Chapter 11

The bindable infrastructure

One of the most basic language constructs of C# is the class member known as the *property*. All of us very early on in our first encounters with C# learned the general routine of defining a property. The property is often backed by a private field and includes `set` and `get` accessors that reference the private field and do something with a new value:

```
public class MyClass
{
    …
    double quality;

    public double Quality
    {
        set
        {
            quality = value;
            // Do something with the new value
        }
        get
        {
            return quality;
        }
    }
    …
}
```

Properties are sometimes referred to as *smart fields*. Syntactically, code that accesses a property resembles code that accesses a field. Yet the property can execute some of its own code when the property is accessed.

Properties are also like methods. Indeed, C# code is compiled into intermediate language that implements a property such as `Quality` with a pair of methods named `set_Quality` and `get_Quality`. Yet despite the close functional resemblance between properties and a pair of *set* and *get* methods, the property syntax reveals itself to be much more suitable when moving from code to markup. It's hard to imagine XAML built on an underlying API that is missing properties.

So you may be surprised to learn that Xamarin.Forms implements an enhanced property definition that builds upon C# properties. Or maybe you won't be surprised. If you already have experience with Microsoft's XAML-based platforms, you'll encounter some familiar concepts in this chapter.

The property definition shown above is known as a *CLR property* because it's supported by the .NET common language runtime. The enhanced property definition in Xamarin.Forms builds upon the CLR property and is called a *bindable property*, encapsulated by the `BindableProperty` class and supported by the `BindableObject` class.

The Xamarin.Forms class hierarchy

Before exploring the details of the important `BindableObject` class, let's first discover how `BindableObject` fits into the overall Xamarin.Forms architecture by constructing a class hierarchy.

In an object-oriented programming framework such as Xamarin.Forms, a class hierarchy can often reveal important inner structures of the environment. The class hierarchy shows how various classes relate to one another and the properties, methods, and events that they share, including how bindable properties are supported.

You can construct such a class hierarchy by laboriously going through the online documentation and taking note of what classes derive from what other classes. Or you can write a Xamarin.Forms program to do the work for you and display the class hierarchy on the phone. Such a program makes use of .NET reflection to obtain all the public classes, structures, and enumerations in the **Xamarin.Forms.Core** and **Xamarin.Forms.Xaml** assemblies and arrange them in a tree. The **ClassHierarchy** application demonstrates this technique.

As usual, the **ClassHierarchy** project contains a class that derives from `ContentPage`, named `ClassHierarchyPage`, but it also contains two additional classes, named `TypeInformation` and `ClassAndSubclasses`.

The program creates one `TypeInformation` instance for every public class (and structure and enumeration) in the **Xamarin.Forms.Core** and **Xamarin.Forms.Xaml** assemblies, plus any .NET class that serves as a base class for any Xamarin.Forms class, with the exception of `Object`. (These .NET classes are `Attribute`, `Delegate`, `Enum`, `EventArgs`, `Exception`, `MulticastDelegate`, and `ValueType`.) The `TypeInformation` constructor requires a `Type` object identifying a type but also obtains some other information:

```
class TypeInformation
{
    bool isBaseGenericType;
    Type baseGenericTypeDef;

    public TypeInformation(Type type, bool isXamarinForms)
    {
        Type = type;
        IsXamarinForms = isXamarinForms;
        TypeInfo typeInfo = type.GetTypeInfo();
        BaseType = typeInfo.BaseType;

        if (BaseType != null)
        {
            TypeInfo baseTypeInfo = BaseType.GetTypeInfo();
            isBaseGenericType = baseTypeInfo.IsGenericType;

            if (isBaseGenericType)
            {
                baseGenericTypeDef = baseTypeInfo.GetGenericTypeDefinition();
```

```
            }
        }
    }

    public Type Type { private set; get; }
    public Type BaseType { private set; get; }
    public bool IsXamarinForms { private set; get; }

    public bool IsDerivedDirectlyFrom(Type parentType)
    {
        if (BaseType != null && isBaseGenericType)
        {
            if (baseGenericTypeDef == parentType)
            {
                return true;
            }
        }
        else if (BaseType == parentType)
        {
            return true;
        }
        return false;
    }
}
```

A very important part of this class is the `IsDerivedDirectlyFrom` method, which will return `true` if passed an argument that is this type's base type. This determination is complicated if generic classes are involved, and that issue largely accounts for the complexity of the class.

The `ClassAndSubclasses` class is considerably shorter:

```
class ClassAndSubclasses
{
    public ClassAndSubclasses(Type parent, bool isXamarinForms)
    {
        Type = parent;
        IsXamarinForms = isXamarinForms;
        Subclasses = new List<ClassAndSubclasses>();
    }

    public Type Type { private set; get; }
    public bool IsXamarinForms { private set; get; }
    public List<ClassAndSubclasses> Subclasses { private set; get; }
}
```

The program creates one instance of this class for every `Type` displayed in the class hierarchy, including `Object`, so the program creates one more `ClassAndSubclasses` instance than the number of `TypeInformation` instances. The `ClassAndSubclasses` instance associated with `Object` contains a collection of all the classes that derive directly from `Object`, and each of those `ClassAndSubclasses` instances contains a collection of all the classes that derive from that one, and so forth for the remainder of the hierarchy tree.

The `ClassHierarchyPage` class consists of a XAML file and a code-behind file, but the XAML file contains little more than a scrollable `StackLayout` ready for some `Label` elements:

```
<ContentPage xmlns="http://xamarin.com/schemas/2014/forms"
             xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
             x:Class="ClassHierarchy.ClassHierarchyPage">

    <ContentPage.Padding>
        <OnPlatform x:TypeArguments="Thickness"
                    iOS="5, 20, 0, 0"
                    Android="5, 0, 0, 0"
                    WinPhone="5, 0, 0, 0" />
    </ContentPage.Padding>

    <ScrollView>
        <StackLayout x:Name="stackLayout"
                     Spacing="0" />
    </ScrollView>
</ContentPage>
```

The code-behind file obtains references to the two Xamarin.Forms `Assembly` objects and then accumulates all the public classes, structures, and enumerations in the `classList` collection. It then checks for the necessity of including any base classes from the .NET assemblies, sorts the result, and then calls two recursive methods, `AddChildrenToParent` and `AddItemToStackLayout`:

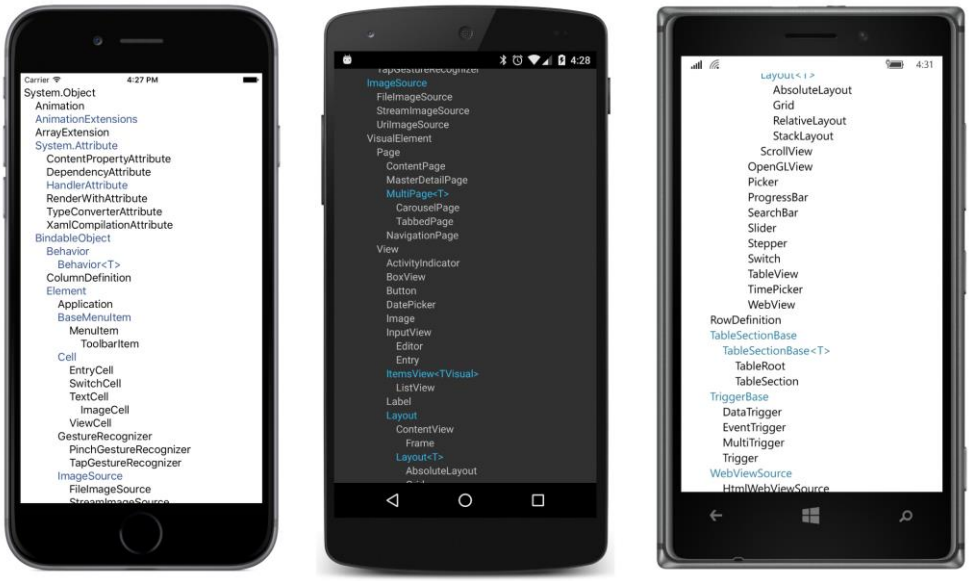
```
public partial class ClassHierarchyPage : ContentPage
{
    public ClassHierarchyPage()
    {
        InitializeComponent();

        List<TypeInformation> classList = new List<TypeInformation>();

        // Get types in Xamarin.Forms.Core assembly.
        GetPublicTypes(typeof(View).GetTypeInfo().Assembly, classList);

        // Get types in Xamarin.Forms.Xaml assembly.
        GetPublicTypes(typeof(Extensions).GetTypeInfo().Assembly, classList);

        // Ensure that all classes have a base type in the list.
        //  (i.e., add Attribute, ValueType, Enum, EventArgs, etc.)
        int index = 0;

        // Watch out! Loops through expanding classList!
        do
        {
            // Get a child type from the list.
            TypeInformation childType = classList[index];

            if (childType.Type != typeof(Object))
            {
                bool hasBaseType = false;
```

```
                // Loop through the list looking for a base type.
                foreach (TypeInformation parentType in classList)
                {
                    if (childType.IsDerivedDirectlyFrom(parentType.Type))
                    {
                        hasBaseType = true;
                    }
                }

                // If there's no base type, add it.
                if (!hasBaseType && childType.BaseType != typeof(Object))
                {
                    classList.Add(new TypeInformation(childType.BaseType, false));
                }
            }
            index++;
        }
        while (index < classList.Count);

        // Now sort the list.
        classList.Sort((t1, t2) =>
        {
            return String.Compare(t1.Type.Name, t2.Type.Name);
        });

        // Start the display with System.Object.
        ClassAndSubclasses rootClass = new ClassAndSubclasses(typeof(Object), false);

        // Recursive method to build the hierarchy tree.
        AddChildrenToParent(rootClass, classList);

        // Recursive method for adding items to StackLayout.
        AddItemToStackLayout(rootClass, 0);
    }

    void GetPublicTypes(Assembly assembly,
                        List<TypeInformation> classList)
    {
        // Loop through all the types.
        foreach (Type type in assembly.ExportedTypes)
        {
            TypeInfo typeInfo = type.GetTypeInfo();

            // Public types only but exclude interfaces.
            if (typeInfo.IsPublic && !typeInfo.IsInterface)
            {
                // Add type to list.
                classList.Add(new TypeInformation(type, true));
            }
        }
    }

    void AddChildrenToParent(ClassAndSubclasses parentClass,
                             List<TypeInformation> classList)
```

```
{
    foreach (TypeInformation typeInformation in classList)
    {
        if (typeInformation.IsDerivedDirectlyFrom(parentClass.Type))
        {
            ClassAndSubclasses subClass =
                new ClassAndSubclasses(typeInformation.Type,
                                       typeInformation.IsXamarinForms);
            parentClass.Subclasses.Add(subClass);
            AddChildrenToParent(subClass, classList);
        }
    }
}

void AddItemToStackLayout(ClassAndSubclasses parentClass, int level)
{
    // If assembly is not Xamarin.Forms, display full name.
    string name = parentClass.IsXamarinForms ? parentClass.Type.Name :
                                               parentClass.Type.FullName;

    TypeInfo typeInfo = parentClass.Type.GetTypeInfo();

    // If generic, display angle brackets and parameters.
    if (typeInfo.IsGenericType)
    {
        Type[] parameters = typeInfo.GenericTypeParameters;
        name = name.Substring(0, name.Length - 2);
        name += "<";

        for (int i = 0; i < parameters.Length; i++)
        {
            name += parameters[i].Name;
            if (i < parameters.Length - 1)
            {
                name += ", ";
            }
        }
        name += ">";
    }

    // Create Label and add to StackLayout.
    Label label = new Label
    {
        Text = String.Format("{0}{1}", new string(' ', 4 * level), name),
        TextColor = parentClass.Type.GetTypeInfo().IsAbstract ?
                        Color.Accent : Color.Default
    };

    stackLayout.Children.Add(label);

    // Now display nested types.
    foreach (ClassAndSubclasses subclass in parentClass.Subclasses)
    {
        AddItemToStackLayout(subclass, level + 1);
```

```
        }
    }
}
```

The recursive `AddChildrenToParent` method assembles the linked list of `ClassAndSubclasses` instances from the flat `classList` collection. The `AddItemToStackLayout` method is also recursive because it is responsible for adding the `ClassesAndSubclasses` linked list to the `StackLayout` object by creating a `Label` view for each class, with a little blank space at the beginning for the proper indentation. The method displays the Xamarin.Forms types with just the class names, but the .NET types include the fully qualified name to distinguish them. The method uses the platform accent color for classes that are not instantiable because they are abstract or static:



Overall, you'll see that the Xamarin.Forms visual elements have the following general hierarchy:

```
System.Object
    BindableObject
        Element
            VisualElement
                View
                    …
                    Layout
                        …
                        Layout<T>
                            …
                Page
                    …
```

Aside from `Object`, all the classes in this abbreviated class hierarchy are implemented in the Xamarin.Forms.Core.dll assembly and associated with a namespace of `Xamarin.Forms`.

