvas.ZIndex`** displays in the *foreground*. If this property is not defined for the controls, then the *last* control added to the canvas displays in the foreground. When you provide a name for a control via the Properties window, the IDE adds an `x:Name` attribute to the controls XAML. This name is used in the C# code as the control's variable name.

*Layout in **Design** Mode*

As you're creating your GUI in **Design** mode, you'll notice many helpful layout features. For example, as you *resize* a control, its width and height are displayed. In addition, *snaplines* appear as necessary to help you align the edges of elements. These lines will also appear when you move controls around the design area.

When you select a control, *margin lines* that extend from the control to the edges of its container appear, as shown in Fig. 23.7. If a solid line containing a number extends to the edge of the container, then the distance between the control and that edge is *fixed*. If a dashed line appears between the edge of the control and the edge of the container, then the distance between the control and that edge of the container is *dynamic*—the distance changes as the container size changes. You can toggle between the two by clicking the icons at the ends of the lines.

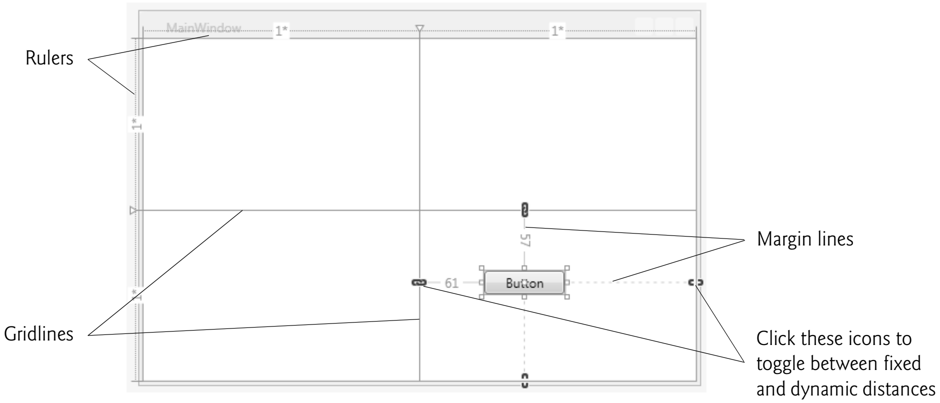


Fig. 23.7 | Margin lines and gridlines in **Design** view.

Furthermore, the **Design** view also helps you use a `Grid`. As shown in Fig. 23.7, when you select a control in a `Grid`, the `Grid`'s rulers appear to the *left* and on *top* of it. The widths and heights of each column and row, respectively, appear on the rulers. Gridlines that outline the `Grid`'s rows and columns also appear, helping you align and position the `Grid`'s elements. You also can create more rows and columns by clicking where you want to separate them on the ruler.

23.6 Event Handling

Basic event handling in WPF is almost identical to Windows `Forms` event handling, but there is a fundamental difference, which we'll explain later in this section. We'll use the `Painter` example to introduce WPF event handling. Figure 23.8 provides the code-behind class for the `Painter` `Window`. As in Windows Forms GUIs, when you double click a control, the IDE automatically generates an event handler for that control's primary event. The IDE also adds an attribute to the control's XAML element specifying the event name and the name of the event handler that responds to the event. For example, in line 32 of Fig. 23.5, the attribute

```
Checked="redRadioButton_Checked"
```

specifies that the `redRadioButton`'s `Checked` event handler is `redRadioButton_Checked`.

```
// Fig. 23.8: MainWindow.xaml.cs
// Code-behind for MainWindow.xaml.
using System.Windows;
using System.Windows.Controls;
using System.Windows.Input;
using System.Windows.Media;
using System.Windows.Shapes;

namespace Painter
{
   public partial class MainWindow : Window
   {
      private int diameter = (int) Sizes.MEDIUM; // diameter of circle
      private Brush brushColor = Brushes.Black; // drawing color
      private bool shouldErase = false; // specify whether to erase
      private bool shouldPaint = false; // specify whether to paint

      private enum Sizes // size constants for diameter of the circle
      {
         SMALL = 4,
         MEDIUM = 8,
         LARGE = 10
      } // end enum Sizes

      // constructor
      public MainWindow()
      {
```

Fig. 23.8 | Code-behind for `MainWindow.xaml`. (Part 1 of 4.)

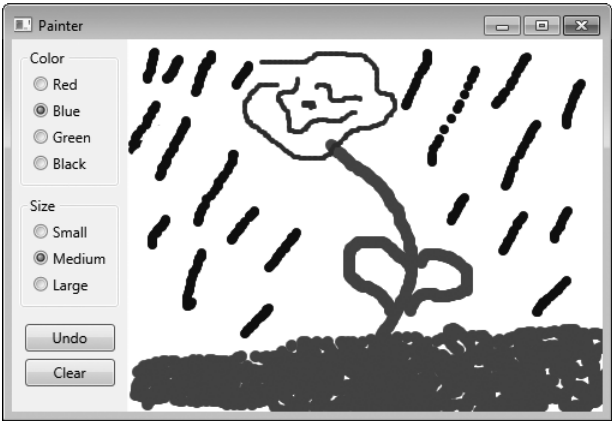
```
         InitializeComponent();
      } // end constructor

      // paints a circle on the Canvas
      private void PaintCircle( Brush circleColor, Point position )
      {
         Ellipse newEllipse = new Ellipse(); // create an Ellipse

         newEllipse.Fill = circleColor; // set Ellipse's color
         newEllipse.Width = diameter; // set its horizontal diameter
         newEllipse.Height = diameter; // set its vertical diameter

         // set the Ellipse's position
         Canvas.SetTop( newEllipse, position.Y );
         Canvas.SetLeft( newEllipse, position.X );

         paintCanvas.Children.Add( newEllipse );
      } // end method PaintCircle

      // handles paintCanvas's MouseLeftButtonDown event
      private void paintCanvas_MouseLeftButtonDown( object sender,
         MouseButtonEventArgs e )
      {
         shouldPaint = true; // OK to draw on the Canvas
      } // end method paintCanvas_MouseLeftButtonDown

      // handles paintCanvas's MouseLeftButtonUp event
      private void paintCanvas_MouseLeftButtonUp( object sender,
         MouseButtonEventArgs e )
      {
         shouldPaint = false; // do not draw on the Canvas
      } // end method paintCanvas_MouseLeftButtonUp

      // handles paintCanvas's MouseRightButtonDown event
      private void paintCanvas_MouseRightButtonDown( object sender,
         MouseButtonEventArgs e )
      {
         shouldErase = true; // OK to erase the Canvas
      } // end method paintCanvas_MouseRightButtonDown

      // handles paintCanvas's MouseRightButtonUp event
      private void paintCanvas_MouseRightButtonUp( object sender,
         MouseButtonEventArgs e )
      {
         shouldErase = false; // do not erase the Canvas
      } // end method paintCanvas_MouseRightButtonUp

      // handles paintCanvas's MouseMove event
      private void paintCanvas_MouseMove( object sender,
         MouseEventArgs e )
      {
         if ( shouldPaint )
         {
```

Fig. 23.8 | Code-behind for `MainWindow.xaml`. (Part 2 of 4.)

```
            // draw a circle of selected color at current mouse position
            Point mousePosition = e.GetPosition( paintCanvas );
            PaintCircle( brushColor, mousePosition );
         } // end if
         else if ( shouldErase )
         {
            // erase by drawing circles of the Canvas's background color
            Point mousePosition = e.GetPosition( paintCanvas );
            PaintCircle( paintCanvas.Background, mousePosition );
         } // end else if
      } // end method paintCanvas_MouseMove

      // handles Red RadioButton's Checked event
      private void redRadioButton_Checked( object sender,
         RoutedEventArgs e )
      {
         brushColor = Brushes.Red;
      } // end method redRadioButton_Checked

      // handles Blue RadioButton's Checked event
      private void blueRadioButton_Checked( object sender,
         RoutedEventArgs e )
      {
         brushColor = Brushes.Blue;
      } // end method blueRadioButton_Checked

      // handles Green RadioButton's Checked event
      private void greenRadioButton_Checked( object sender,
         RoutedEventArgs e )
      {
         brushColor = Brushes.Green;
      } // end method greenRadioButton_Checked

      // handles Black RadioButton's Checked event
      private void blackRadioButton_Checked( object sender,
         RoutedEventArgs e )
      {
         brushColor = Brushes.Black;
      } // end method blackRadioButton_Checked

      // handles Small RadioButton's Checked event
      private void smallRadioButton_Checked( object sender,
         RoutedEventArgs e )
      {
         diameter = ( int ) Sizes.SMALL;
      } // end method smallRadioButton_Checked

      // handles Medium RadioButton's Checked event
      private void mediumRadioButton_Checked( object sender,
         RoutedEventArgs e )
      {
         diameter = ( int ) Sizes.MEDIUM;
      } // end method mediumRadioButton_Checked
```

Fig. 23.8 | Code-behind for `MainWindow.xaml`. (Part 3 of 4.)

```
134
135         // handles Large RadioButton's Checked event
136         private void largeRadioButton_Checked( object sender,
137            RoutedEventArgs e )
138         {
139            diameter = ( int ) Sizes.LARGE;
140         } // end method largeRadioButton_Checked
141
142         // handles Undo Button's Click event
143         private void undoButton_Click( object sender, RoutedEventArgs e )
144         {
145            int count = paintCanvas.Children.Count;
146
147            // if there are any shapes on Canvas remove the last one added
148            if ( count > 0 )
149               paintCanvas.Children.RemoveAt( count - 1 );
150         } // end method undoButton_Click
151
152         // handles Clear Button's Click event
153         private void clearButton_Click( object sender, RoutedEventArgs e )
154         {
155            paintCanvas.Children.Clear(); // clear the canvas
156         } // end method clearButton_Click
157      } // end class MainWindow
158   } // end namespace Painter
```



Color
○ Red
● Blue
○ Green
○ Black

Size
○ Small
● Medium
○ Large

Fig. 23.8 | Code-behind for `MainWindow.xaml`. (Part 4 of 4.)

The `Painter` app "draws" by placing colored circles on the `Canvas` at the mouse pointer's position as you drag the mouse. The `PaintCircle` method (lines 32–45 in Fig. 23.8) creates the circle by defining an `Ellipse` object (lines 34–38), and positions it using the **`Canvas.SetTop`** and **`Canvas.SetLeft`** methods (lines 41–42), which change the circle's `Canvas.Left` and `Canvas.Top` attached properties, respectively.

The **`Children`** property stores a list (of type **`UIElementCollection`**) of a layout container's child elements. This allows you to edit the layout container's child elements with C# code as you would any other implementation of the `IEnumerable` interface. You can add an element to the container by calling the **`Add`** method of the `Children` list (for example, line 44). The **Undo** and **Clear** buttons work by invoking the **`RemoveAt`** and **`Clear`** methods of the `Children` list (lines 149 and 155), respectively.

