msdn training

Module 10: Inheritance in C#

Contents

This course is based on the prerelease Beta 1 version of Microsoft® Visual Studio .NET. Content in the final release of the course may be different from the content included in this prerelease version. All labs in the course are to be completed with the Beta 1 version of Visual Studio .NET.

Microsoft

Overview

- Deriving Classes
- Implementing Methods
- Using Sealed Classes
- Using Interfaces
- Using Abstract Classes

Inheritance, in an object-oriented system, is the ability of an object to inherit data and functionality from its parent object. Therefore, a child object can substitute for the parent object. Also, by using inheritance, you can create new classes from existing classes instead of starting at the beginning and creating them new. You can then write new code to add the features required in the new class. The parent class on which the new class is based is known as a *base class*, and the child class is known as a *derived class*.

When you create a derived class, it is important to remember that a derived class can substitute for the base class type. Therefore, inheritance is a type-classification mechanism in addition to a code-reuse mechanism, and the former is more important than the latter.

In this module, you will learn how to derive a class from a base class. You will also learn how to implement methods in a derived class by defining them as virtual methods in the base class and overriding or hiding them in the derived class, as required. You will learn how to seal a class so that it cannot be derived from. You will also learn how to implement interfaces and abstract classes, which define the terms of a contract to which derived classes must adhere.

After completing this module, you will be able to:

- Derive a new class from a base class, and call members and constructors of the base class from the derived class.
- Declare methods as **virtual** and **override** or hide them as required.
- Seal a class so that it cannot be derived from.
- Implement interfaces by using both the implicit as well as the explicit methods.
- Describe the use of abstract classes and their implementation of interfaces.

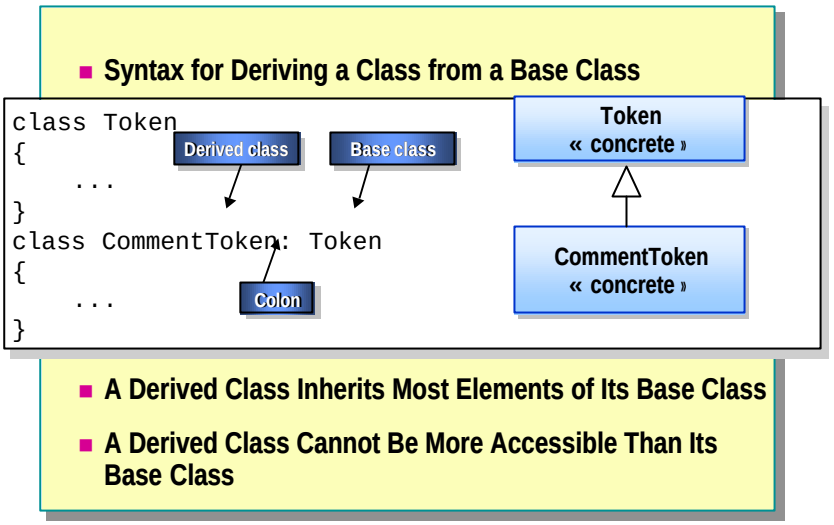
Deriving Classes

- Extending Base Classes
- Accessing Base Class Members
- Calling Base Class Constructors

You can only derive a class from a base class if the base class was designed to enable inheritance. This is because objects must have the proper structure or inheritance cannot work effectively. A base class that is designed for inheritance should make this fact clear. If a new class is derived from a base class that is not designed appropriately, then the base class might change at some later time, and this would make the derived class inoperable.

In this section, you will learn how to derive a class from a base class, and how to access the members and constructors of the base class from the derived class.

Extending Base Classes



Deriving a class from a base class is also known as *extending* the base class. A C# class can extend at most one class.

Syntax for Deriving a Class

To specify that one class is derived from another, you use the following syntax:

```
class Derived: Base
{
    ...
}
```

The elements of this syntax are labeled on the slide. When you declare a derived class, the base class is specified after a colon. The white space around the colon is not significant. The recommended style for using this syntax is to include no spaces before the colon and a single space after it.

Derived Class Inheritance

A derived class inherits everything from its base class except for the base class constructors and destructors. It usually adds its own members to those that it inherits from its base class. Public members of the base class are implicitly public members of the derived class. Private members of the base class, though inherited by the derived class, are accessible only to the members of the base class.

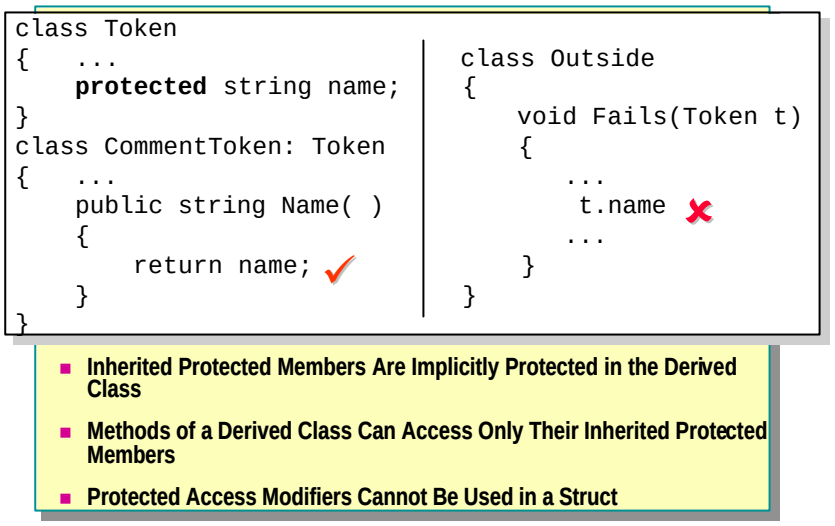
Accessibility of a Derived Class

A derived class cannot be more accessible than its base class. For example, it is not possible to derive a public class from a private class, as is shown in the following code:

```
class Example
{
    private class NestedBase { }
    public class NestedDerived: NestedBase { } // Error
}
```

The C# syntax for deriving one class from another is also allowed in C++, where it implicitly specifies a private inheritance relationship between the derived and base classes. C# has no private inheritance; all inheritance is public.