Let's examine some of these major classes in detail.

As the name of the `BindableObject` class implies, the primary function of this class is to support data binding—the linking of two properties of two objects so that they maintain the same value. But `BindableObject` also supports styles and the `DynamicResource` markup extension as well. It does this in two ways: through `BindableObject` property definitions in the form of `BindableProperty` objects and also by implementing the .NET `INotifyPropertyChanged` interface. All of this will be discussed in much more detail in this chapter and future chapters.

Let's continue down the hierarchy: as you've seen, user-interface objects in Xamarin.Forms are often arranged on the page in a parent-child hierarchy, and the `Element` class includes support for parent and child relationships.

`VisualElement` is an exceptionally important class in Xamarin.Forms. A visual element is anything in Xamarin.Forms that occupies an area on the screen. The `VisualElement` class defines 28 public properties related to size, location, background color, and other visual and functional characteristics, such as `IsEnabled` and `IsVisible`.

In Xamarin.Forms the word *view* is often used to refer to individual visual objects such as buttons, sliders, and text-entry boxes, but you can see that the `View` class is the parent to the layout classes as well. Interestingly, `View` adds only three public members to what it inherits from `VisualElement`. These are `HorizontalOptions` and `VerticalOptions`—which make sense because these properties don't apply to pages—and `GestureRecognizers` to support touch input.

The descendants of `Layout` are capable of having children views. A child view appears on the screen visually within the boundaries of its parent. Classes that derive from `Layout` can have only one child of type `View`, but the generic `Layout<T>` class defines a `Children` property, which is a collection of multiple child views, including other layouts. You've already seen the `StackLayout`, which arranges its children in a horizontal or vertical stack. Although the `Layout` class derives from `View`, layouts are so important in Xamarin.Forms that they are often considered a category in themselves.

ClassHierarchy lists all the public classes, structures, and enumerations defined in the **Xamarin.Forms.Core** and **Xamarin.Forms.Xaml** assemblies, but it does not list interfaces. Those are important as well, but you'll just have to explore them on your own. (Or enhance the program to list them.)

Nor does **ClassHierarchy** list the many public classes that help implement Xamarin.Forms on the various platforms. In the final chapter of this book, you'll see a version that does.

A peek into BindableObject and BindableProperty

The existence of classes named `BindableObject` and `BindableProperty` is likely to be a little confusing at first. Keep in mind that `BindableObject` is much like `Object` in that it serves as a base class to a large chunk of the Xamarin.Forms API, and particularly to `Element` and hence `VisualElement`.

`BindableObject` provides support for objects of type `BindableProperty`. A `BindableProperty` object extends a CLR property. The best insights into bindable properties come when you create a few of your own—as you'll be doing before the end of this chapter—but you can also glean some understanding by exploring the existing bindable properties.

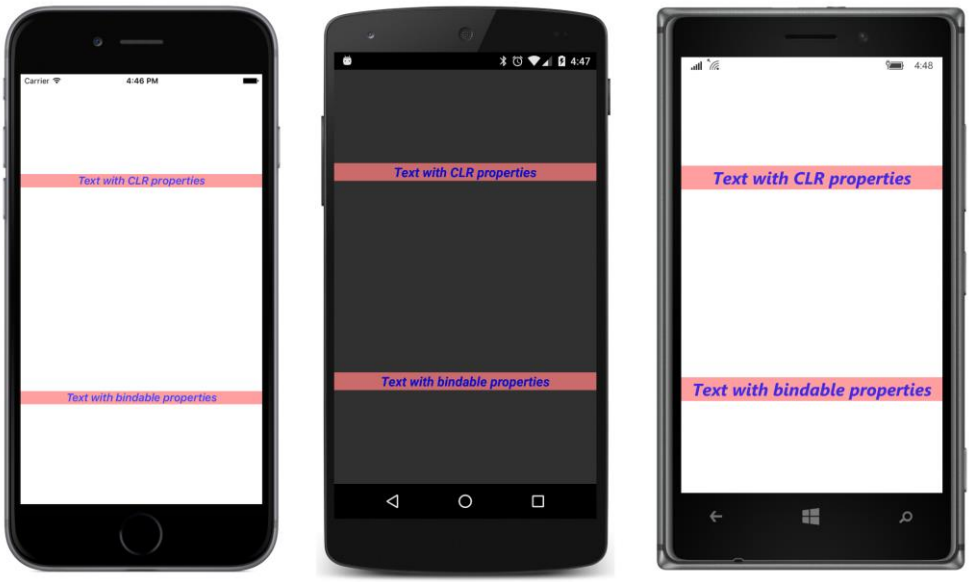
Toward the beginning of Chapter 7, "XAML vs. code," two buttons were created with many of the same property settings, except that the properties of one button were set in code using the C# 3.0 object initialization syntax and the other button was instantiated and initialized in XAML.

Here's a similar (but code-only) program named **PropertySettings** that also creates and initializes two buttons in two different ways. The properties of the first `Label` are set the old-fashioned way, while the properties of the second `Label` are set with a more verbose technique:

```
public class PropertySettingsPage : ContentPage
{
    public PropertySettingsPage()
    {
        Label label1 = new Label();
        label1.Text = "Text with CLR properties";
        label1.IsVisible = true;
        label1.Opacity = 0.75;
        label1.HorizontalTextAlignment = TextAlignment.Center;
        label1.VerticalOptions = LayoutOptions.CenterAndExpand;
        label1.TextColor = Color.Blue;
        label1.BackgroundColor = Color.FromRgb(255, 128, 128);
        label1.FontSize = Device.GetNamedSize(NamedSize.Medium, new Label());
        label1.FontAttributes = FontAttributes.Bold | FontAttributes.Italic;

        Label label2 = new Label();
        label2.SetValue(Label.TextProperty, "Text with bindable properties");
        label2.SetValue(Label.IsVisibleProperty, true);
        label2.SetValue(Label.OpacityProperty, 0.75);
        label2.SetValue(Label.HorizontalTextAlignmentProperty, TextAlignment.Center);
        label2.SetValue(Label.VerticalOptionsProperty, LayoutOptions.CenterAndExpand);
        label2.SetValue(Label.TextColorProperty, Color.Blue);
        label2.SetValue(Label.BackgroundColorProperty, Color.FromRgb(255, 128, 128));
        label2.SetValue(Label.FontSizeProperty,
                        Device.GetNamedSize(NamedSize.Medium, new Label()));
        label2.SetValue(Label.FontAttributesProperty,
                        FontAttributes.Bold | FontAttributes.Italic);

        Content = new StackLayout
        {
```

```
            Children =
            {
                label1,
                label2
            }
        };
    }
}
```

These two ways to set properties are entirely consistent:



Yet the alternative syntax seems very odd. For example:

```
label2.SetValue(Label.TextProperty, "Text with bindable properties");
```

What is that `SetValue` method? `SetValue` is defined by `BindableObject`, from which every visual object derives. `BindableObject` also defines a `GetValue` method.