Just as with a Windows `Forms` `RadioButton`, a WPF `RadioButton` has a `Checked` event. Lines 94–140 handle the **`Checked`** event for each of the `RadioButtons` in this example, which change the color and the size of the circles painted on the `Canvas`. The `Button` control's **`Click`** event also functions the same in WPF as it did in Windows `Forms`. Lines 143–156 handle the **Undo** and **Clear** `Buttons`. The event-handler declarations look almost identical to how they would look in a Windows `Forms` app, except that the event-arguments object (`e`) is a `RoutedEventArgs` object instead of an `EventArgs` object. We'll explain why later in this section.

Mouse and Keyboard Events

WPF has built-in support for keyboard and mouse events that's nearly identical to the support in Windows `Forms`. `Painter` uses the **`MouseMove`** event of the paintable `Canvas` to paint and erase (lines 76–91). A control's `MouseMove` event is triggered whenever the mouse moves within the boundaries of the control. Information for the event is passed to the event handler using a **`MouseEventArgs`** object, which contains mouse-specific information. The **`GetPosition`** method of `MouseEventArgs`, for example, returns the current position of the mouse relative to the control that triggered the event (for example, lines 82 and 88). `MouseMove` works the same as it does in Windows `Forms`. [*Note:* Much of the functionality in our sample `Painter` app is already provided by the WPF `InkCanvas` control. We chose not to use this control so we could demonstrate various other WPF features.]

WPF has additional mouse events. `Painter` also uses the **`MouseLeftButtonDown`** and **`MouseLeftButtonUp`** events to toggle painting on and off (lines 48–59), and the **`MouseRightButtonDown`** and **`MouseRightButtonUp`** events to toggle erasing on and off (lines 62–73). All of these events pass information to the event handler using the **`MouseButtonEventArgs`** object, which has properties specific to a mouse button (for example, `ButtonState` or `ClickCount`) in addition to mouse-specific ones. These events are new to WPF and are more specific versions of `MouseUp` and `MouseDown` (which are still available in WPF). A summary of commonly used mouse and keyboard events is provided in Fig. 23.9.

Common mouse and keyboard events	
Mouse Event with an Event Argument of Type `MouseEventArgs`	
`MouseMove`	Raised when you move the mouse within a control's boundaries.
Mouse Events with an Event Argument of Type `MouseButtonEventArgs`	
`MouseLeftButtonDown`	Raised when the left mouse button is pressed.
`MouseLeftButtonUp`	Raised when the left mouse button is released.
`MouseRightButtonDown`	Raised when the right mouse button is pressed.
`MouseRightButtonUp`	Raised when the right mouse button is released.
Mouse Event with an Event Argument of Type `MouseWheelEventArgs`	
`MouseWheel`	Raised when the mouse wheel is rotated.

Fig. 23.9 | Common mouse and keyboard events. (Part 1 of 2.)

Common mouse and keyboard events	
Keyboard Events with an Event Argument of Type `KeyEventArgs`	
`KeyDown`	Raised when a key is pressed.
`KeyUp`	Raised when a key is released.

Fig. 23.9 | Common mouse and keyboard events. (Part 2 of 2.)

Routed Events

WPF events have a significant distinction from their Windows `Forms` counterparts—they can travel either up (from child to parent) or down (from parent to child) the containment hierarchy—the hierarchy of nested elements defined within a control. This is called **event routing**, and all WPF events are **routed events**.

The event-arguments object that's passed to the event handler of a WPF `Button`'s `Click` event or a `RadioButton`'s `Check` event is of the type **`RoutedEventArgs`**. All event-argument objects in WPF are of type `RoutedEventArgs` or one of its subclasses. As an event travels up or down the hierarchy, it may be useful to stop it before it reaches the end. When the **`Handled`** property of the `RoutedEventArgs` parameter is set to `true`, event handlers ignore the event. It may also be useful to know the source where the event was first triggered. The **`Source`** property stores this information. You can learn more about the benefits of routed events at `bit.ly/RoutedEvents`.

Demonstrating Routed Events

Figures 23.10 and 23.11 show the XAML and code-behind for a program that demonstrates event routing. The program contains two `GroupBox`es, each with a `Label` inside (lines 15–27 in Fig. 23.10). One group handles a left-mouse-button press with `MouseLeftButtonUp`, and the other with `PreviewMouseLeftButtonUp`. As the event travels up or down the containment hierarchy, a log of where the event has traveled is displayed in a **`TextBox`** (line 29). The WPF `TextBox` functions just like its Windows `Forms` counterpart.

```
 1  <!-- Fig. 23.10: MainWindow.xaml -->
 2  <!-- Routed-events example (XAML). -->
 3  <Window x:Class="RoutedEvents.MainWindow"
 4     xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
 5     xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
 6     Title="Routed Events" Height="300" Width="300"
 7     x:Name="routedEventsWindow">
 8     <Grid>
 9        <Grid.RowDefinitions>
10           <RowDefinition Height="Auto" />
11           <RowDefinition Height="Auto" />
12           <RowDefinition Height="*" />
13        </Grid.RowDefinitions>
14
15        <GroupBox x:Name="tunnelingGroupBox" Grid.Row="0" Header="Tunneling"
16           Margin="5" PreviewMouseLeftButtonUp="Tunneling">
```

Fig. 23.10 | Routed-events example (XAML). (Part 1 of 2.)

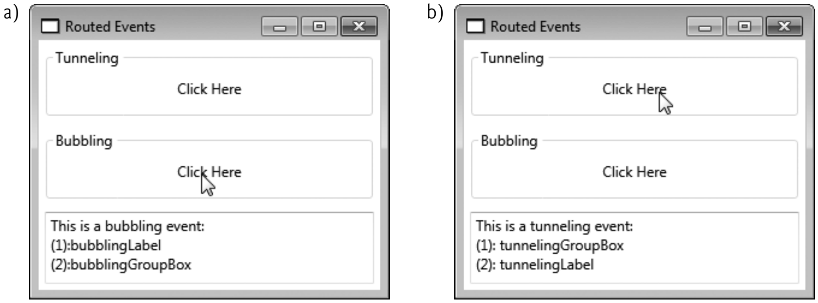
```
            <Label x:Name="tunnelingLabel" Margin="5"
               HorizontalAlignment="Center"
               PreviewMouseLeftButtonUp="Tunneling" Content="Click Here"/>
         </GroupBox>

         <GroupBox x:Name="bubblingGroupBox" Grid.Row="1" Header="Bubbling"
            Margin="5" MouseLeftButtonUp="Bubbling">
            <Label x:Name="bubblingLabel" Margin="5"
               MouseLeftButtonUp="Bubbling" HorizontalAlignment="Center"
               Content="Click Here"/>
         </GroupBox>

         <TextBox x:Name="logTextBox" Grid.Row="2" Margin="5" />
      </Grid>
   </Window>
```

Fig. 23.10 | Routed-events example (XAML). (Part 2 of 2.)

```
// Fig. 23.11: MainWindow.xaml.cs
// Routed-events example (code-behind).
using System.Windows;
using System.Windows.Controls;
using System.Windows.Input;

namespace RoutedEvents
{
   public partial class MainWindow : Window
   {
      int bubblingEventStep = 1; // step counter for Bubbling
      int tunnelingEventStep = 1; // step counter for Tunneling
      string tunnelingLogText = string.Empty; // temporary Tunneling log

      public RoutedEventsWindow()
      {
         InitializeComponent();
      } // end constructor

      // PreviewMouseUp is a tunneling event
      private void Tunneling( object sender, MouseButtonEventArgs e )
      {
         // append step number and sender
         tunnelingLogText = string.Format( "{0}({1}): {2}\n",
            tunnelingLogText, tunnelingEventStep,
            ( ( Control ) sender ).Name );
         ++tunnelingEventStep; // increment counter

         // execution goes from parent to child, ending with the source
         if ( e.Source.Equals( sender ) )
         {
            tunnelingLogText = string.Format(
               "This is a tunneling event:\n{0}", tunnelingLogText );
```

Fig. 23.11 | Routed-events example (code-behind). (Part 1 of 2.)

```
34             logTextBox.Text = tunnelingLogText; // set logTextBox text
35             tunnelingLogText = string.Empty; // clear temporary log
36             tunnelingEventStep = 1; // reset counter
37          } // end if
38       } // end method Tunneling
39
40       // MouseUp is a bubbling event
41       private void Bubbling( object sender, MouseButtonEventArgs e )
42       {
43          // execution goes from child to parent, starting at the source
44          if ( e.Source.Equals( sender ) )
45          {
46             logTextBox.Clear(); // clear the logTextBox
47             bubblingEventStep = 1; // reset counter
48             logTextBox.Text = "This is a bubbling event:\n";
49          } // end if
50
51          // append step number and sender
52          logTextBox.Text = string.Format( "{0}({1}): {2}\n",
53             logTextBox.Text, bubblingEventStep,
54             ( ( Control ) sender ).Name );
55          ++bubblingEventStep;
56       } // end method Bubbling
57    } // end class MainWindow
58 } // end namespace RoutedEvents
```



a)

```
This is a bubbling event:
(1):bubblingLabel
(2):bubblingGroupBox
```

b)

```
This is a tunneling event:
(1): tunnelingGroupBox
(2): tunnelingLabel
```

Fig. 23.11 | Routed-events example (code-behind). (Part 2 of 2.)

There are three types of routed events—**direct events**, **bubbling events** and **tunneling events**. *Direct events* are like ordinary Windows `Forms` events—they do *not* travel up or down the containment hierarchy. Bubbling events start at the `Source` and travel *up* the hierarchy ending at the root (`Window`) or until you set `Handled` to `true`. *Tunneling events* start at the top and travel *down* the hierarchy until they reach the `Source` or `Handled` is `true`. To help you distinguish tunneling events from bubbling events, WPF prefixes the names of tunneling events with `Preview`. For example, **`PreviewMouseLeftButtonDown`** is the tunneling version of `MouseLeftButtonDown`, which is a bubbling event.

If you click the **Click Here** `Label` in the **Tunneling** `GroupBox`, the click is handled first by the `GroupBox`, then by the contained `Label`. The event handler that responds to the click handles the **`PreviewMouseLeftButtonUp`** event—a tunneling event. The `Tunneling` method (lines 21–38 in Fig. 23.11) handles the events of both the `GroupBox` and the

`Label`. An event handler can handle events for many controls. Simply select each control then use the events tab in the **Properties** window to select the appropriate event handler for the corresponding event of each control. If you click the other `Label`, the click is handled first by the `Label`, then by the containing `GroupBox`. The `Bubbling` method (lines 41–56) handles the `MouseLeftButtonUp` events of both controls.