Accessing Base Class Members



The meaning of the **protected** access modifier depends on the relationship between the class that has the modifier and the class that seeks to access the members that use the modifier.

Members of a derived class can access all of the protected members of their base class. To a derived class, the **protected** keyword behaves like the **public** keyword. Hence, in the code fragment shown on the slide, the **Name** method of **CommentToken** can access the string *name*, which is protected inside **Token**. It is protected inside **Token** because **CommentToken** has specified **Token** as its base class.

However, between two classes that are not related by a derived-class and base-class relationship, protected members of one class act like private members for the other class. Hence, in the other code fragment shown on the slide, the **Fails** method of **Outside** cannot access the string *name*, which is protected inside **Token** because **Outside** does not specify **Token** as its base class.

Inherited Protected Members

When a derived class inherits a protected member, that member is also implicitly a protected member of the derived class. This means that protected members are accessible to all directly and indirectly derived classes of the base class. This is shown in the following example:

```
class Base
{
    protected string name;
}

class Derived: Base
{
}

class FurtherDerived: Derived
{
    void Compiles( )
    {
        Console.WriteLine(name); // Okay
    }
}
```

Protected Members and Methods

Methods of a derived class can only access their own inherited protected members. They cannot access the protected members of the base class through references to the base class. For example, the following code will generate an error:

```
class CommentToken: Token
{
    void AlsoFails(Token t)
    {
        Console.WriteLine(t.name); // Compile-time error
    }
}
```

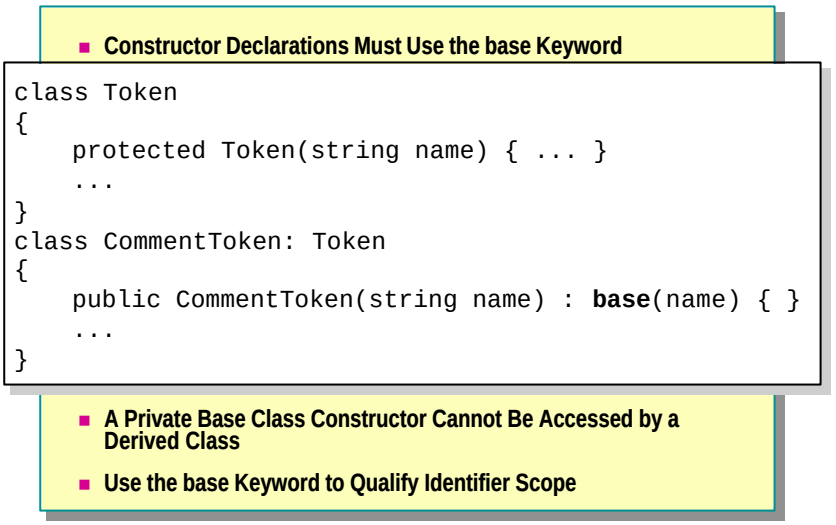
Tip Many coding guidelines recommend keeping all data private and using protected access only for methods.

Protected Members and structs

A **struct** does not support inheritance. Consequently, you cannot derive from a **struct**, and, therefore, the **protected** access modifier cannot be used in a **struct**. For example, the following code will generate an error:

```
struct Base
{
    protected string name; // Compile-time error
}
```

Calling Base Class Constructors



To call a base class constructor from the derived class constructor, use the keyword **base**. The syntax for this keyword is as follows:

```
C(...): base( ) {...}
```

The colon and the accompanying base class constructor call are together known as the *constructor initializer*.

Constructor Declarations

If the derived class does not explicitly call a base class constructor, the C# compiler will implicitly use a constructor initializer of the form `:base( )`. This implies that a constructor declaration of the form

```
C(...) {...}
```

is equivalent to

```
C(...): base( ) {...}
```

Often this implicit behavior is perfectly adequate because:

- A class with no explicit base classes implicitly extends the **System.Object** class, which contains a public parameterless constructor.
- If a class does not contain a constructor, the compiler will automatically provide a public parameterless constructor called the default constructor.

If a class provides an explicit constructor of its own, the compiler will not create a default constructor. However, if the specified constructor does not match any constructor in the base class, the compiler will generate an error as shown in the following code:

```
class Token
{
    protected Token(string name) { ... }
}

class CommentToken: Token
{
    public CommentToken(string name) { ... } // Error here
}
```

The error occurs because the **CommentToken** constructor implicitly contains a `:base( )` constructor initializer, but the base class **Token** does not contain a parameterless constructor. You can fix this error by using the code shown on the slide.

Constructor Access Rules

The access rules for a derived constructor to call a base class constructor are exactly the same as those for regular methods. For example, if the base class constructor is private, then the derived class cannot access it:

```
class NonDerivable
{
    private NonDerivable( ) { ... }
}

class Impossible: NonDerivable
{
    public Impossible( ) { ... } // Compile-time error
}
```

In this case, there is no way for a derived class to call the base class constructor.