That first argument to `SetValue` has the name `Label.TextProperty`, which indicates that `TextProperty` is static, but despite its name, it's not a property at all. It's a static *field* of the `Label` class. `TextProperty` is also read-only, and it's defined in the `Label` class something like this:

```
public static readonly BindableProperty TextProperty;
```

That's an object of type `BindableProperty`. Of course, it may seem a little disturbing that a field is named `TextProperty`, but there it is. Because it's static, however, it exists independently of any `Label` objects that might or might not exist.

If you look in the documentation of the `Label` class, you'll see that it defines 10 properties, including `Text`, `TextColor`, `FontSize`, `FontAttributes`, and others. You'll also see 10 corresponding

public static read-only fields of type `BindableProperty` with the names `TextProperty`, `TextColorProperty`, `FontSizeProperty`, `FontAttributesProperty`, and so forth.

These properties and fields are closely related. Indeed, internal to the `Label` class, the `Text` CLR property is defined like this to reference the corresponding `TextProperty` object:

```
public string Text
{
    set { SetValue(Label.TextProperty, value); }
    get { return (string)GetValue(Label.TextProperty); }
}
```

So you see why it is that your application calling `SetValue` with a `Label.TextProperty` argument is exactly equivalent to setting the `Text` property directly, and perhaps just a tinier bit faster!

The internal definition of the `Text` property in `Label` isn't secret information. This is standard code. Although any class can define a `BindableProperty` object, only a class that derives from `BindableObject` can call the `SetValue` and `GetValue` methods that actually implement the property in the class. Casting is required for the `GetValue` method because it's defined as returning `object`.

All the real work involved with maintaining the `Text` property is going on in those `SetValue` and `GetValue` calls. The `BindableObject` and `BindableProperty` objects effectively extend the functionality of standard CLR properties to provide systematic ways to:

- Define properties
- Give properties default values
- Store their current values
- Provide mechanisms for validating property values
- Maintain consistency among related properties in a single class
- Respond to property changes
- Trigger notifications when a property is about to change and has changed
- Support data binding
- Support styles
- Support dynamic resources

The close relationship of a property named `Text` with a `BindableProperty` named `TextProperty` is reflected in the way that programmers speak about these properties: Sometimes a programmer says that the `Text` property is "backed by" a `BindableProperty` named `TextProperty` because `TextProperty` provides infrastructure support for `Text`. But a common shortcut is to say that `Text` is itself a "bindable property," and generally no one will be confused.

Not every Xamarin.Forms property is a bindable property. Neither the `Content` property of `ContentPage` nor the `Children` property of `Layout<T>` is a bindable property. Of the 28 properties defined by `VisualElement`, 26 are backed by bindable properties, but the `Bounds` property and the `Resources` properties are not.

The `Span` class used in connection with `FormattedString` does not derive from `BindableObject`. Therefore, `Span` does not inherit `SetValue` and `GetValue` methods, and it cannot implement `BindableProperty` objects.

This means that the `Text` property of `Label` is backed by a bindable property, but the `Text` property of `Span` is not. Does it make a difference?

Of course it makes a difference! If you recall the **DynamicVsStatic** program in the previous chapter, you discovered that `DynamicResource` worked on the `Text` property of `Label` but not the `Text` property of `Span`. Can it be that `DynamicResource` works only with bindable properties?

This supposition is pretty much confirmed by the definition of the following public method defined by `Element`:

```
public void SetDynamicResource(BindableProperty property, string key);
```

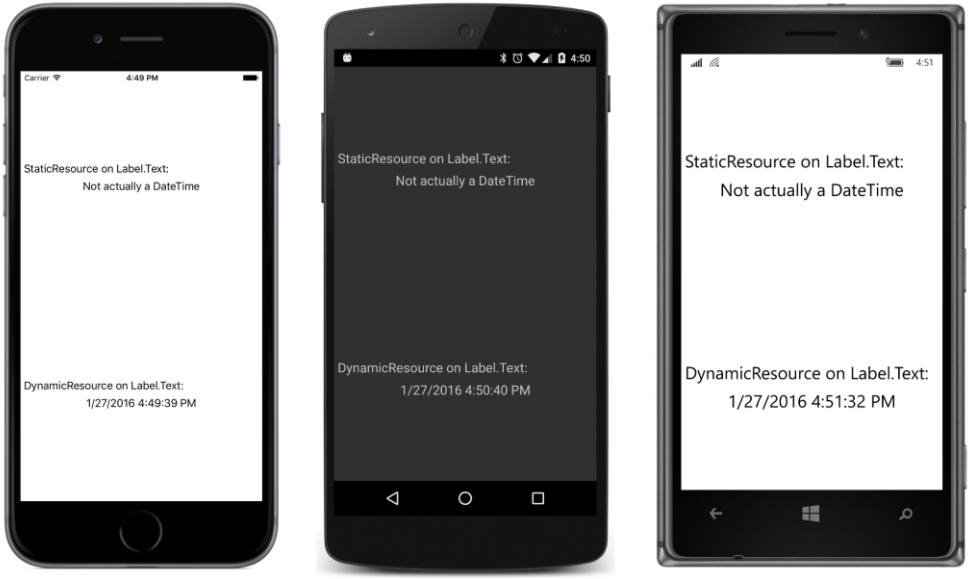
This is how a dictionary key is associated with a particular property of an element when that property is the target of a `DynamicResource` markup extension.