23.7 Commands and Common Application Tasks

In Windows `Forms`, event handling is the only way to respond to user actions. WPF provides an alternate technique called a **command**—an action or a task that may be triggered by many different user interactions. In Visual Studio, for example, you can cut, copy and paste code. You can execute these tasks through the **Edit** menu, a toolbar or keyboard shortcuts. To program this functionality in WPF, you can define a single command for each task, thus centralizing the handling of common tasks—this is not easily done in Windows `Forms`.

Commands also enable you to synchronize a task's availability to the state of its corresponding controls. For example, users should be able to copy something only if they have content selected. When you define the copy command, you can specify this as a requirement. As a result, if the user has no content selected, then the menu item, toolbar item and keyboard shortcut for copying are all automatically disabled.

Commands are implementations of the **`ICommand`** interface. When a command is executed, the **`Execute`** method is called. However, the command's execution logic is not defined in its `Execute` method. You must specify this logic when implementing the command. An `ICommand`'s **`CanExecute`** method works the same way. The logic that specifies when a command is enabled and disabled is not determined by the `CanExecute` method and must instead be specified by responding to an appropriate event. Class `RoutedCommand` is the standard implementation of `ICommand`. Every `RoutedCommand` has a `Name` and a collection of **`InputGestures`** (that is, keyboard shortcuts) associated with it. `RoutedUICommand` is an extension of `RoutedCommand` with a `Text` property, which specifies the default text to display on a GUI element that triggers the command.

WPF provides a command library of built-in commands. These commands have their standard keyboard shortcuts already associated with them. For example, `Copy` is a built-in command and has *Ctrl-C* associated with it. Figure 23.12 provides a list of some common built-in commands, separated by the classes in which they're defined.

Common built-in commands from the WPF command library			
`ApplicationCommands` properties			
`New`	`Open`	`Save`	`Close`
`Cut`	`Copy`	`Paste`	
`EditingCommands` properties			
`ToggleBold`	`ToggleItalic`	`ToggleUnderline`	
`MediaCommands` properties			
`Play`	`Stop`	`Rewind`	`FastForward`
`IncreaseVolume`	`DecreaseVolume`	`NextTrack`	`PreviousTrack`

Fig. 23.12 | Common built-in commands from the WPF command library.

Figures 23.13 and 23.14 are the XAML markup and C# code for a simple text-editor app that allows users to format text into bold and italics, and also to cut, copy and paste text. The example uses the **`RichTextBox`** control (line 49), which allows users to enter, edit and format text. We use this app to demonstrate several built-in commands from the command library.

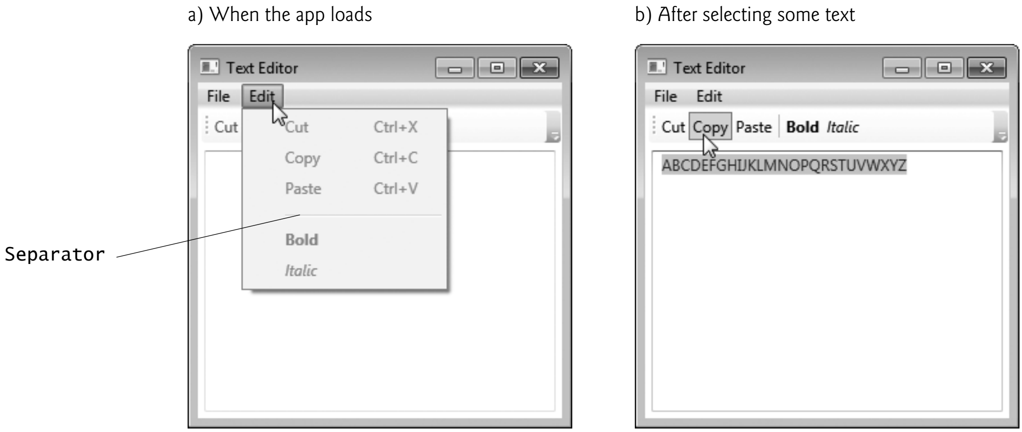
```
 1  <!-- Fig. 23.13: MainWindow.xaml -->
 2  <!-- Creating menus and toolbars, and using commands (XAML). -->
 3  <Window x:Class="TextEditor.MainWindow"
 4     xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
 5     xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
 6     Title="Text Editor" Height="300" Width="300">
 7
 8     <Window.CommandBindings> <!-- define command bindings -->
 9        <!-- bind the Close command to handler -->
10        <CommandBinding Command="Close" Executed="closeCommand_Executed" />
11     </Window.CommandBindings>
12
13     <Grid> <!-- define the GUI -->
14        <Grid.RowDefinitions>
15           <RowDefinition Height="Auto" />
16           <RowDefinition Height="Auto" />
17           <RowDefinition Height="*" />
18        </Grid.RowDefinitions>
19
20        <Menu Grid.Row="0"> <!-- create the menu -->
21           <!-- map each menu item to corresponding command -->
22           <MenuItem Header="File">
23              <MenuItem Header="Exit" Command="Close" />
24           </MenuItem>
25           <MenuItem Header="Edit">
26              <MenuItem Header="Cut" Command="Cut" />
27              <MenuItem Header="Copy" Command="Copy" />
28              <MenuItem Header="Paste" Command="Paste" />
29              <Separator /> <!-- separates groups of menu items -->
30              <MenuItem Header="Bold" Command="ToggleBold"
31                 FontWeight="Bold" />
32              <MenuItem Header="Italic" Command="ToggleItalic"
33                 FontStyle="Italic" />
34           </MenuItem>
35        </Menu>
36
37        <ToolBar Grid.Row="1"> <!-- create the toolbar -->
38           <!-- map each toolbar item to corresponding command -->
39           <Button Command="Cut">Cut</Button>
40           <Button Command="Copy">Copy</Button>
41           <Button Command="Paste">Paste</Button>
42           <Separator /> <!-- separates groups of toolbar items -->
43           <Button FontWeight="Bold" Command="ToggleBold">Bold</Button>
44           <Button FontStyle="Italic" Command="ToggleItalic">
45              Italic</Button>
46        </ToolBar>
```

Fig. 23.13 | Creating menus and toolbars, and using commands (XAML). (Part 1 of 2.)

```

      <!-- display editable, formattable text -->
      <RichTextBox Grid.Row="2" Margin="5" />
  </Grid>
</Window>
```

Fig. 23.13 | Creating menus and toolbars, and using commands (XAML). (Part 2 of 2.)

```
// Fig. 23.14: MainWindow.xaml.cs
// Code-behind class for a simple text editor.
using System.Windows;
using System.Windows.Input;

namespace TextEditor
{
   public partial class MainWindow : Window
   {
      public MainWindow()
      {
         InitializeComponent();
      } // end constructor

      // exit the app
      private void closeCommand_Executed( object sender,
         ExecutedRoutedEventArgs e )
      {
         Application.Current.Shutdown();
      } // end method closeCommand_Executed
   } // end class MainWindow
} // end namespace TextEditor
```


a) When the app loads

b) After selecting some text

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Fig. 23.14 | Code-behind class for a simple text editor. (Part 1 of 2.)

c) After copying some text

ABCDEFGHIJKLMNOPQRSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Fig. 23.14 | Code-behind class for a simple text editor. (Part 2 of 2.)

A command is executed when it's triggered by a *command source*. For example, the `Close` command is triggered by a `MenuItem` (line 23 in Fig. 23.13). The `Cut` command has two sources, a `MenuItem` and a `ToolBar` `Button` (lines 26 and 39, respectively). A command can have many sources.

To make use of a command, you must create a **command binding**—a link between a command and the methods containing its logic. You can declare a command binding by creating a **`CommandBinding`** object in XAML and setting its `Command` property to the name of the associated command (line 10). A command binding raises the **`Executed`** and **`PreviewExecuted`** events (*bubbling* and *tunneling* versions of the same event) when its associated command is executed. You program the command's functionality into an event handler for one of these events. In line 10, we set the `Executed` attribute to a method name, telling the program that the specified method (`closeCommand_Executed`) handles the command binding's `Executed` event.

In this example, we demonstrate the use of a *command binding* by implementing the `Close` command. When it executes, it shuts down the app. The method that executes this task is **`Application.Current.Shutdown`**, as shown in line 19 of Fig. 23.14.

You also can use a command binding to specify the logic for determining when a command should be *enabled* or *disabled*. You can do so by handling either the **`CanExecute`** or **`PreviewCanExecute`** (*bubbling* and *tunneling* versions of the same events) events in the same way that you handle the `Executed` or `PreviewExecuted` events. Because we do not define such a handler for the `Close` command in its command binding, it's always enabled. Command bindings should be defined within the **`Window.CommandBindings`** element (for example, lines 8–11 in Fig. 23.13).

The only time a command binding is *not* necessary is when a control has built-in functionality for dealing with a command. A `Button` or `MenuItem` linked to the `Cut`, `Copy`, or `Paste` commands is an example (for example, lines 26–28 and lines 39–41). As Fig. 23.14(a) shows, all three commands are disabled when the app loads. If you select some text, the `Cut` and `Copy` commands are enabled, as shown in Fig. 23.14(b). Once you have copied some text, the `Paste` command is enabled, as evidenced by Fig. 23.14(c). We did not have to define any associated command bindings or event handlers to implement these commands. The `ToggleBold` and `ToggleItalic` commands are also implemented without any command bindings.

Menus and Toolbars

The text editor uses menus and toolbars. The **`Menu`** control creates a menu containing **`MenuItem`**s. `MenuItems` can be top-level menus such as **File** or **Edit** (lines 22 and 25 in Fig. 23.13), submenus, or items in a menu, which function like `Buttons` (for example, lines 26–28). If a `MenuItem` has nested `MenuItems`, then it's a top-level menu or a submenu. Otherwise, it's an item that executes an action via either an event or a command. `MenuItems` are content controls and thus can display any single GUI element as content.

A **`ToolBar`** is a single row or column (depending on the `Orientation` property) of options. A `ToolBar`'s `Orientation` is a *read-only* property that gets its value from the parent **`ToolBarTray`**, which can host multiple `ToolBars`. If a `ToolBar` has no parent `ToolBarTray`, as is the case in this example, its `Orientation` is `Horizontal` by default. Unlike elements in a `Menu`, a `ToolBar`'s child elements are not of a specific type. A `ToolBar` usually contains `Buttons`, `CheckBoxes`, `ComboBoxes`, `RadioButtons` and `Separators`, but any WPF control can be used. `ToolBars` overwrite the look-and-feel of their child elements with their own specifications, so that the controls look seamless together. You can override the default specifications to create your own look-and-feel. Lines 37–46 define the text editor's `ToolBar`.

`Menus` and `ToolBars` can incorporate **`Separators`** (for example, lines 29 and 42) that differentiate groups of `MenuItems` or controls. In a `Menu`, a `Separator` displays as a horizontal bar—as shown between the **Paste** and **Bold** menu options in Fig. 23.14(a). In a horizontal `ToolBar`, it displays as a short vertical bar—as shown in Fig. 23.14(b). You can use `Separators` in any type of control that can contain multiple child elements, such as a `StackPanel`.