Scoping an Identifier

You can use the keyword **base** to also qualify the scope of an identifier. This can be useful, since a derived class is permitted to declare members that have the same names as base class members. The following code provides an example:

```
class Token
{
    protected string name;
}
class CommentToken: Token
{
    public void Method(string name)
    {
        base.name = name;
    }
}
```

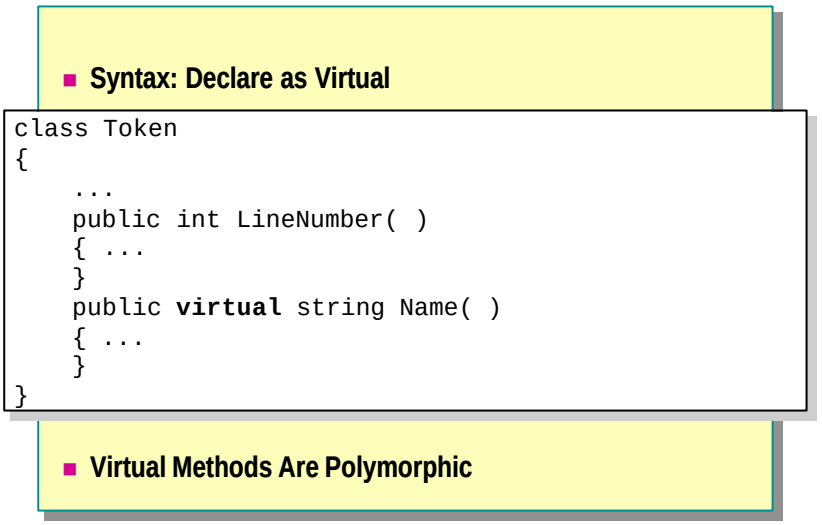
Note Unlike in C++, the name of the base class, such as **Token** in the example in the slide, is not used. The keyword **base** unambiguously refers to the base class because in C# a class can extend one base class at most.

Implementing Methods

- Defining Virtual Methods
- Working with Virtual Methods
- Overriding Methods
- Working with Override Methods
- Using new to Hide Methods
- Working with the new Keyword
- Practice: Implementing Methods
- Quiz: Spot the Bugs

You can redefine the methods of a base class in a derived class when the methods of the base class have been designed for overriding. In this section, you will learn how to use the **virtual**, **override**, and **hide** method types to implement this functionality.

Defining Virtual Methods



A virtual method specifies *an* implementation of a method that can be polymorphically overridden in a derived class. Conversely, a non-virtual method specifies *the only* implementation of a method. You cannot polymorphically override a non-virtual method in a derived class.

Note In C#, whether a class contains a virtual method or not is a good indication of whether the author designed it to be used as a base class.

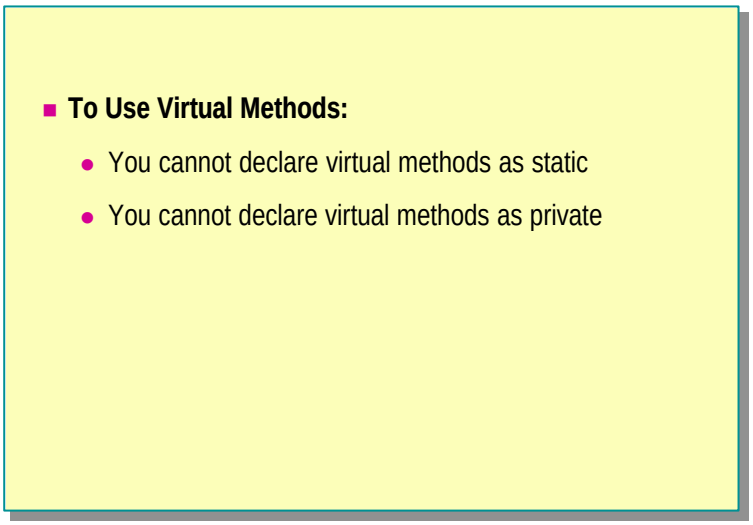
Keyword Syntax

To declare a virtual method, you use the **virtual** keyword. The syntax for this keyword is shown on the slide.

When you declare a virtual method, it must contain a method body. If it does not contain a body, the compiler will generate an error, as shown:

```
class Token
{
    public virtual string Name( ); // Compile-time error
}
```

Working with Virtual Methods



To use virtual methods effectively, you need to understand the following:

- You cannot declare virtual methods as static.

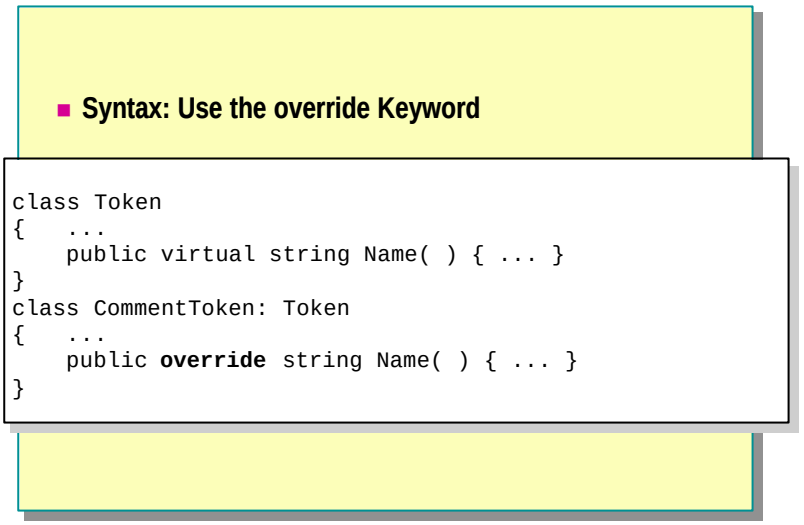
  You cannot qualify virtual methods as static because static methods are class methods and polymorphism works on objects, not on classes.

- You cannot declare virtual methods as private.

  You cannot declare virtual methods as private because they cannot be polymorphically overridden in a derived class. Following is an example:

```
class Token
{
    private virtual string Name( ) { ... }
    // Compile-time error
}
```

Overriding Methods



An override method specifies *another* implementation of a virtual method. You define virtual methods in a base class, and they can be polymorphically overridden in a derived class.