This `SetDynamicResource` method also allows you to set a dynamic resource link on a property in code. Here's the page class from a code-only version of **DynamicVsStatic** called **DynamicVsStaticCode**. It's somewhat simplified to exclude the use of a `FormattedString` and `Span` object, but otherwise it pretty accurately mimics how the previous XAML file is parsed and, in particular, how the `Text` properties of the `Label` elements are set by the XAML parser:

```
public class DynamicVsStaticCodePage : ContentPage
{
    public DynamicVsStaticCodePage()
    {
        Padding = new Thickness(5, 0);

        // Create resource dictionary and add item.
        Resources = new ResourceDictionary
        {
            { "currentDateTime", "Not actually a DateTime" }
        };

        Content = new StackLayout
        {
            Children =
            {
                new Label
                {
                    Text = "StaticResource on Label.Text:",
                    VerticalOptions = LayoutOptions.EndAndExpand,
```

```
                    FontSize = Device.GetNamedSize(NamedSize.Medium, typeof(Label))
                },

                new Label
                {
                    Text = (string)Resources["currentDateTime"],
                    VerticalOptions = LayoutOptions.StartAndExpand,
                    HorizontalTextAlignment = TextAlignment.Center,
                    FontSize = Device.GetNamedSize(NamedSize.Medium, typeof(Label))
                },

                new Label
                {
                    Text = "DynamicResource on Label.Text:",
                    VerticalOptions = LayoutOptions.EndAndExpand,
                    FontSize = Device.GetNamedSize(NamedSize.Medium, typeof(Label))
                }
            }
        };

        // Create the final label with the dynamic resource.
        Label label = new Label
        {
            VerticalOptions = LayoutOptions.StartAndExpand,
            HorizontalTextAlignment = TextAlignment.Center,
            FontSize = Device.GetNamedSize(NamedSize.Medium, typeof(Label))
        };

        label.SetDynamicResource(Label.TextProperty, "currentDateTime");

        ((StackLayout)Content).Children.Add(label);

        // Start the timer going.
        Device.StartTimer(TimeSpan.FromSeconds(1),
            () =>
            {
                Resources["currentDateTime"] = DateTime.Now.ToString();
                return true;
            });
    }
}
```

The `Text` property of the second `Label` is set directly from the dictionary entry and makes the use of the dictionary seem a little pointless in this context. But the `Text` property of the last `Label` is bound to the dictionary key through a call to `SetDynamicResource`, which allows the property to be updated when the dictionary contents change:



Consider this: What would the signature of this `SetDynamicResource` method be if it could not refer to a property using the `BindableProperty` object? It's easy to reference a property *value* in method calls, but not the property itself. There are a couple of ways, such as the `PropertyInfo` class in the `System.Reflection` namespace or the LINQ `Expression` object. But the `BindableProperty` object is designed specifically for this purpose, as well as the essential job of handling the underlying link between the property and the dictionary key.

Similarly, when we explore styles in the next chapter, you'll encounter a `Setter` class used in connection with styles. `Setter` defines a property named `Property` of type `BindableProperty`, which mandates that any property targeted by a style must be backed by a bindable property. This allows a style to be defined prior to the elements targeted by the style.

Likewise for data bindings. The `BindableObject` class defines a `SetBinding` method that is very similar to the `SetDynamicResource` method defined on `Element`:

```
public void SetBinding(BindableProperty targetProperty, BindingBase binding);
```

Again, notice the type of the first argument. Any property targeted by a data binding must be backed by a bindable property.

For these reasons, whenever you create a custom view and need to define public properties, your default inclination should be to define them as bindable properties. Only if after careful consideration you conclude that it is not necessary or appropriate for the property to be targeted by a style or a data binding should you retreat and define an ordinary CLR property instead.

So whenever you create a class that derives from `BindableObject`, one of the first pieces of code you should be typing in that class begins "public static readonly BindableProperty"—perhaps the most characteristic sequence of four words in all of Xamarin.Forms programming.

Defining bindable properties

Suppose you'd like an enhanced `Label` class that lets you specify font sizes in units of points. Let's call this class `AltLabel` for "alternative `Label`." It derives from `Label` and includes a new property named `PointSize`.

Should `PointSize` be backed by a bindable property? Of course! (Although the real advantages of doing so won't be demonstrated until upcoming chapters.)

The code-only `AltLabel` class is included in the **Xamarin.FormsBook.Toolkit** library, so it's accessible to multiple applications. The new `PointSize` property is implemented with a `BindableProperty` object named `PointSizeProperty` and a CLR property named `PointSize` that references `PointSizeProperty`:

```
public class AltLabel : Label
{
    public static readonly BindableProperty PointSizeProperty … ;
    …
    public double PointSize
    {
        set { SetValue(PointSizeProperty, value); }
        get { return (double)GetValue(PointSizeProperty); }
    }
    …
}
```

Both the field and the property definition must be public.

Because `PointSizeProperty` is defined as `static` and `readonly`, it must be assigned either in a static constructor or right in the field definition, after which it cannot be changed. Generally, a `BindableProperty` object is assigned in the field definition by using the static `BindableProperty.Create` method. Four arguments are required (shown here with the argument names):

- `propertyName` The text name of the property (in this case "PointSize")
- `returnType` The type of the property (a `double` in this example)
- `declaringType` The type of the class defining the property (`AltLabel`)
- `defaultValue` A default value (let's say 8 points)

The second and third arguments are generally defined with `typeof` expressions. Here's the assignment statement with these four arguments passed to `BindableProperty.Create`:

```
public class AltLabel : Label
{
    public static readonly BindableProperty PointSizeProperty =
        BindableProperty.Create("PointSize",        // propertyName
                                typeof(double),     // returnType
                                typeof(AltLabel),   // declaringType
                                8.0,                // defaultValue
                                …);
    …
}
```

Notice that the default value is specified as 8.0 rather than just 8. Because `BindableProperty.Create` is designed to handle properties of any type, the `defaultValue` parameter is defined as `object`. When the C# compiler encounters just an 8 as that argument, it will assume that the 8 is an `int` and pass an `int` to the method. The problem won't be revealed until run time, however, when the `BindableProperty.Create` method will be expecting the default value to be of type `double` and respond by raising a `TypeInitializationException`.

You must be explicit about the type of the value you're specifying as the default. Not doing so is a very common error in defining bindable properties. A *very* common error.