23.8 WPF GUI Customization

One advantage of WPF over Windows `Forms` is the ability to customize controls. WPF provides several techniques to customize the look and behavior of controls. The simplest takes full advantage of a control's properties. The value of a control's **`Background`** property, for example, is a *brush* (i.e, `Brush` object). This allows you to create a *gradient* or an *image* and use it as the background rather than a solid color. For more information about brushes, see Section 24.5. In addition, many controls that allowed only text content in Windows `Forms` are `ContentControls` in WPF, which can host any type of content—including other controls. The caption of a WPF `Button`, for example, could be an *image* or even a *video*.

In Section 23.9, we demonstrate how to use styles in WPF to achieve a uniform look-and-feel. In Windows `Forms`, if you want to make all your `Buttons` look the same, you have to manually set properties for every `Button`, or copy and paste. To achieve the same result in WPF, you can define the properties once as a style and apply the style to each `Button`. This is similar to the CSS/HTML implementation of styles. HTML specifies the content and structure of a website, and CSS defines styles that specify the presentation of elements in a website. For more information on CSS and HTML, see our Resource Centers at `www.deitel.com/ResourceCenters.html`.

Styles are limited to modifying a control's look-and-feel through its properties. In Section 23.11, we introduce control templates, which offer you the freedom to define a control's appearance by modifying its visual structure. With a custom control template, you can completely strip a control of all its visual settings and rebuild it to look exactly the way you like, while maintaining its existing functionality. A `Button` with a custom control template might look structurally different from a default `Button`, but it still functions the same as any other `Button`.

If you want to change only the appearance of an element, a style or control template should suffice. However, you also can create entirely new custom controls that have their own functionality, properties, methods and events.

23.9 Using Styles to Change the Appearance of Controls

Once defined, a **WPF style** is a collection of property-value and event-handler definitions that can be reused. Styles enable you to eliminate repetitive code or markup. For example, if you want to change the look-and-feel of the standard `Button` throughout a section of your app, you can define a style and apply it to all the `Buttons` in that section. Without styles, you have to set the properties for each individual `Button`. Furthermore, if you later decided that you wanted to tweak the appearance of these `Buttons`, you would have to modify your markup or code several times. By using a style, you can make the change only once in the style and it's automatically be applied to any control which uses that style.

Styles are **WPF resources**. A resource is an object that's defined for an entire section of your app and can be reused multiple times. A resource can be as simple as a property or as complex as a control template. Every WPF control can hold a collection of resources that can be accessed by any element down the containment hierarchy. In a way, this is similar in approach to the concept of variable scope that you learned about in Chapter 7. For example, if you define a style as a resource of a `Window`, then any element in the `Window` can use that style. If you define a style as a resource of a layout container, then only the elements of the layout container can use that style. You also can define application-wide resources for an `Application` object in the `App.xaml` file. These resources can be accessed in any file in the app.

Color Chooser App

Figure 23.15 provides the XAML markup and Fig. 23.16 provides the C# code for a color-chooser app. This example demonstrates styles and introduces the `Slider` user input control.

```
<!-- Fig. 23.15: MainWindow.xaml -->
<!-- Color chooser app showing the use of styles (XAML). -->
<Window x:Class="ColorChooser.MainWindow"
   xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
   xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
   Title="Color Chooser" Height="150" Width="500">

   <Window.Resources> <!-- define Window's resources -->
      <Style x:Key="SliderStyle"> <!-- define style for Sliders -->

         <!-- set properties for Sliders -->
         <Setter Property="Slider.Width" Value="256" />
         <Setter Property="Slider.Minimum" Value="0" />
         <Setter Property="Slider.Maximum" Value="255" />
```

Fig. 23.15 | Color-chooser app showing the use of styles (XAML). (Part 1 of 3.)

```
         <Setter Property="Slider.IsSnapToTickEnabled" Value="True" />
         <Setter Property="Slider.VerticalAlignment" Value="Center" />
         <Setter Property="Slider.HorizontalAlignment" Value="Center" />
         <Setter Property="Slider.Value" Value="0" />
         <Setter Property="Slider.AutoToolTipPlacement"
            Value="TopLeft" />

         <!-- set event handler for ValueChanged event -->
         <EventSetter Event="Slider.ValueChanged"
            Handler="slider_ValueChanged" />
      </Style>
   </Window.Resources>

   <Grid Margin="5"> <!-- define GUI -->
      <Grid.RowDefinitions>
         <RowDefinition />
         <RowDefinition />
         <RowDefinition />
         <RowDefinition />
      </Grid.RowDefinitions>
      <Grid.ColumnDefinitions>
         <ColumnDefinition Width="Auto" />
         <ColumnDefinition Width="Auto" />
         <ColumnDefinition Width="50" />
         <ColumnDefinition />
      </Grid.ColumnDefinitions>

      <!-- define Labels for Sliders -->
      <Label Grid.Row="0" Grid.Column="0" HorizontalAlignment="Right"
         VerticalAlignment="Center" Content="Red:"/>
      <Label Grid.Row="1" Grid.Column="0" HorizontalAlignment="Right"
         VerticalAlignment="Center" Content="Green:"/>
      <Label Grid.Row="2" Grid.Column="0" HorizontalAlignment="Right"
         VerticalAlignment="Center" Content="Blue:"/>
      <Label Grid.Row="3" Grid.Column="0" HorizontalAlignment="Right"
         VerticalAlignment="Center" Content="Alpha:"/>

      <!-- define Label that displays the color -->
      <Label x:Name="colorLabel" Grid.RowSpan="4" Grid.Column="3"
         Margin="10" />

      <!-- define Sliders and apply style to them -->
      <Slider x:Name="redSlider" Grid.Row="0" Grid.Column="1"
         Style="{StaticResource SliderStyle}"
         Value="{Binding Text, ElementName=redBox}" />‘
      <Slider x:Name="greenSlider" Grid.Row="1" Grid.Column="1"
         Style="{StaticResource SliderStyle}"
         Value="{Binding Text, ElementName=greenBox}"/>
      <Slider x:Name="blueSlider" Grid.Row="2" Grid.Column="1"
         Style="{StaticResource SliderStyle}"
         Value="{Binding Text, ElementName=blueBox}"/>
```

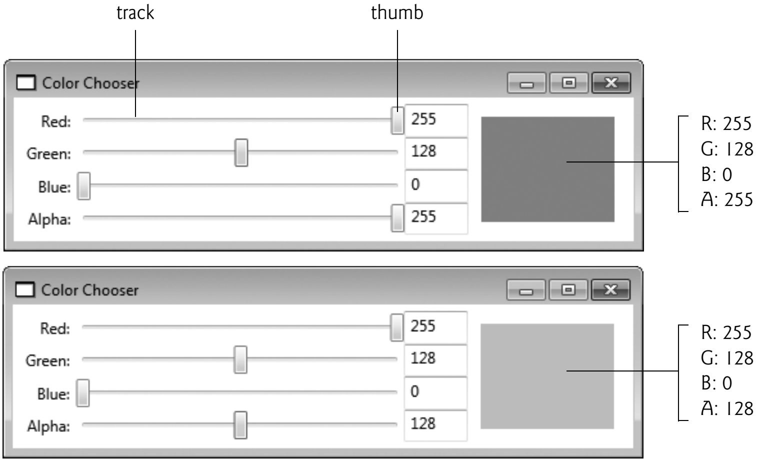
Fig. 23.15 | Color-chooser app showing the use of styles (XAML). (Part 2 of 3.)

```
         <Slider x:Name="alphaSlider" Grid.Row="3" Grid.Column="1"
            Style="{StaticResource SliderStyle}"
            Value="{Binding Text, ElementName=alphaBox}" />

         <TextBox x:Name="redBox" Grid.Row="0" Grid.Column="2"
            Text="{Binding Value, ElementName=redSlider}"/>
         <TextBox x:Name="greenBox" Grid.Row="1" Grid.Column="2"
            Text="{Binding Value, ElementName=greenSlider}"/>
         <TextBox x:Name="blueBox" Grid.Row="2" Grid.Column="2"
            Text="{Binding Value, ElementName=blueSlider}"/>
         <TextBox x:Name="alphaBox" Grid.Row="3" Grid.Column="2"
            Text="{Binding Value, ElementName=alphaSlider}"/>
      </Grid>
   </Window>
```

Fig. 23.15 | Color-chooser app showing the use of styles (XAML). (Part 3 of 3.)

```
// Fig. 23.16: MainWindow.xaml.cs
// Color chooser app showing the use of styles (code-behind).
using System.Windows;
using System.Windows.Media;

namespace ColorChooser
{
   public partial class MainWindow : Window
   {
      public MainWindow()
      {
         InitializeComponent();
         alphaSlider.Value = 255; // override Value from style
      } // constructor

      // handles the ValueChanged event for the Sliders
      private void slider_ValueChanged( object sender,
         RoutedPropertyChangedEventArgs< double > e )
      {
         // generates new color
         SolidColorBrush backgroundColor = new SolidColorBrush();
         backgroundColor.Color = Color.FromArgb(
            ( byte ) alphaSlider.Value, ( byte ) redSlider.Value,
            ( byte ) greenSlider.Value, ( byte ) blueSlider.Value );

         // set colorLabel's background to new color
         colorLabel.Background = backgroundColor;
      } // end method slider_ValueChanged
   } // end class MainWindow
} // end namespace ColorChooser
```

Fig. 23.16 | Color-chooser app showing the use of styles (code-behind). (Part 1 of 2.)



a) Using the **Red** and **Green** sliders to create an opaque orange color

Color Chooser
Red: 255
Green: 128
Blue: 0
Alpha: 255

b) Using the **Red**, **Green** and **Alpha** sliders to create a semi-transparent orange color

Color Chooser
Red: 255
Green: 128
Blue: 0
Alpha: 128

Fig. 23.16 | Color-chooser app showing the use of styles (code-behind). (Part 2 of 2.)

RGBA Colors

This app uses the RGBA color system. Every color is represented by its red, green and blue color values, each ranging from 0 to 255, where 0 denotes no color and 255 full color. For example, a color with a red value of 0 would contain no red component. The alpha value (A)—which also ranges from 0 to 255—represents a color's *opacity*, with 0 being completely *transparent* and 255 completely *opaque*. The two colors in Fig. 23.16's sample outputs have the same RGB values, but the color displayed in Fig. 23.16(b) is *semitransparent*.