Keyword Syntax

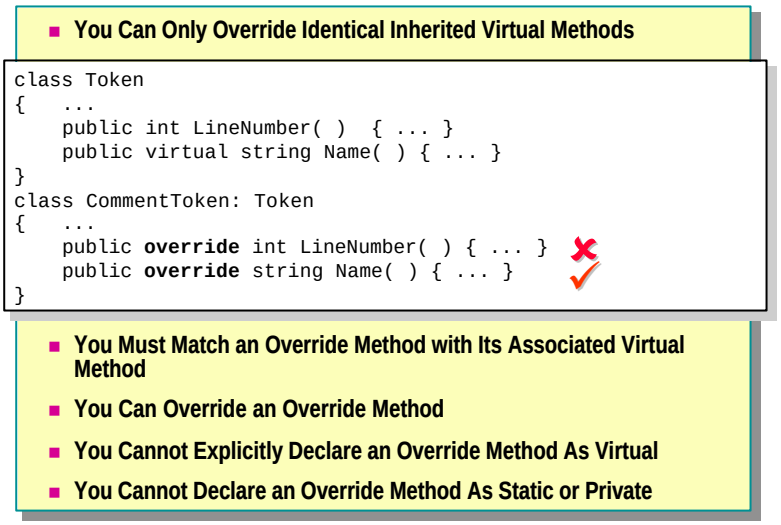
You declare an override method by using the keyword **override**, as shown in the following code:

```
class Token
{   ...
        public virtual string Name( ) { ... }
}
class CommentToken: Token
{   ...
        public override string Name( ) { ... }
}
```

As with a virtual method, you must include a method body in an override method or the compiler generates an error. Following is an example:

```
class Token
{
    public virtual string Name( ) { ... }
}
class CommentToken: Token
{
    public override string Name( ); // Compile-time error
}
```

Working with Override Methods



To use override methods effectively, you must understand a few important restrictions:

- You can only override identical inherited virtual methods.
- You must match an override method with its associated virtual method.
- You can override an override method.
- You cannot implicitly declare an override method as virtual.
- You cannot declare an override method as static or private.

Each of these restrictions is described in more detail as in the following topics.

You Can Only Override Identical Inherited Virtual Methods

You can use an override method to override only an identical inherited virtual method. In the code on the slide, the **LineNumber** method in the derived class **CommentToken** causes a compile-time error because the inherited method **Token.LineNumber** is not marked virtual.

You Must Match an Override Method with Its Associated Virtual Method

An override declaration must be identical in every way to the virtual method it overrides. They must have the same access level, the same return type, the same name, and the same parameters.

For example, the override in the following example fails because the access-levels are different (protected as opposed to public), the return types are different (**string** as opposed to **void**), and the parameters are different (**none** as opposed to **int**):

```
class Token
{
    protected virtual string Name( ) { ... }
}
class CommentToken: Token
{
    public override void Name(int i) { ... } // Errors
}
```

You Can Override an Override Method

An override method is implicitly virtual, so you can override it. Following is an example:

```
class Token
{
    public virtual string Name( ) { ... }
}
class CommentToken: Token
{
    public override string Name( ) { ... }
}
class OneLineCommentToken: CommentToken
{
    public override string Name( ) { ... }   // Okay
}
```

You Cannot Explicitly Declare an Override Method As Virtual

An override method is implicitly virtual but cannot be explicitly qualified as virtual. Following is an example:

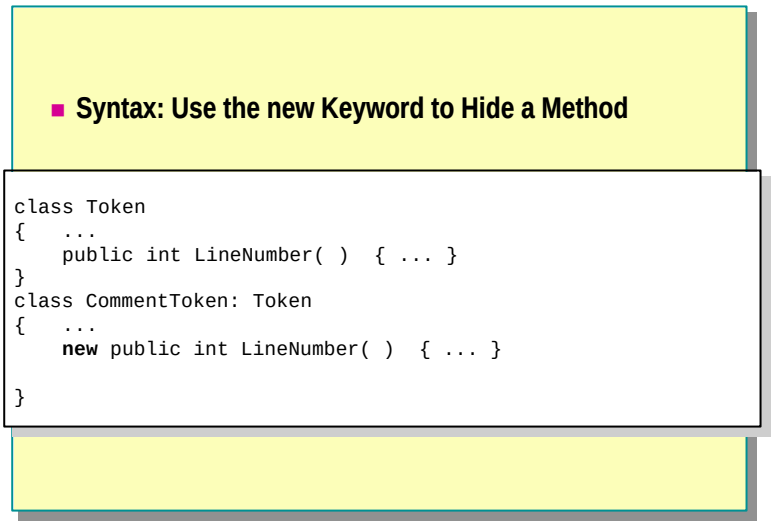
```
class Token
{
    public virtual string Name( ) { ... }
}
class CommentToken: Token
{
    public virtual override string Name( ) { ... } // Error
}
```

You Cannot Declare an Override Method As Static or Private

An override method can never be qualified as static because static methods are class methods and polymorphism works on objects rather than classes.

Also, an override method can never be private. This is because an override method must override a virtual method, and a virtual method cannot be private.

Using new to Hide Methods



You can hide an identical inherited method by introducing a new method into the class hierarchy. The old method that was inherited by the derived class from the base class is then replaced by a completely different method.

Keyword Syntax

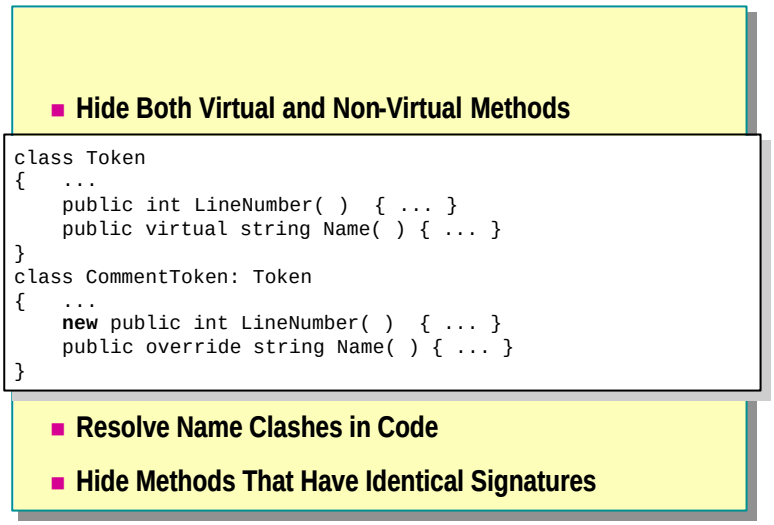
You use the **new** keyword to hide a method. The syntax for this keyword is as follows:

```
class Token
{   ...
    public int LineNumber( )  { ... }

    }
class CommentToken: Token
{   ...
    new public int LineNumber( ) { ... }

}
```

Working with the new Keyword



By using the **new** keyword, you can do the following:

- Hide both virtual and non-virtual methods.
- Resolve name clashes in code.
- Hide methods that have identical signatures.