`BindableProperty.Create` also has six optional arguments. Here they are with the argument names and their purpose:

- `defaultBindingMode` Used in connection with data binding
- `validateValue` A callback to check for a valid value
- `propertyChanged` A callback to indicate when the property has changed
- `propertyChanging` A callback to indicate when the property is about to change
- `coerceValue` A callback to coerce a set value to another value (for example, to restrict the values to a range)
- `defaultValueCreator` A callback to create a default value. This is generally used to instantiate a default object that can't be shared among all instances of the class; for example, a collection object such as `List` or `Dictionary`.

Do not perform any validation, coercion, or property-changed handling in the CLR property. The CLR property should be restricted to `SetValue` and `GetValue` calls. Everything else should be done in the callbacks provided by the bindable property infrastructure.

It is very rare that a particular call to `BindableProperty.Create` would need all of these optional arguments. For that reason, these optional arguments are commonly indicated with the named argument feature introduced in C# 4.0. To specify a particular optional argument, use the argument name followed by a colon. For example:

```
public class AltLabel : Label
{
    public static readonly BindableProperty PointSizeProperty =
        BindableProperty.Create("PointSize",        // propertyName
                                typeof(double),     // returnType
                                typeof(AltLabel),   // declaringType
                                8.0,                // defaultValue
                                propertyChanged: OnPointSizeChanged);
    …
}
```

Without a doubt, `propertyChanged` is the most important of the optional arguments because the class uses this callback to be notified when the property changes, either directly from a call to `SetValue` or through the CLR property.

In this example, the property-changed handler is called `OnPointSizeChanged`. It will be called only when the property truly changes and not when it's simply set to the same value. However, because `OnPointSizeChanged` is referenced from a static field, the method itself must also be static. Here's what it looks like:

```
public class AltLabel : Label
{
    …
    static void OnPointSizeChanged(BindableObject bindable, object oldValue, object newValue)
    {
        …
    }
    …
}
```

This seems a little odd. We might have multiple `AltLabel` instances in a program, yet whenever the `PointSize` property changes in any one of these instances, this same static method is called. How does the method know exactly which `AltLabel` instance has changed?

The method can tell which instance's property has changed because that instance is always the first argument to the property-changed handler. Although that first argument is defined as a `BindableObject`, in this case it's actually of type `AltLabel` and indicates which `AltLabel` instance's property has changed. This means that you can safely cast the first argument to an `AltLabel` instance:

```
static void OnPointSizeChanged(BindableObject bindable, object oldValue, object newValue)
{
    AltLabel altLabel = (AltLabel)bindable;
    …
}
```

You can then reference anything in the particular instance of `AltLabel` whose property has changed. The second and third arguments are actually of type `double` for this example and indicate the previous value and the new value.

Often it's convenient for this static method to call an instance method with the arguments converted to their actual types:

```
public class AltLabel : Label
{
    …
    static void OnPointSizeChanged(BindableObject bindable, object oldValue, object newValue)
    {
        ((AltLabel)bindable).OnPointSizeChanged((double)oldValue, (double)newValue);
    }

    void OnPointSizeChanged(double oldValue, double newValue)
    {
        …
    }
}
```

The instance method can then make use of any instance properties or methods of the underlying base class as it would normally.

For this class, this `OnPointSizeChanged` method needs to set the `FontSize` property based on the new point size and a conversion factor. In addition, the constructor needs to initialize the `FontSize` property based on the default `PointSize` value. This is done through a simple `SetLabelFontSize` method. Here's the final complete class:

```
public class AltLabel : Label
{
    public static readonly BindableProperty PointSizeProperty =
        BindableProperty.Create("PointSize",        // propertyName
                                typeof(double),     // returnType
                                typeof(AltLabel),   // declaringType
                                8.0,                // defaultValue
                                propertyChanged: OnPointSizeChanged);

    public AltLabel()
    {
        SetLabelFontSize((double)PointSizeProperty.DefaultValue);
    }

    public double PointSize
    {
        set { SetValue(PointSizeProperty, value); }
        get { return (double)GetValue(PointSizeProperty); }
    }

    static void OnPointSizeChanged(BindableObject bindable, object oldValue, object newValue)
    {
        ((AltLabel)bindable).OnPointSizeChanged((double)oldValue, (double)newValue);
    }

    void OnPointSizeChanged(double oldValue, double newValue)
    {
        SetLabelFontSize(newValue);
    }

    void SetLabelFontSize(double pointSize)
```

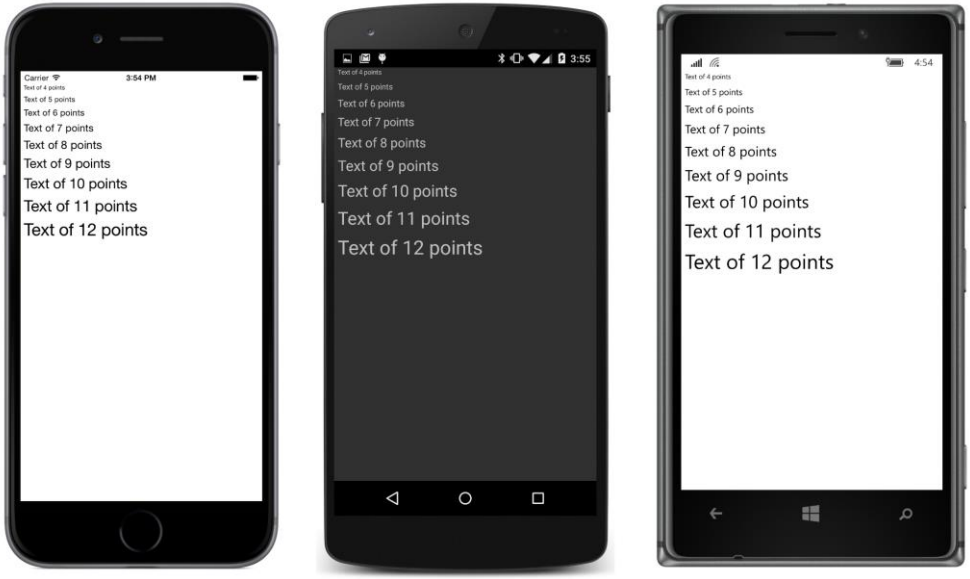
```
    {
        FontSize = 160 * pointSize / 72;
    }
}
```

It is also possible for the instance `OnPointSizeChanged` property to access the `PointSize` property directly rather than use `newValue`. By the time the property-changed handler is called, the underlying property value has already been changed. However, you don't have direct access to that underlying value, as you do when a private field backs a CLR property. That underlying value is private to `BindableObject` and accessible only through the `GetValue` call.