`Slider` Controls

The color-chooser GUI uses four **`Slider`** controls that change the RGBA values of a color displayed by a `Label`. Next to each `Slider` is a `TextBox` that displays the `Slider`'s current value. You also can type a number in a `TextBox` to update the value of the corresponding `Slider`. A `Slider` is a numeric user input control that allows users to drag a "thumb" along a track to select the value. Whenever the user moves a `Slider`, the app generates a new color, the corresponding `TextBox` is updated and the `Label` displays the new color as its background. The new color is generated by using class `Color`'s `FromArgb` method, which returns a color based on the four RGBA byte values you pass it (Fig. 23.16, lines 22–24). The color is then applied as the `Background` of the `Label`. Similarly, changing the value of a `TextBox` updates the thumb of the corresponding `Slider` to reflect the change, which then updates the `Label` with the new color. We discuss the updates of the `TextBox`es shortly.

Style for the `Slider`s

Styles can be defined as a resource of any control. In the color-chooser app, we defined the style as a resource of the entire `Window`. We also could have defined it as a resource of the `Grid`. To define resources for a control, you set a control's **Resources** property. Thus, to define a resource for a `Window`, as we did in this example, you would use `Window.Resources` (lines 8–26 in Fig. 23.15). To define a resource for a `Grid`, you'd use `Grid.Resources`.

Style objects can be defined in XAML using the **`Style`** element. The `x:Key` attribute (i.e., attribute `Key` from the standard XAML namespace) must be set in every style (or other resource) so that it can be referenced later by other controls (line 9). The children of a `Style` element set properties and define event handlers. A **`Setter`** sets a property to a specific value (e.g., line 12, which sets the styled `Slider`'s `Width` property to `256`). An **`EventSetter`** specifies the method that responds to an event (e.g., lines 23–24, which specifies that method `slider_ValueChanged` handles the `Slider`'s `ValueChanged` event).

The `Style` in the color-chooser example (`SliderStyle`) primarily uses `Setter`s. It lays out the color `Sliders` by specifying the `Width`, `VerticalAlignment` and `HorizontalAlignment` properties (lines 12, 16 and 17). It also sets the `Minimum` and `Maximum` properties, which determine a `Slider`'s range of values (lines 13–14). In line 18, the default `Value` is set to `0`. `IsSnapToTickEnabled` is set to `True`, meaning that only values that fall on a "tick" are allowed (line 15). By default, each tick is separated by a value of `1`, so this setting makes the styled `Slider` accept only integer values. Lastly, the style also sets the `AutoToolTipPlacement` property, which specifies where a `Slider`'s tooltip should appear, if at all.

Although the `Style` defined in the color-chooser example is clearly meant for `Sliders`, it can be applied to any control. Styles are not control specific. You can make all controls of one type use the same default style by setting the style's **`TargetType`** attribute to the control type. For example, if we wanted all of the `Window`'s `Sliders` to use a `Style`, we would add `TargetType="Slider"` to the `Style`'s start tag.

Using a Style

To apply a style to a control, you create a **resource binding** between a control's `Style` property and the `Style` resource. You can create a resource binding in XAML by specifying the resource in a **markup extension**—an expression enclosed in curly braces (`{}`). The form of a markup extension calling a resource is `{`*ResourceType ResourceKey*`}` (for example, `{StaticResource SliderStyle}` in Fig. 23.15, line 58).

Static and Dynamic Resources

There are two types of resources. **Static resources** are applied only at initialization time. **Dynamic resources** are applied every time the resource is modified by the app. To use a style as a *static* resource, use `StaticResource` as the type in the markup extension. To use a style as a *dynamic* resource, use `DynamicResource` as the type. Because styles don't normally change during runtime, they are usually used as static resources. However, using one as a dynamic resource is sometimes necessary, such as when you wish to enable users to customize a style at runtime.

In this app, we apply `SliderStyle` as a static resource to each `Slider` (lines 58, 61, 64 and 67). Once you apply a style to a control, the **Design** view and **Properties** window update to display the control's new appearance settings. If you then modify the control through the **Properties** window, the control itself is updated, not the style.

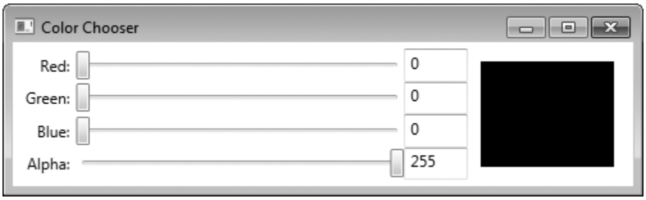
Element-to-Element Bindings

In this app, we use a new feature of WPF called **element-to-element binding** in which a property of one element is always equal to a property of another element. This enables us to declare in XAML that each `TextBox`'s `Text` property should always have the value of the corresponding `Slider`'s `Value` property, and that each `Slider`'s `Value` property should always have the value of the corresponding `TextBox`'s `Text` property. Once these bindings are defined, changing a `Slider` updates the corresponding `TextBox` and vice versa. In

Fig. 23.15, lines 59, 62, 65 and 68 each use a `Binding` markup extension to bind a `Slider`'s `Value` property to the `Text` property of the appropriate `TextBox`. Similary, lines 71, 73, 75 and 77 each use a `Binding` markup extension to bind a `TextBox`'s `Text` property to the `Value` property of the appropriate `Slider`.

Programmatically Changing the Alpha `Slider`'s Value

As shown in Fig. 23.17, the `Slider` that adjusts the alpha value in the color-chooser example starts with a value of 255, whereas the R, G and B `Sliders`' values start at 0. The `Value` property is defined by a `Setter` in the style to be `0` (line 18 in Fig. 23.15). This is why the R, G and B values are 0. The `Value` property of the alpha `Slider` is programmatically defined to be `255` (line 13 in Fig. 23.16), but it could also be set locally in the XAML. Because a local declaration takes precedence over a style setter, the alpha `Slider`'s value would start at 255 when the app loads.



Red: 0
Green: 0
Blue: 0
Alpha: 255

Fig. 23.17 | GUI of the color-chooser app at initialization.

Dependency Properties

Most WPF properties, though they might look and behave exactly like ordinary ones, are in fact **dependency properties**. Such properties have built-in support for change notification—that is, an app knows and can respond to changes in property values. In addition, they support inheritance down the control-containment hierarchy. For example, when you specify `FontSize` in a `Window`, every control in the `Window` inherits it as the default `FontSize`. You also can specify a control's property in one of its child elements. This is how *attached properties* work.

A control's properties may be set at many different levels in WPF, so instead of holding a fixed value, a *dependency property's value* is determined during execution by a value-determination system. If a property is defined at several levels at once, then the current value is the one defined at the level with the highest precedence. A style, for example, overwrites the default appearance of a control, because it takes higher precedence. A summary of the levels, in order from highest to lowest precedence, is shown in Fig. 23.18.

Levels of value determination system	
Animation	The value is defined by an active animation. For more information about animation, see Chapter 33.

Fig. 23.18 | Levels of value determination from highest to lowest precedence. (Part 1 of 2.)

Levels of value determination system	
Local declaration	The value is defined as an attribute in XAML or set in code. This is how ordinary properties are set.
Trigger	The value is defined by an active trigger. For more information about triggers, see Section 23.11.
Style	The value is defined by a setter in a style.
Inherited value	The value is inherited from a definition in a containing element.
Default value	The value is not explicitly defined.

Fig. 23.18 | Levels of value determination from highest to lowest precedence. (Part 2 of 2.)

23.10 Customizing Windows

For over a decade, the standard design of an app window has remained practically the same—a framed rectangular box with a header in the top left and a set of buttons in the top right for minimizing, maximizing and closing the window. Cutting-edge apps, however, have begun to use *custom windows* that diverge from this standard to create a more interesting look.

WPF lets you do this more easily. To create a custom window, set the **`WindowStyle`** property to `None`. This removes the standard frame around your `Window`. To make your `Window` irregularly shaped, you set the **`AllowsTransparency`** property to `True` and the `Background` property to `Transparent`. If you then add controls, only the space within the boundaries of those controls behaves as part of the window. This works because a user cannot interact with any part of a `Window` that's *transparent*. You still define your `Window` as a rectangle with a width and a height, but when a user clicks in a transparent part of the `Window`, it behaves as if the user clicked *outside* the `Window`'s boundaries—that is, the window does not respond to the click.

Figure 23.19 is the XAML markup that defines a GUI for a circular digital clock. The `Window`'s `WindowStyle` is set to `None` and `AllowsTransparency` is set to `True` (line 7). In this example, we set the background to be an image using an `ImageBrush` (lines 10–12). The background image is a *circle* with a *drop shadow* surrounded by *transparency*. Thus, the `Window` appears *circular*.

```
1   <!-- Fig. 23.19: MainWindow.xaml -->
2   <!-- Creating a custom window and using a timer (XAML). -->
3   <Window x:Class="Clock.MainWindow"
4      xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
5      xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
6      Title="Clock" Name="clockWindow" Height="118" Width="118"
7      WindowStyle="None" AllowsTransparency="True"
8      MouseLeftButtonDown="clockWindow_MouseLeftButtonDown">
9
10     <Window.Background> <!-- Set background image -->
11        <ImageBrush ImageSource="images/circle.png" />
```

Fig. 23.19 | Creating a custom window and using a timer (XAML). (Part 1 of 2.)

```
12      </Window.Background>
13

14      <Grid>
15         <TextBox x:Name="timeTextBox" Margin="0,42,0,0"
16            Background="Transparent" TextAlignment="Center"
17            FontWeight="Bold" Foreground="White" FontSize="16"
18            BorderThickness="0" Cursor="Arrow" Focusable="False" />
19      </Grid>
20   </Window>
```

Fig. 23.19 | Creating a custom window and using a timer (XAML). (Part 2 of 2.)

The time is displayed in the center of the window in a `TextBox` (lines 15–18). Its `Background` is set to `Transparent` so that the text displays directly on the circular background (line 16). We configured the text to be size 16, bold, and white by setting the `FontSize`, `FontWeight`, and `Foreground` properties. The `Cursor` property is set to `Arrow`, so that the mouse cursor doesn't change when it moves over the time (line 18). Setting `Focusable` to `False` disables the user's ability to select the text (line 18).