Each of these tasks is described in detail in the following subtopics.

Hide Both Virtual and Non-Virtual Methods

Using the **new** keyword to hide a method has implications if you use polymorphism. For example, in the code on the slide, **CommentToken.LineNumber** is a **new** method. It is not related to the **Token.LineNumber** method at all. Even if **Token.LineNumber** was a virtual method, **CommentToken.LineNumber** would still be a **new** unrelated method.

In this example, **CommentToken.LineNumber** is not virtual. This means that a further derived class cannot override **CommentToken.LineNumber**. However, the **new CommentLineToken.LineNumber** method could be declared virtual, in which case further derived classes could override it, as follows:

```
class CommentToken: Token
{
    ...
    new public virtual int LineNumber( ) { ... }
}
class OneLineCommentToken: CommentToken
{
    public override int LineNumber( ) { ... }
}
```

Tip The recommended layout style for new virtual methods is

```
    new public virtual int LineNumber( ) { ... }
```

rather than

```
    public new virtual int LineNumber( ) { ... }
```

Resolve Name Clashes in Code

Name clashes often generate warnings during compilation. For example, consider the following code:

```
class Token
{
    public virtual int LineNumber( ) { ... }
}
class CommentToken: Token
{
    public int LineNumber( ) { ... }
}
```

When you compile this code, you will receive a warning stating that **CommentToken.LineNumber** hides **Token.LineNumber**. This warning highlights the name clash. You then have three options to choose from:

1. Add an **override** qualifier to **CommentToken.LineNumber**.
2. Add a **new** qualifier to **CommentToken.LineNumber**. In this case, the method still hides the identical method in the base class, but the explicit **new** tells the compiler and the code maintenance personnel that the name clash is not accidental.
3. Change the name of the method.

Hide Methods That Have Identical Signatures

The **new** modifier is necessary only when a derived class method hides a visible base class method that has an identical signature. In the following example, the compiler warns that **new** is unnecessary because the methods take different parameters and so do not have identical signatures:

```
class Token
{
    public int LineNumber(short s) { ... }
}
class CommentToken: Token
{
    new public int LineNumber(int i) { ... } // Warning
}
```

Conversely, if two methods have identical signatures, then the compiler will warn that **new** should be considered because the base class method is hidden. In the following example, the two methods have identical signatures because return types are not a part of a method's signature:

```
class Token
{
    public virtual int LineNumber( ) { ... }
}
class CommentToken: Token
{
    public void LineNumber( ) { ... } // Warning
}
```

Note You can also use the **new** keyword to hide fields and nested classes.

Practice: Implementing Methods

```
class A {
   public virtual void M() { Console.Write("A"); }
}
class B: A {
   public override void M() { Console.Write("B"); }
}
class C: B {
   new public virtual void M() { Console.Write("C"); }
}
class D: C {
   public override void M() { Console.Write("D"); }
   static void Main() {
       D d = new D(); C c = d; B b = c; A a = b;
       d.M(); c.M(); b.M(); a.M();
   }
}
```

To practice the use of the **virtual**, **override** and **new** keywords, work through the code displayed on this slide to figure out what the output of the code will be.

The Solution

After the program executes, it will display the result DDBB to the console.

Program Logic

There is only one object created by the program. This is the object of type **D** created in the following declaration:

```
D d = new D( );
```

The remaining declaration statements in **Main** declare variables of different types that all refer to this one object:

- c is a **C** reference to d.
- b is a **B** reference to c, which is reference to d.
- a is an **A** reference to b, which is reference to c, which is reference to d.

Then come the four expression statements. The following text explains each one individually.

The first statement is

```
d.M( )
```

This is a call to **D.M**, which is declared override and hence is implicitly virtual. This means that at run time the compiler calls the most derived implementation of **D.M** in the object of type **D**. This implementation is **D.M**, which writes D to the console.

The second statement is

```
c.M( )
```

This is a call to **C.M**, which is declared virtual. This means that at run time the compiler calls the most derived implementation of **C.M** in the object of type **D**. Since **D.M** overrides **C.M**, **D.M** is the most derived implementation, in this case. Hence **D.M** is called, and it writes D to the console again.

The third statement is

```
b.M( )
```

This is a call to **B.M**, which is declared override and hence is implicitly virtual. This means that at run time the compiler calls the most derived implementation of **B.M** in the object of type **D**. Since **C.M** does not override **B.M** but introduces a **new** method that *hides* **C.M**, the most derived implementation of **B.M** in the object of type **D** is **B.M**. Hence **B.M** is called, and it writes B to the console.

The last statement is

```
a.M( )
```

This is a call to **A.M**, which is declared virtual. This means that at run time the compiler calls the most derived implementation of **A.M** in the object of type **D**. **B.M** overrides **A.M**, but as before **C.M** does not override **B.M**. Hence the most derived implementation of **A.M** in the object of type **D** is **B.M**. Hence **B.M** is called, which writes B to the console again.

This is how the program generates the output DDBB and writes it to the console.

In this example, the **C** and **D** classes contain two **virtual** methods that have the same signature: the one introduced by **A** and the one introduced by **C**. The method introduced by **C** hides the method introduced by **A**. Thus, the **override** declaration in **D** overrides the method introduced by **C**, and it is not possible for **D** to override the method introduced by **A**.

This page intentionally left blank.