Of course, nothing prevents code that's using `AltLabel` from setting the `FontSize` property and overriding the `PointSize` setting, but let's hope such code is aware of that. Here's some code that is—a program called **PointSizedText,** which uses `AltLabel` to display point sizes from 4 through 12:

```
<ContentPage xmlns="http://xamarin.com/schemas/2014/forms"
             xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
             xmlns:toolkit=
                 "clr-namespace:Xamarin.FormsBook.Toolkit;assembly=Xamarin.FormsBook.Toolkit"
             x:Class="PointSizedText.PointSizedTextPage">
    <ContentPage.Padding>
        <OnPlatform x:TypeArguments="Thickness"
                    iOS="5, 20, 0, 0"
                    Android="5, 0, 0, 0"
                    WinPhone="5, 0, 0, 0" />
    </ContentPage.Padding>

    <StackLayout x:Name="stackLayout">
        <toolkit:AltLabel Text="Text of 4 points" PointSize="4" />
        <toolkit:AltLabel Text="Text of 5 points" PointSize="5" />
        <toolkit:AltLabel Text="Text of 6 points" PointSize="6" />
        <toolkit:AltLabel Text="Text of 7 points" PointSize="7" />
        <toolkit:AltLabel Text="Text of 8 points" PointSize="8" />
        <toolkit:AltLabel Text="Text of 9 points" PointSize="9" />
        <toolkit:AltLabel Text="Text of 10 points" PointSize="10" />
        <toolkit:AltLabel Text="Text of 11 points" PointSize="11" />
        <toolkit:AltLabel Text="Text of 12 points" PointSize="12" />
    </StackLayout>
</ContentPage>
```

And here are the screenshots:



The read-only bindable property

Suppose you're working with an application in which it's convenient to know the number of words in the text that is displayed by a `Label` element. Perhaps you'd like to build that facility right into a class that derives from `Label`. Let's call this new class `CountedLabel`.

By now, your first thought should be to define a `BindableProperty` object named `WordCountProperty` and a corresponding CLR property named `WordCount`.

But wait: It only makes sense for this `WordCount` property to be set from within the `CountedLabel` class. That means the `WordCount` CLR property should not have a public `set` accessor. It should be defined this way:

```
public int WordCount
{
    private set { SetValue(WordCountProperty, value); }
    get { return (double)GetValue(WordCountProperty); }
}
```

The `get` accessor is still public, but the `set` accessor is private. Is that sufficient?

Not exactly. Despite the private `set` accessor in the CLR property, code external to `CountedLabel` can still call `SetValue` with the `CountedLabel.WordCountProperty` bindable property object. That type of property setting should be prohibited as well. But how can that work if the `WordCountProperty` object is public?

The solution is to make a *read-only* bindable property by using the `BindableProperty.CreateReadOnly` method. The

Xamarin.Forms API itself defines several read-only bindable properties—for example, the `Width` and `Height` properties defined by `VisualElement`.

Here's how you can make one of your own:

The first step is to call `BindableProperty.CreateReadOnly` with the same arguments as for `BindableProperty.Create`. However, the `CreateReadOnly` method returns an object of `BindablePropertyKey` rather than `BindableProperty`. Define this object as `static` and `readonly`, as with the `BindableProperty`, but make it be private to the class:

```
public class CountedLabel : Label
{
    static readonly BindablePropertyKey WordCountKey =
        BindableProperty.CreateReadOnly("WordCount",            // propertyName
                                        typeof(int),            // returnType
                                        typeof(CountedLabel),   // declaringType
                                        0);                     // defaultValue
    …
}
```

Don't think of this `BindablePropertyKey` object as an encryption key or anything like that. It's much simpler—really just an object that is private to the class.

The second step is to make a public `BindableProperty` object by using the `BindableProperty` property of the `BindablePropertyKey`:

```
public class CountedLabel : Label
{
    …
    public static readonly BindableProperty WordCountProperty = WordCountKey.BindableProperty;
    …
}
```

This `BindableProperty` object is public, but it's a special kind of `BindableProperty`: It cannot be used in a `SetValue` call. Attempting to do so will raise an `InvalidOperationException`.

However, there is an overload of the `SetValue` method that accepts a `BindablePropertyKey` object. The CLR `set` accessor can call `SetValue` using this object, but this `set` accessor must be private to prevent the property from being set outside the class:

```
public class CountedLabel : Label
{
    …
    public int WordCount
    {
        private set { SetValue(WordCountKey, value); }
        get { return (int)GetValue(WordCountProperty); }
    }
    …
}
```

The `WordCount` property can now be set from within the `CountedLabel` class. But when should the

class set it? This `CountedLabel` class derives from `Label`, but it needs to detect when the `Text` property has changed so that it can count up the words.

Does `Label` have a `TextChanged` event? No it does not. However, `BindableObject` implements the `INotifyPropertyChanged` interface. This is a very important .NET interface, particularly for applications that implement the Model-View-ViewModel (MVVM) architecture. In Chapter 18 you'll see how to use it in your own data classes.

The `INotifyPropertyChanged` interface is defined in the `System.ComponentModel` namespace like so:

```
public interface INotifyPropertyChanged
{
    event PropertyChangedEventHandler PropertyChanged;
}
```

Every class that derives from `BindableObject` automatically fires this `PropertyChanged` event whenever any property backed by a `BindableProperty` changes. The `PropertyChangedEventArgs` object that accompanies this event includes a property named `PropertyName` of type `string` that identifies the property that has changed.

So all that's necessary is for `CountedLabel` to attach a handler for the `PropertyChanged` event and check for a property name of "Text". From there it can use whatever technique it wants for calculating a word count. The complete `CountedLabel` class uses a lambda function on the `PropertyChanged` event. The handler calls `Split` to break the string into words and see how many pieces result. The `Split` method splits the text based on spaces, dashes, and em dashes (Unicode \u2014):

```
public class CountedLabel : Label
{
    static readonly BindablePropertyKey WordCountKey =
        BindableProperty.CreateReadOnly("WordCount",            // propertyName
                                        typeof(int),            // returnType
                                        typeof(CountedLabel),   // declaringType
                                        0);                     // defaultValue

    public static readonly BindableProperty WordCountProperty = WordCountKey.BindableProperty;

    public CountedLabel()
    {
        // Set the WordCount property when the Text property changes.
        PropertyChanged += (object sender, PropertyChangedEventArgs args) =>
            {
                if (args.PropertyName == "Text")
                {
                    if (String.IsNullOrEmpty(Text))
                    {
                        WordCount = 0;
                    }
                    else
                    {
                        WordCount = Text.Split(' ', '-', '\u2014').Length;
```

```
                    }
                }
            };
    }

    public int WordCount
    {
        private set { SetValue(WordCountKey, value); }
        get { return (int)GetValue(WordCountProperty); }
    }
}
```

The class includes a `using` directive for the `System.ComponentModel` namespace for the `PropertyChangedEventArgs` argument to the handler. Watch out: Xamarin.Forms defines a class named `PropertyChangingEventArgs` (present tense). That's not what you want for the `PropertyChanged` handler. You want `PropertyChangedEventArgs` (past tense).