When you create a custom window, there's no built-in functionality for doing the simple tasks that normal windows do. For example, there is no way for the user to move, resize, minimize, maximize, or close a window unless you write the code to enable these features. You can move the clock around, because we implemented this functionality in the `Window`'s code-behind class (Fig. 23.20). Whenever the left mouse button is held down on the clock (handled by the `MouseLeftButtonDown` event), the `Window` is dragged around using the **`DragMove`** method (lines 27–31). Because we did not define how to close or minimize the `Window`, you can shut down the clock by pressing *Alt-F4*—this is a feature built into Windows—or by right clicking its icon on the taskbar and selecting **Close window**.

```
 1   // Fig. 23.20: MainWindow.xaml.cs
 2   // Creating a custom window and using a timer (code-behind).
 3   using System;
 4   using System.Windows;
 5   using System.Windows.Input;
 6
 7   namespace Clock
 8   {
 9      public partial class MainWindow : Window
10      {
11         // create a timer to control clock
12         private System.Windows.Threading.DispatcherTimer timer =
13            new System.Windows.Threading.DispatcherTimer();
```

Fig. 23.20 | Creating a custom window and using a timer (code-behind). (Part 1 of 2.)

```
14
15       // constructor
16       public MainWindow()
17       {
18          InitializeComponent();
19
20          timer.Interval = TimeSpan.FromSeconds( 1 ); // tick every second
21          timer.IsEnabled = true; // enable timer
22
23          timer.Tick += timer_Tick;
24       } // end constructor
25
26       // drag Window when the left mouse button is held down
27       private void clockWindow_MouseLeftButtonDown( object sender,
28          MouseButtonEventArgs e )
29       {
30          this.DragMove(); // moves the window
31       } // end method clockWindow_MouseLeftButtonDown
32
33       // update the time when the timer ticks
34       private void timer_Tick( object sender, EventArgs e )
35       {
36          DateTime currentTime = DateTime.Now; // get the current time
37
38          // display the time as hh:mm:ss
39          timeTextBox.Text = currentTime.ToLongTimeString();
40       } // end method timer_Tick
41    } // end class MainWindow
42 } // end namespace Clock
```

Fig. 23.20 | Creating a custom window and using a timer (code-behind). (Part 2 of 2.)

The clock works by getting the current time every second and displaying it in the `TextBox`. To do this, the clock uses a **`DispatcherTimer`** object (of the `Windows.Threading` namespace), which raises the **`Tick`** event repeatedly at a prespecified time interval. Since the `DispatcherTimer` is defined in the C# code rather than the XAML, we need to specify the method to handle the `Tick` event in the C# code. Line 23 assigns method `timer_Tick` to the `Tick` event's delegate. This adds the `timer_Tick` method as an `EventHandler` for the specified event. After it's declared, you must specify the interval between `Ticks` by setting the **`Interval`** property, which takes a `TimeSpan` as its value. **`TimeSpan`** has several class methods for instantiating a `TimeSpan` object, including `FromSeconds`, which defines a `TimeSpan` lasting the number of seconds you pass to the method. Line 20 creates a one-second `TimeSpan` and sets it as the `DispatcherTimer`'s `Interval`. A `DispatcherTimer` is disabled by default. Until you enable it by setting the **`IsEnabled`** property to `true` (line 21), it will not `Tick`. In this example, the `Tick` event handler gets the current time and displays it in the `TextBox`.

You may recall that the `Timer` component provided the same capabilities in Windows `Forms`. A similar object that you can drag-and-drop onto your GUI doesn't exist in WPF. Instead, you must create a `DispatcherTimer` object, as illustrated in this example.

23.11 Defining a Control's Appearance with Control Templates

We now update the clock example to include buttons for minimizing and closing the app. We also introduce **control templates**—a powerful tool for customizing the look-and-feel of your GUIs. As previously mentioned, a custom control template can redefine the appearance of any control *without* changing its functionality. In Windows `Forms`, if you want to create a round button, you have to create a new control and simulate the functionality of a `Button`. With control templates, you can simply redefine the visual elements that compose the `Button` control and still use the preexisting functionality.

All WPF controls are **lookless**—that is, a control's properties, methods and events are coded into the control's class, but its *appearance* is *not*. Instead, the appearance of a control is determined by a *control template*, which is a hierarchy of visual elements. Every control has a built-in default control template. All of the GUIs discussed so far in this chapter have used these default templates.

The hierarchy of visual elements defined by a control template can be represented as a tree, called a control's **visual tree**. Figure 23.21(b) shows the visual tree of a default `Button` (Fig. 23.22). This is a more detailed version of the same `Button`'s **logical tree**, which is shown in Fig. 23.21(a). A logical tree depicts how a control is a defined, whereas a visual tree depicts how a control is graphically rendered.

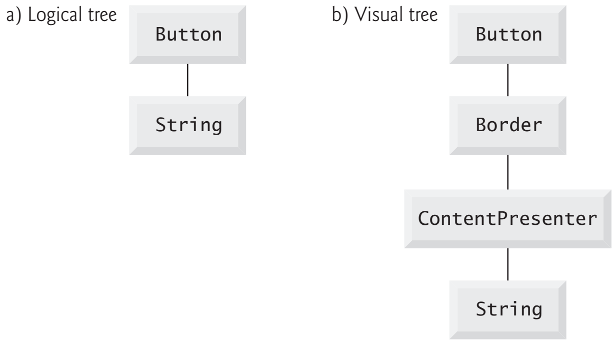


Fig. 23.21 | The logical and visual trees for a default `Button`.

A control's logical tree always mirrors its definition in XAML. For example, you'll notice that the `Button`'s logical tree, which comprises only the `Button` and its `string` caption, exactly represents the hierarchy outlined by its XAML definition, which is

```
<Button>
   Click Me
</Button>
```

To actually render the `Button`, WPF displays a `ContentPresenter` with a `Border` around it. These elements are included in the `Button`'s visual tree. A **`ContentPresenter`** is an object used to display a single element of content on the screen. It's often used in a template to specify where to display content.

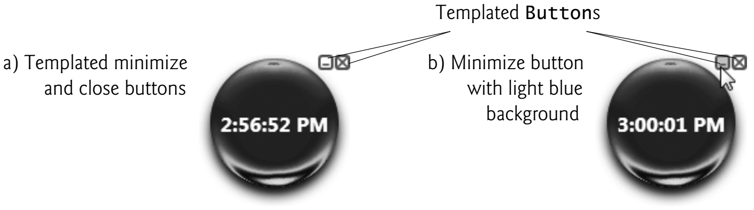
Fig. 23.22 | The default `Button`.

In the updated clock example, we create a custom control template (named `ButtonTemplate`) for rendering `Button`s and apply it to the two `Button`s in the app. The XAML markup is shown in Fig. 23.23. Like a style, a control template is usually defined as a resource, and applied by binding a control's **`Template`** property to the control template using a *resource binding* (for example, lines 47 and 52). After you apply a control template to a control, the **Design** view will update to display the new appearance of the control. The **Properties** window remains unchanged, since a control template does *not* modify a control's properties.

```
 1  <!-- Fig. 23.23: MainWindow.xaml -->
 2  <!-- Using control templates (XAML). -->
 3  <Window x:Class="Clock.MainWindow"
 4     xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
 5     xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
 6     Title="Clock" Name="clockWindow" Height="118" Width="118"
 7     WindowStyle="None" AllowsTransparency="True"
 8     MouseLeftButtonDown="clockWindow_MouseLeftButtonDown">
 9
10     <Window.Resources>
11        <!-- control template for Buttons -->
12        <ControlTemplate x:Key="ButtonTemplate" TargetType="Button">
13           <Border Name="Border" BorderThickness="2" CornerRadius="2"
14              BorderBrush="RoyalBlue">
15
16              <!-- Template binding to Button.Content -->
17              <ContentPresenter Margin="0" Width="8"
18                 Content="{TemplateBinding Content}" />
19           </Border>
20
21           <ControlTemplate.Triggers>
22              <!-- if mouse is over the button -->
23              <Trigger Property="IsMouseOver" Value="True">
24                 <!-- make the background blue -->
25                 <Setter TargetName="Border" Property="Background"
26                    Value="LightBlue" />
27              </Trigger>
28           </ControlTemplate.Triggers>
29        </ControlTemplate>
30     </Window.Resources>
31
32     <Window.Background> <!-- Set background image -->
33        <ImageBrush ImageSource="images/circle.png" />
34     </Window.Background>
35
```

Fig. 23.23 | Using control templates (XAML). (Part 1 of 2.)

```
36       <Grid>
37          <Grid.RowDefinitions>
38             <RowDefinition Height="Auto" />
39             <RowDefinition />
40          </Grid.RowDefinitions>
41
42          <StackPanel Grid.Row="0" Orientation="Horizontal"
43             HorizontalAlignment="Right">
44
45             <!-- these buttons use the control template -->
46             <Button x:Name="minimizeButton" Margin="0" Focusable="False"
47                IsTabStop="False" Template="{StaticResource ButtonTemplate}"
48                Click="minimizeButton_Click">
49                <Image Source="images/minimize.png" Margin="0" />
50             </Button>
51             <Button x:Name="closeButton" Margin="1,0,0,0" Focusable="False"
52                IsTabStop="False" Template="{StaticResource ButtonTemplate}"
53                Click="closeButton_Click">
54                <Image Source="images/close.png" Margin="0"/>
55             </Button>
56          </StackPanel>
57
58          <TextBox x:Name="timeTextBox" Grid.Row="1" Margin="0,30,0,0"
59             Background="Transparent" TextAlignment="Center"
60             FontWeight="Bold" Foreground="White" FontSize="16"
61             BorderThickness="0" Cursor="Arrow" Focusable="False" />
62       </Grid>
63    </Window>
```



a) Templated minimize and close buttons

b) Minimize button with light blue background

Fig. 23.23 | Using control templates (XAML). (Part 2 of 2.)

To define a control template in XAML, you create a **`ControlTemplate`** element. Just as with a style, you must specify the control template's `x:Key` attribute so you can reference it later (line 12). You must also set the **`TargetType`** attribute to the type of control for which the template is designed (line 12). Inside the `ControlTemplate` element, you can build the control using any WPF visual element (lines 13–19). In this example, we replace the default `Border` and `ContentPresenter` with our own custom ones.

Sometimes, when defining a control template, it may be beneficial to use the value of one of the templated control's properties. For example, if you want several controls of different sizes to use the same control template, you may need to use the values of their `Width` and `Height` properties in the template. WPF allows you to do this with a **template binding**, which can be created in XAML with the markup extension, `{TemplateBinding`

PropertyName}. To *bind* a property of an element in a control template to one of the properties of the templated control (that is, the control that the template is applied to), you need to set the appropriate markup extension as the value of that property. In `ButtonTemplate`, we bind the **`Content`** property of a `ContentPresenter` to the `Content` property of the templated `Button` (line 18). The nested element of a `ContentControl` is the value of its `Content` property. Thus, the images defined in lines 49 and 54 are the `Content` of the `Buttons` and are displayed by the `ContentPresenters` in their respective control templates. You also can create template bindings to a control's events.

Often you'll use a combination of control templates, styles and local declarations to define the appearance of your app. Recall that a control template defines the default appearance of a control and thus has a lower precedence than a style in dependency property-value determination.

Triggers

The control template for `Buttons` used in the updated clock example defines a **trigger**, which changes a control's appearance when that control enters a certain state. For example, when your mouse is over the clock's minimize or close `Buttons`, the `Button` is highlighted with a light blue background. This simple change in appearance is caused by a trigger that fires whenever the `IsMouseOver` property becomes `True`.