Quiz: Spot the Bugs

```
class Base
{
    public void Alpha( ) { ... }
    public virtual void Beta( ) { ... }
    public virtual void Gamma(int i) { ... }
    public virtual void Delta( ) { ... }
    private virtual void Epsilon( ) { ... }
}
class Derived: Base
{
    public override void Alpha( ) { ... }
    protected override void Beta( ) { ... }
    public override void Gamma(double d) { ... }
    public override int Delta( ) { ... }
}
```

In this quiz, you can work with a partner to spot the bugs in the code on the slide. To see the answers to this quiz, turn the page.

Answers

The following errors occur in this code:

1. The **Base** class declares a private virtual method called **Epsilon**. Private methods cannot be virtual. The C# compiler traps this bug as a compile-time error. You can correct the code as follows:

```
class Base
{
    ...
    public virtual void Epsilon( ) { ... }
}
```

   You can also correct the code in this manner:

```
class Base
{
    ...
    private void Epsilon( ) { ... } // Not virtual
}
```

2. The **Derived** class declares the **Alpha** method with the **override** modifier. However, the **Alpha** method in the base class is not marked virtual. You can only override a virtual method. The C# compiler traps this bug as a compile-time error. You can correct the code as follows:

```
class Base
{
    public virtual void Alpha( ) { ... }
    ...
}
```

   You can also correct the code in this manner:

```
class Derived: Base
{
    /*any*/ new void Alpha( ) { ... }
    ...
}
```

3. The **Derived** class declares a protected method called **Beta** with the **override** modifier. However, the base class method **Beta** is public. When overriding a method, you cannot change its access. The C# compiler traps this bug as a compile-time error. You can correct the code as follows:

```
class Derived: Base
{
    ...
    public override void Beta( ) { ... }
    ...
}
```

You can also correct the code in this manner:

```
class Derived: Base
{
    ...
    /* any access */ new void Beta( ) { ... }
    ...
}
```

4. The **Derived** class declares a public method called **Gamma** with the **override** modifier. However, the base class method called **Gamma** and the **Derived** class method called **Gamma** take different parameters. When overriding a method, you cannot change the parameter types. The C# compiler traps this bug as a compile-time error. You can correct the code as follows:

```
class Derived: Base
{
    ...
    public virtual void Gamma(int i) { ... }
}
```

   You can also correct the code in this manner:

```
class Derived: Base
{
    ...
    /* any access */ void Gamma(double d) { ... }
    ...
}
```

5. The **Derived** class declares a public method called **Delta** with the **override** modifier. However, the base class method called **Delta** and the derived class method called **Delta** return different types. When overriding a method, you cannot change the return type. The C# compiler traps this bug as a compile-time error. You can correct the code as follows:

```
class Derived: Base
{
    ...
    public override int Delta( ) { ... }
}
```

   You can also correct the code in this manner:

```
class Derived: Base
{
    ...
    /* any access */ new int Delta( ) { ... }
    ...
}
```

Using Sealed Classes

- You Cannot Derive from a Sealed Class
- You Can Use Sealed Classes for Optimizing Operations at Run Time
- Many .NET Classes Are Sealed: String, StringBuilder, and so on
- Syntax: Use the sealed Keyword

```
namespace System
{
    public sealed class String
    {
        ...
    }
}
namespace Mine
{
    class FancyString: String { ... }
}
```


Creating a flexible inheritance hierarchy is not easy. Most classes are standalone classes and are not designed to have other classes derived from them. However, in terms of the syntax, deriving from a class is very easy and the procedure involves only a few keystrokes. This ease of derivation creates a dangerous opportunity for programmers to derive from a class that is not designed to act as a base class.

To alleviate this problem and to better express the programmers' intentions to the compiler and to fellow programmers, C# allows a class to be declared *sealed*. You cannot derive from a sealed class.

Keyword Syntax

You can seal a class by using the **sealed** keyword. The syntax for this keyword is as shown:

```
namespace System
{
    public sealed class String
    {
        ...
    }
}
```

There are many examples of sealed classes in the Microsoft® .NET Framework. The slide shows the **System.String** class, where the keyword **string** is an alias for this class. This class is sealed, and so you cannot derive from it.

Optimizing Operations at Run Time

The **sealed** modifier enables certain run-time optimizations. In particular, because a sealed class is known to never have any derived classes, it is possible to transform virtual function member calls on sealed class instances into non-virtual function member calls.

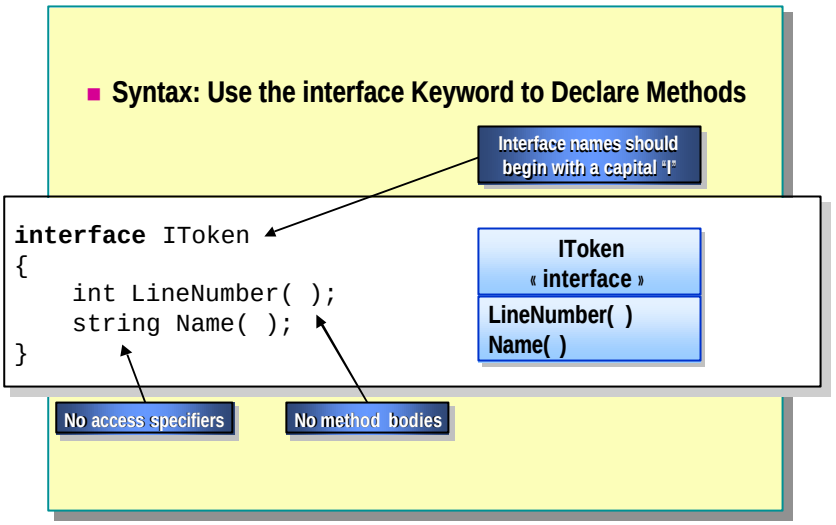
◆ Using Interfaces

- Declaring Interfaces
- Implementing Multiple Interfaces
- Implementing Interface Methods
- Implementing Interface Methods Explicitly
- Quiz: Spot the Bugs

An interface specifies a syntactic and semantic contract that all derived classes must adhere to. Specifically, an interface describes the *what* part of the contract and the classes that implement the interface describe the *how* part of the contract.