Because this call of the `Split` method splits the text at blank characters, dashes, and em dashes, you might assume that `CountedLabel` will be demonstrated with text that contains some dashes and em dashes. This is true. The **BaskervillesCount** program is a variation of the **Baskervilles** program from Chapter 3, but here the paragraph of text is displayed with a `CountedLabel`, and a regular `Label` is included to display the word count:

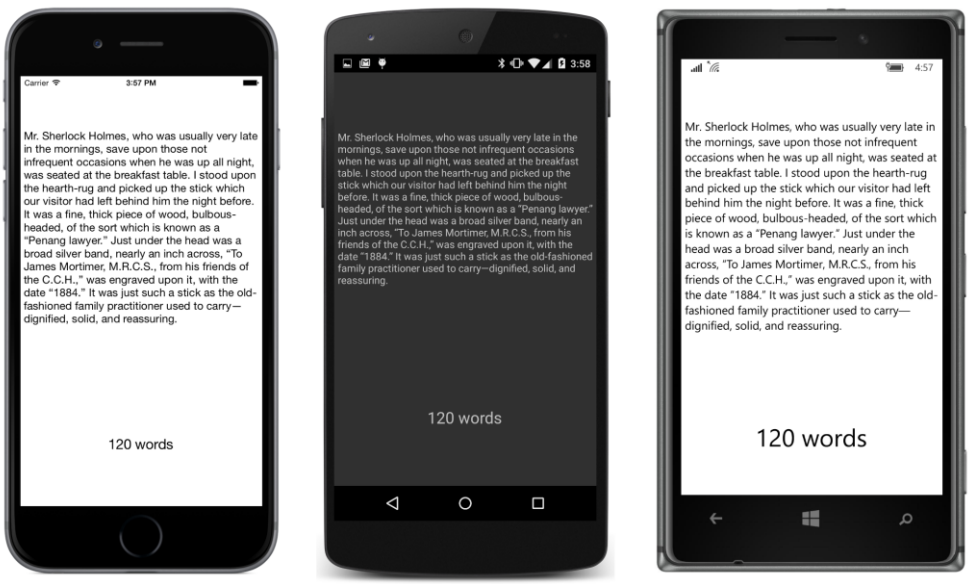
```
<ContentPage xmlns="http://xamarin.com/schemas/2014/forms"
             xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
             xmlns:toolkit=
                 "clr-namespace:Xamarin.FormsBook.Toolkit;assembly=Xamarin.FormsBook.Toolkit"
             x:Class="BaskervillesCount.BaskervillesCountPage"
             Padding="5, 0">

    <StackLayout>
        <toolkit:CountedLabel x:Name="countedLabel"
                              VerticalOptions="CenterAndExpand"
                              Text=
"Mr. Sherlock Holmes, who was usually very late in
the mornings, save upon those not infrequent
occasions when he was up all night, was seated at
the breakfast table. I stood upon the hearth-rug
and picked up the stick which our visitor had left
behind him the night before. It was a fine, thick
piece of wood, bulbous-headed, of the sort which
is known as a &#x201C;Penang lawyer.&#x201D; Just
under the head was a broad silver band, nearly an
inch across, &#x201C;To James Mortimer, M.R.C.S.,
from his friends of the C.C.H.,&#x201D; was engraved
upon it, with the date &#x201C;1884.&#x201D; It was
just such a stick as the old-fashioned family
practitioner used to carry&#x2014;dignified, solid,
and reassuring." />

        <Label x:Name="wordCountLabel"
               Text="???"
```

```
                FontSize="Large"
                VerticalOptions="CenterAndExpand"
                HorizontalOptions="Center" />

    </StackLayout>
</ContentPage>
```

That regular `Label` is set in the code-behind file:

```
public partial class BaskervillesCountPage : ContentPage
{
    public BaskervillesCountPage()
    {
        InitializeComponent();

        int wordCount = countedLabel.WordCount;
        wordCountLabel.Text = wordCount + " words";
    }
}
```

The word count that it calculates is based on the assumption that all hyphens in the text separate two words and that "hearth-rug" and "bulbous-headed" should be counted as two words each. That's not always true, of course, but word counts are not quite as algorithmically simple as this code might imply:



How would the program be structured if the text changed dynamically while the program was running? In that case, it would be necessary to update the word count whenever the `WordCount` property of the `CountedLabel` object changed. You could attach a `PropertyChanged` handler on the `CountedLabel` object and check for the property named "WordCount".

However, exercise caution if you try to set such an event handler from XAML—for example, like so:

```
<toolkit:CountedLabel x:Name="countedLabel"
                      VerticalOptions="CenterAndExpand"
                      PropertyChanged="OnCountedLabelPropertyChanged"
                      Text=" … " />
```

You'll probably want to code the event handler in the code-behind file like this:

```
void OnCountedLabelPropertyChanged(object sender,
                                   PropertyChangedEventArgs args)
{
    wordCountLabel.Text = countedLabel.WordCount + " words";
}
```

That handler will fire when the `Text` property is set by the XAML parser, but the event handler is trying to set the `Text` property of the second `Label`, which hasn't been instantiated yet, which means that the `wordCountLabel` field is still set to `null`. This is an issue that will come up again in Chapter 15 when working with interactive controls, but it will be pretty much solved when we work with data binding in Chapter 16.

There is another variation of a bindable property coming up in Chapter 14 on the `AbsoluteLayout`: this is the *attached bindable property,* and it is very useful in implementing certain types of layouts, as you'll also discover in Chapter 26, "Custom layouts."

Meanwhile, let's look at one of the most important applications of bindable properties: styles.