A trigger must be defined in the **`Style.Triggers`** or **`ControlTemplate.Triggers`** element of a style or a control template, respectively (for example, lines 21–28). You can create a trigger by defining a **`Trigger`** object. The **`Property`** and **`Value`** attributes define the state when a trigger is active. `Setters` *nested* in the `Trigger` element are carried out when the trigger is fired. When the trigger no longer applies, the changes are removed. A `Setter`'s **`TargetName`** property specifies the name of the element that the `Setter` applies to (for example, line 25).

Lines 23–27 define the `IsMouseOver` trigger for the minimize and close `Buttons`. When the mouse is over the `Button`, **`IsMouseOver`** becomes `True`, and the trigger becomes active. The trigger's `Setter` makes the background of the `Border` in the control template temporarily light blue. When the mouse exits the boundaries of the `Button`, `IsMouseOver` becomes `False`. Thus, the `Border`'s background returns to its *default setting*, which in this case is transparent.

Functionality

Figure 23.24 shows the code-behind class for the clock app. Although the custom control template makes the `Buttons` in this app look different, it doesn't change how they behave. Lines 3–40 remain unchanged from the code in the first clock example (Fig. 23.20). The functionality for the minimize and close `Buttons` is implemented in the same way as any other button—by handling the `Click` event (lines 43–47 and 50–53 of Fig. 23.24, respectively). To minimize the window, we set the **`WindowState`** of the `Window` to **`WindowState.Minimized`** (line 46).

```
1   // Fig. 23.24: MainWindow.xaml.cs
2   // Using control templates (code-behind).
3   using System;
```

Fig. 23.24 | Using control templates (code-behind). (Part 1 of 2.)

```
using System.Windows;
using System.Windows.Input;

namespace Clock
{
   public partial class MainWindow : Window
   {
      // creates a timer to control clock
      private System.Windows.Threading.DispatcherTimer timer =
         new System.Windows.Threading.DispatcherTimer();

      // constructor
      public MainWindow()
      {
         InitializeComponent();

         timer.Interval = TimeSpan.FromSeconds( 1 ); // tick every second
         timer.IsEnabled = true; // enable timer

         timer.Tick += timer_Tick;
      } // end constructor

      // drag Window when the left mouse button is held down
      private void clockWindow_MouseLeftButtonDown( object sender,
         MouseButtonEventArgs e )
      {
         this.DragMove();
      } // end method clockWindow_MouseLeftButtonDown

      // update the time when the timer ticks
      private void timer_Tick( object sender, EventArgs e )
      {
         DateTime currentTime = DateTime.Now; // get the current time

         // display the time as hh:mm:ss
         timeTextBox.Text = currentTime.ToLongTimeString();
      } // end method timer_Tick

      // minimize the app
      private void minimizeButton_Click( object sender,
         RoutedEventArgs e )
      {
         this.WindowState = WindowState.Minimized; // minimize window
      } // end method minimizeButton_Click

      // close the app
      private void closeButton_Click( object sender, RoutedEventArgs e )
      {
         Application.Current.Shutdown(); // shut down app
      } // end method closeButton_Click
   } // end class MainWindow
} // end namespace Clock
```

Fig. 23.24 | Using control templates (code-behind). (Part 2 of 2.)

23.12 Data-Driven GUIs with Data Binding

WPF provides a comprehensive model for allowing GUIs to interact with data.

Bindings

A **data binding** is a pointer to data, represented by a **`Binding`** object. WPF allows you to create a *binding* to a broad range of data types. At the simplest level, you could create a binding to a single property. Often, however, it's useful to create a binding to a data object—an object of a class with properties that describe the data. You also can create a binding to objects like arrays, collections and data in an XML document. The versatility of the WPF data model even allows you to bind to data represented by LINQ statements.

Like other binding types, a *data binding* can be created declaratively in XAML markup with a *markup extension*. To declare a data binding, you must specify the data's *source*. If it's another element in the XAML markup, use property **`ElementName`**. Otherwise, use **`Source`**. Then, if you're binding to a specific data point of the source, such as a property of a control, you must specify the **`Path`** to that piece of information. Use a comma to separate the binding's property declarations. For example, to create a binding to a control's property, you would use `{Binding ElementName=`*ControlName*`, Path=`*PropertyName*`}`.

Figure 23.25 presents the XAML markup of a book-cover viewer that lets the user select from a list of books, and displays the cover of the currently selected book. The list of books is presented in a **`ListView`** control (lines 15–24), which displays a set of data as items in a selectable list. Its current selection can be retrieved from the **`SelectedItem`** property. A large image of the currently selected book's cover is displayed in an `Image` control (lines 27–28), which automatically updates when the user makes a new selection. Each book is represented by a `Book` object, which has four `string` properties:

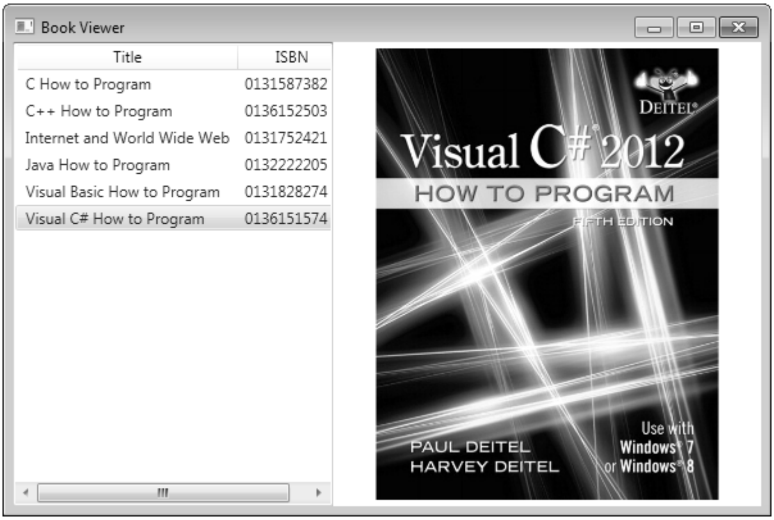
1. `ThumbImage`—the full path to the small cover image of the book.
2. `LargeImage`—the full path to the large cover image of the book.
3. `Title`—the title of the book.
4. `ISBN`—the 10-digit ISBN of the book.

Class `Book` also contains a constructor that initializes a `Book` and sets each of its properties. The full source code of the `Book` class is not presented here but you can view it in the IDE by opening this example's project.

```
 1  <!-- Fig. 23.25: MainWindow.xaml -->
 2  <!-- Using data binding (XAML). -->
 3  <Window x:Class="BookViewer.MainWindow"
 4     xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
 5     xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
 6     Title="Book Viewer" Height="400" Width="600">
 7
 8     <Grid> <!-- define GUI -->
 9        <Grid.ColumnDefinitions>
10           <ColumnDefinition Width="Auto" />
11           <ColumnDefinition />
12        </Grid.ColumnDefinitions>
```

Fig. 23.25 | Using data binding (XAML). (Part 1 of 2.)

```
13
14       <!-- use ListView and GridView to display data -->
15       <ListView x:Name="booksListView" Grid.Column="0" MaxWidth="250">
16          <ListView.View>
17             <GridView>
18                <GridViewColumn Header="Title" Width="100"
19                   DisplayMemberBinding="{Binding Path=Title}" />
20                <GridViewColumn Header="ISBN" Width="80"
21                   DisplayMemberBinding="{Binding Path=ISBN}" />
22             </GridView>
23          </ListView.View>
24       </ListView>
25
26       <!-- bind to selected item's full-size image -->
27       <Image Grid.Column="1" Source="{Binding ElementName=booksListView,
28          Path=SelectedItem.LargeImage}" Margin="5" />
29    </Grid>
30 </Window>
```



Title	ISBN
C How to Program	0131587382
C++ How to Program	0136152503
Internet and World Wide Web	0131752421
Java How to Program	0132222205
Visual Basic How to Program	0131828274
Visual C# How to Program	0136151574

Fig. 23.25 | Using data binding (XAML). (Part 2 of 2.)

To *synchronize* the book cover that's being displayed with the currently selected book, we bind the `Image`'s `Source` property to the file location of the currently selected book's large cover image (lines 27–28). The `Binding`'s `ElementName` property is the name of the selector control, `booksListView`. The `Path` property is `SelectedItem.LargeImage`. This indicates that the binding should be linked to the `LargeImage` property of the `Book` object that's currently `booksListView`'s `SelectedItem`.

Some controls have built-in support for data binding, and a separate `Binding` object doesn't need to be created. A `ListView`, for example, has a built-in **`ItemsSource`** property that specifies the *data source* from which the items of the list are determined. There is no need to create a binding—instead, you can just set the `ItemsSource` property as you would any other property. When you set `ItemsSource` to a collection of data, the objects in the collection automatically become the items in the list. Figure 23.26 presents the code-behind class for the book-cover viewer. When the `Window` is created, a collection of six `Book` objects is initialized (lines 17–29) and set as the `ItemsSource` of the `booksListView`, meaning that each item displayed in the selector is one of the `Book`s.

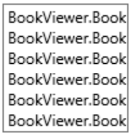
```
 1  // Fig. 23.26: MainWindow.xaml.cs
 2  // Using data binding (code-behind).
 3  using System.Collections.Generic;
 4  using System.Windows;
 5
 6  namespace BookViewer
 7  {
 8     public partial class MainWindow : Window
 9     {
10        private List< Book > books = new List< Book >();
11
12        public MainWindow()
13        {
14           InitializeComponent();
15
16           // add Book objects to the List
17           books.Add( new Book( "C How to Program", "013299044X",
18              "images/small/chtp.jpg", "images/large/chtp.jpg" ) );
19           books.Add( new Book( "C++ How to Program", "0133378713",
20              "images/small/cpphtp.jpg", "images/large/cpphtp.jpg" ) );
21           books.Add( new Book(
22              "Internet and World Wide Web How to Program", "0132151006",
23              "images/small/iw3htp.jpg", "images/large/iw3htp.jpg" ) );
24           books.Add( new Book( "Java How to Program", "0132940949",
25              "images/small/jhtp.jpg", "images/large/jhtp.jpg" ) );
26           books.Add( new Book( "Visual Basic How to Program", "0133406954",
27              "images/small/vbhtp.jpg", "images/large/vbhtp.jpg" ) );
28           books.Add( new Book( "Visual C# How to Program", "0133379337",
29              "images/small/vcshtp.jpg", "images/large/vcshtp.jpg" ) );
30
31           booksListView.ItemsSource = books; // bind data to the list
32        } // end constructor
33     } // end class MainWindow
34  } // end namespace BookViewer
```

Fig. 23.26 | Using data binding (code-behind).

Displaying Data in the ListView

For a `ListView` to display objects in a useful manner, you must specify how. For example, if you don't specify how to display each `Book`, the `ListView` simply displays the result of the item's `ToString` method, as shown in Fig. 23.27.