In this section, you will learn the syntax for declaring interfaces and the two techniques for implementing interface methods in derived classes.

Declaring Interfaces



An interface resembles a class without any code. You declare an interface in a similar manner to the way in which you declare a class. To declare an interface in C#, you use the keyword **interface** instead of **class**. The syntax for this keyword is explained on the slide.

Note It is recommended that all interface names be prefixed with a capital "I." For example, use **IToken** rather than **Token**.

Features of Interfaces

The following are two important features of interfaces.

Interface Methods Are Implicitly Public

The methods declared in an interface are implicitly public. Therefore, explicit **public** access modifiers are not allowed, as shown in the following example:

```
interface IToken
{
    public int LineNumber( ); // Compile-time error
}
```

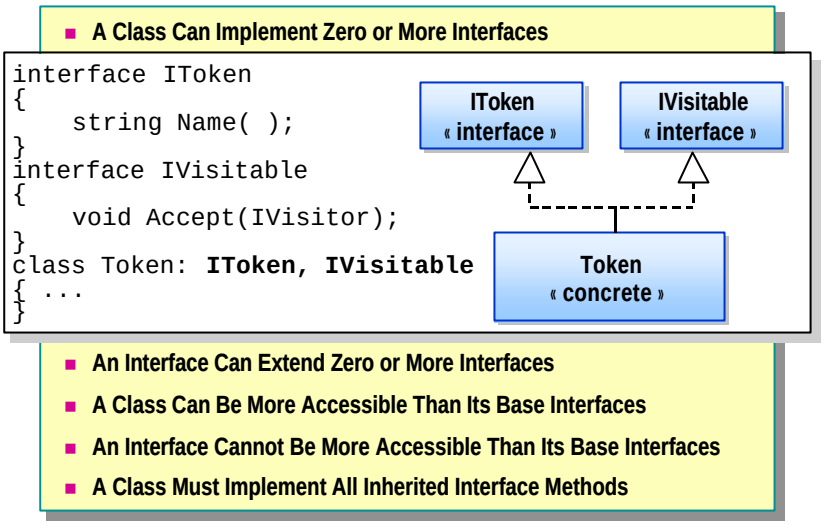
Interface Methods Do Not Contain Method Bodies

The methods declared in an interface are not allowed to contain method bodies. For example, the following code is not allowed:

```
interface IToken
{
    int LineNumber( ) { ... } // Compile-time error
}
```

Strictly speaking, interfaces can contain interface property declarations, which are declarations of properties with no body, interface event declarations, which are declarations of events with no body, and interface indexer declarations, which are declarations of indexers with no body.

Implementing Multiple Interfaces



Although C# permits only single inheritance, it allows you to implement multiple interfaces in a single class. This topic discusses the differences between a class and an interface with respect to implementation and extension of interfaces, respectively, in addition to their accessibility in comparison to their base interfaces.

Interface Implementation

A class can implement zero or more interfaces but can explicitly extend no more than one class. An example of this feature is displayed on the slide.

Note Strictly speaking, a class always extends one class. If you do not specify a base class, your class will implicitly inherit from **object**.

In contrast, an interface can extend zero or more interfaces. For example, you can rewrite the code on the slide as follows:

```
interface IToken { ... }
interface IVisitable { ... }
interface IVisitableToken: IVisitable, IToken { ... }
class Token: IVisitableToken { ... }
```

Accessibility

A class can be more accessible than its base interfaces. For example, you can declare a public class that implements a private interface, as follows:

```
class Example
{
    private interface INested { }
    public class Nested: INested { } // Okay
}
```

However, an interface cannot be more accessible than any of its base interfaces. It is an error to declare a public interface that extends a private interface, as shown in the following example:

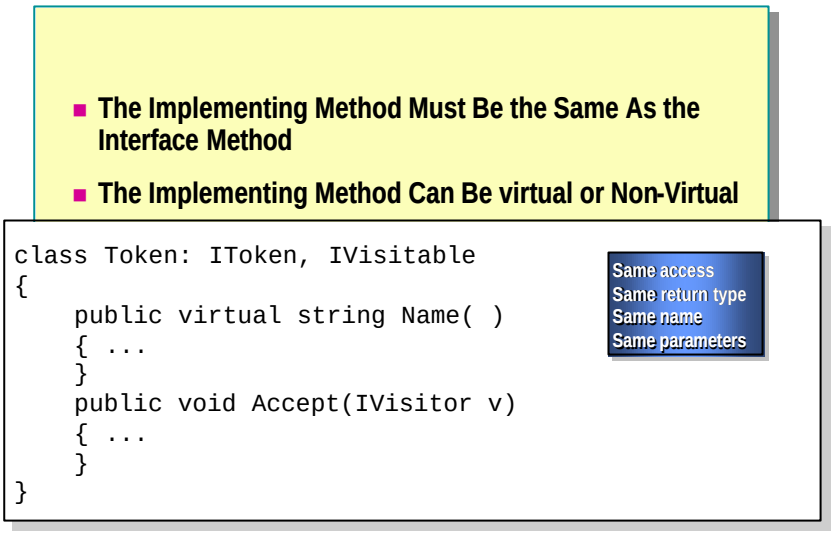
```
class Example
{
    private interface INested { }

    public interface IAlsoNested: INested { }
    // Compile-time error
}
```

Interface Methods

A class must implement all methods of any interfaces it extends, regardless of whether the interfaces are inherited directly or indirectly.

Implementing Interface Methods



When a class implements an interface, it must implement every method declared in that interface. This requirement is practical because interfaces cannot define their own method bodies.

The method that the class implements must be identical to the interface method in every way. It must have the same:

- Access

  Since an interface method is implicitly public, this means that the implementing method must be explicitly declared public. If the access modifier is omitted, then the method defaults to being private.