There are many ways to format the display of a `ListView`. One such method is to display each item as a row in a *tabular grid*, as shown in Fig. 23.25. This can be achieved by setting a **`GridView`** as the `View` property of a `ListView` (lines 16–23). A `GridView` consists of many **`GridViewColumns`**, each representing a property. In this example, we define two columns, one for **Title** and one for **ISBN** (lines 18–19 and 20–21, respectively). A `GridViewColumn`'s `Header` property specifies what to display as its header. The values displayed



```
BookViewer.Book
BookViewer.Book
BookViewer.Book
BookViewer.Book
BookViewer.Book
BookViewer.Book
```

Fig. 23.27 | `ListView` display with no data template.

in each column are determined by its **`DisplayMemberBinding`** property. We set the **Title** column's `DisplayMemberBinding` to a `Binding` object that points to the `Title` property (line 19), and the **ISBN** column's to one that points to the `ISBN` property (line 21). Neither of the `Binding`s has a specified `ElementName` or `Source`. Because the `ListView` has already specified the data source (line 31 of Fig. 23.26), the two data bindings inherit this source, and we do not need specify it again.

Data Templates

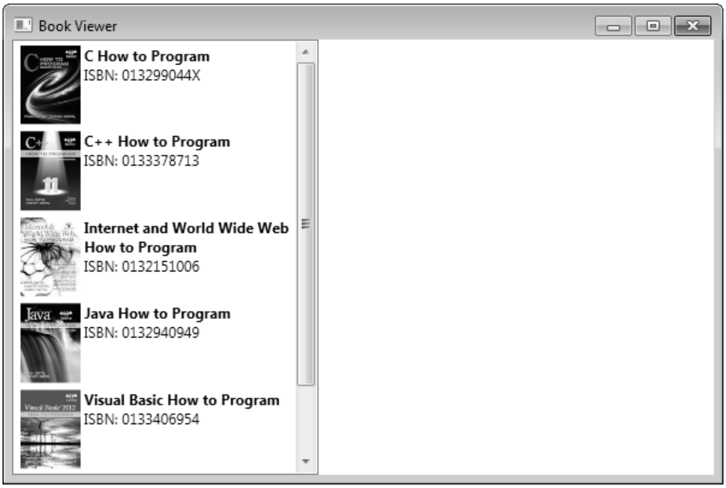
A much more powerful technique for formatting a `ListView` is to specify a template for displaying each item in the list. This template defines how to display bound data and is called a **data template**. Figure 23.28 is the XAML markup that describes a modified version of the book-cover viewer GUI. Each book, instead of being displayed as a row in a table, is represented by a small thumbnail of its cover image with its title and ISBN. Lines 11–32 define the data template (that is, a **`DataTemplate`** object) that specifies how to display a `Book` object. Note the similarity between the structure of a data template and that of a control template. If you define a data template as a resource, you apply it by using a resource binding, just as you would a style or control template. To apply a data template to items in a `ListView`, use the **`ItemTemplate`** property (for example, line 43).

```
 1  <!-- Fig. 23.28: MainWindow.xaml -->
 2  <!-- Using data templates (XAML). -->
 3  <Window x:Class="BookViewer.MainWindow"
 4     xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
 5     xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
 6     Title="Book Viewer" Height="400" Width="600" Name="bookViewerWindow">
 7
 8     <Window.Resources> <!-- Define Window's resources -->
 9
10        <!-- define data template -->
11        <DataTemplate x:Key="BookTemplate">
12           <Grid MaxWidth="250" Margin="3">
13              <Grid.ColumnDefinitions>
14                 <ColumnDefinition Width="Auto" />
15                 <ColumnDefinition />
16              </Grid.ColumnDefinitions>
17
18              <!-- bind image source -->
19              <Image Grid.Column="0" Source="{Binding Path=ThumbImage}"
20                 Width="50" />
21
```

Fig. 23.28 | Using data templates (XAML). (Part 1 of 3.)

```
            <StackPanel Grid.Column="1">
               <!-- bind Title and ISBN -->
               <TextBlock Margin="3,0" Text="{Binding Path=Title}"
                  FontWeight="Bold" TextWrapping="Wrap" />
               <StackPanel Margin="3,0" Orientation="Horizontal">
                  <TextBlock Text="ISBN: " />
                  <TextBlock Text="{Binding Path=ISBN}" />
               </StackPanel>
            </StackPanel>
         </Grid>
      </DataTemplate>
   </Window.Resources>

   <Grid> <!-- define GUI -->
      <Grid.ColumnDefinitions>
         <ColumnDefinition Width="Auto" />
         <ColumnDefinition />
      </Grid.ColumnDefinitions>

      <!-- use ListView and template to display data -->
      <ListView x:Name="booksListView" Grid.Column="0"
         ItemTemplate="{StaticResource BookTemplate}" />

      <!-- bind to selected item's full-size image -->
      <Image Grid.Column="1" Source="{Binding ElementName=booksListView,
         Path=SelectedItem.LargeImage}" Margin="5" />
   </Grid>
</Window>
```

a) App showing the `ListView` with the DataTemplate applied to its items



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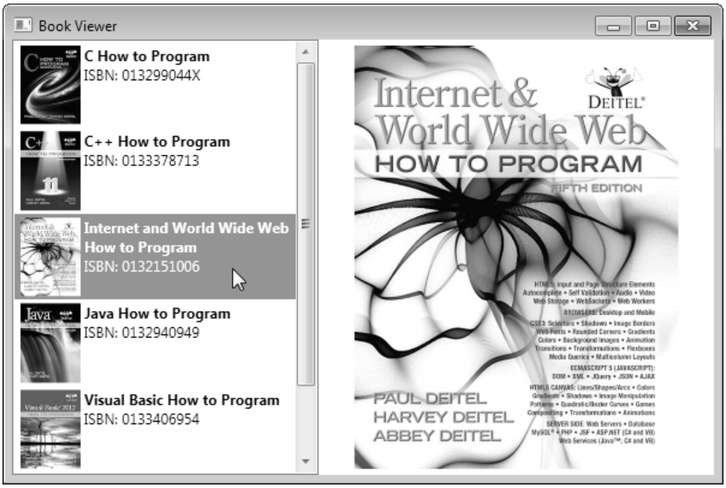
Visual Basic How to Program
ISBN: 0133406954

Fig. 23.28 | Using data templates (XAML). (Part 2 of 3.)



b) Selecting an item from the `ListView`

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Internet and World Wide Web How to Program
ISBN: 0132151006

Java How to Program
ISBN: 0132940949

Visual Basic How to Program
ISBN: 0133406954

Fig. 23.28 | Using data templates (XAML). (Part 3 of 3.)

A data template uses data bindings to specify how to display data. Once again, we can omit the data binding's `ElementName` and `Source` properties, because its source has already been specified by the `ListView` (line 31 of Fig. 23.26). The same principle can be applied in other scenarios as well. If you bind an element's `DataContext` property to a data source, then its child elements can access data within that source without your having to specify it again. In other words, if a binding already has a context (i.e, a `DataContext` has already been defined by a parent), it automatically inherits the data source. For example, if you bind a data source to the `DataContext` property of a `Grid`, then any data binding created in the `Grid` uses that source by default. You can, however, *override* this source by explicitly defining a new one when you define a binding.

In the `BookTemplate` data template, lines 19–20 of Fig. 23.28 define an `Image` whose `Source` is bound to the `Book`'s `ThumbImage` property, which stores the relative file path to the thumbnail cover image. The `Book`'s `Title` and `ISBN` are displayed to the right of the book using **`TextBlocks`**—lightweight controls for displaying text. The `TextBlock` in lines 24–25 displays the `Book`'s `Title` because the `Text` property is bound to it. Because some of the books' titles are long, we set the `TextWrapping` property to `Wrap` (line 25) so that, if the title is too long, it will wrap to multiple lines. We also set the `FontWeight` property to `Bold`. Lines 26–29 display two additional `TextBlocks`, one that displays `ISBN:`, and another that's bound to the `Book`'s `ISBN` property.

Figure 23.28(a) shows the book-viewer app when it first loads. Each item in the `ListView` is represented by a thumbnail of its cover image, its title and its ISBN, as specified in the data template. As illustrated by Fig. 23.28(b), when you select an item in the `ListView`, the large cover image on the right automatically updates, because it's bound to the `SelectedItem` property of the list.

Collection Views

A **collection view** (of class type **`CollectionView`**) is a *wrapper* around a collection of data and can provide multiple "views" of the data based on how it's filtered, sorted and grouped. A *default view* is created in the background every time a *data binding* is created. To retrieve the collection view, use the **`CollectionViewSource.GetDefaultView`** method and pass it the source of your data binding. For example, to retrieve the default view of `bookListView`, you'd use `CollectionViewSource.GetDefaultView(bookListView.ItemsSource)`.

You can then modify the view to create the exact view of the data that you want to display. The methods of filtering, sorting and grouping data are beyond the scope of this book. For more information, see `msdn.microsoft.com/en-us/library/ms752347.aspx#what_are_collection_views`.

Asynchronous Data Binding

Sometimes you may wish to create *asynchronous data bindings* that don't hold up your app while data is being transmitted. To do this, you set the **`IsAsync`** property of a data binding to `True` (it's `False` by default). Often, however, it's not the transmission but the instantiation of data that's the most expensive operation. An asynchronous data binding does not provide a solution for instantiating data asynchronously. To do so, you must use a **data provider**, a class that can create or retrieve data. There are two types of data providers, **`XmlDataProvider`** (for XML) and **`ObjectDataProvider`** (for data objects). Both can be declared as resources in XAML markup. If you set a data provider's **`IsAsynchronous`** property to `True`, the provider will run in the background. Creating and using data providers is beyond the scope of this book. See `msdn.microsoft.com/en-us/library/aa480224.aspx` for more information.

23.13 Wrap-Up

Many of today's commercial apps provide GUIs that are easy to use and manipulate. The demand for sophisticated and user-friendly GUIs makes GUI design an essential programming skill. In Chapters 14–15, we showed you how to create GUIs with Windows `Forms`. In this chapter, we demonstrated how to create GUIs with WPF. You learned how to design a WPF GUI with XAML markup and how to give it functionality in a C# code-behind class. We presented WPF's new flow-based layout scheme, in which a control's size and position are both defined relatively. You learned not only to handle events just as you did in a Windows `Forms` app, but also to implement WPF commands when you want multiple user interactions to execute the same task. We demonstrated the flexibility WPF offers for customizing the look-and-feel of your GUIs. You learned how to use styles, control templates and triggers to define a control's appearance. The chapter concluded with a demonstration of how to create data-driven GUIs with data bindings and data templates.

But WPF is not merely a GUI-building platform. Chapter 24 explores some of the many other capabilities of WPF, showing you how to incorporate 2D and 3D graphics, animation and multimedia into your WPF apps.