- Return type

  If the return type in the interface is declared as **T**, then the return type in the implementing class cannot be declared as a type derived from **T**; it must be **T**. In other words, return type covariance is not supported in C#.

- Name

  Remember that names in C# are case sensitive.

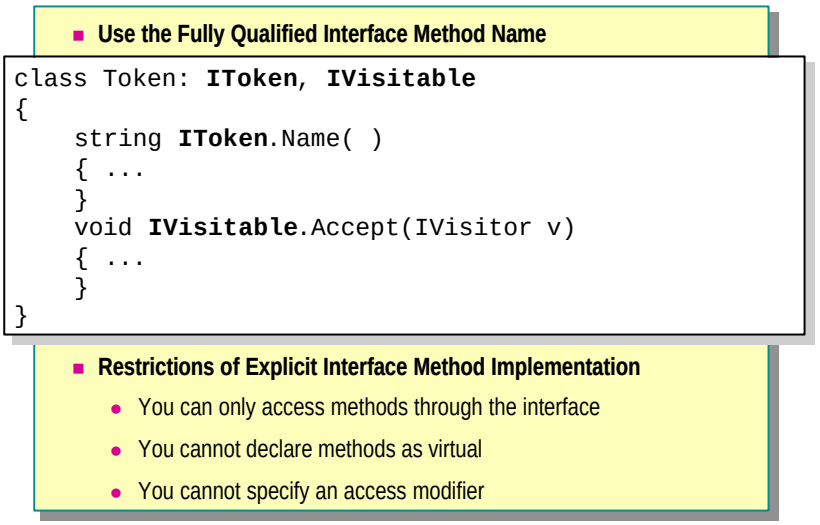
- Parameter-type list

The following code meets all of these requirements:

```
interface IToken
{
    string Name( );
}
interface IVisitable
{
    void Accept(IVisitor);
}
class Token: IToken, IVisitable
{
    public virtual string Name( )
    { ...
    }
    public void Accept(IVisitor v)
    { ...
    }
}
```

The implementing method can be virtual, such as **Name** in the preceding code. In this case, the method can be overridden in further derived classes. The implementing method can also be non-virtual, such as **Accept** in the preceding code. In the latter case, the method cannot be overridden in further derived classes.

Implementing Interface Methods Explicitly



An alternative way for a class to implement a method inherited from an interface is to use an explicit interface method implementation.

Use the Fully Qualified Interface Method Name

When using the explicit interface method implementation, you must use the fully qualified name of the implementing method. This implies that the name of the method must include the name of the interface as well, such as **IToken** in **IToken.Name**.

An example of two interface methods implemented explicitly by the **Token** class is displayed on the slide. Notice the differences between this implementation and the earlier implementation.

Restrictions of Explicit Interface Method Implementation

When implementing explicit interfaces, you need to be aware of certain restrictions.

You Can Only Access Methods Through the Interface

You cannot access an explicit interface method implementation from anywhere except through the interface. This is shown in the following example:

```
class Token: IToken, IVisitable
{
    string IToken.Name( )
    {
        ...
    }
    private void Example( )
    {
        Name( );                // Compile-time error

        ((IToken)this).Name( ); // Okay
    }
}
```

You Cannot Declare Methods As Virtual

In particular, a further derived class cannot access an explicit interface method implementation, and, as a result, no method can override it. This implies that an explicit interface method implementation is not virtual and cannot be declared virtual.

You Cannot Specify an Access Modifier

When defining an explicit interface method implementation, you cannot specify an access modifier. This is because explicit interface member implementations have different accessibility characteristics than other methods.

No Direct Access

An explicit interface method implementation is not directly accessible to clients and in this sense is private. This is shown in the following code:

```
class InOneSensePrivate
{
    void Method(Token t)
    {
        t.Name( ); // Compile-time error
    }
}
```

Indirect Access Through Interface Variable

An explicit interface method implementation is indirectly accessible to clients by means of an interface variable and polymorphism. In this sense, it is public. This is shown in the following code:

```
class InAnotherSensePublic
{
    void Method(Token t)
    {
        ((IToken)t).Name( ); // Okay
    }
}
```

Advantages of an Explicit Implementation

Explicit interface member implementations serve two primary purposes:

1. They allow interface implementations to be excluded from the public interface of a class or **struct**. This is useful when a class or **struct** implements an internal interface that is of no interest to the class or **struct** user.
2. They allow a class or **struct** to provide different implementations for interface methods that have the same signature. Following is an example:

```
interface IArtist
{
    void Draw( );
}
interface ICowboy
{
    void Draw( );
}
class ArtisticCowboy: IArtist, ICowboy
{
    void IArtist.Draw( )
    {
        ...
    }
    void ICowboy.Draw( )
    {
        ...
    }
}
```

This page intentionally left blank.

Quiz: Spot the Bugs

```
interface IToken
{
    string Name( );
    int LineNumber( ) { return 42; }
    string name;
}

class Token
{
    public string IToken.Name( ) { ... }
    static void Main( )
    {
        IToken t = new IToken( );
    }
}
```

In this quiz, you can work with a partner to spot the bugs in the code on the slide. To see the answers to this quiz, turn the page.

Answers

The following bugs occur in the code on the slide:

1. The **IToken** interface declares a method called **LineNumber** that has a body. An interface cannot contain any implementation. The C# compiler traps this bug as a compile-time error. The corrected code is as follows:

```
interface IToken
{
    ...
    int LineNumber( );
    ...
}
```

2. The **IToken** interface declares a field called name. An interface cannot contain any implementation. The C# compiler traps this bug as a compile-time error. The corrected code is as follows:

```
interface IToken
{
    string Name( );
    int LineNumber( );
    //string name; // Field now commented out
}
```

3. The **Token** class contains the explicit interface method implementation `IToken.Name( )` but the class does not specify **IToken** as a base interface. The C# compiler traps this bug as a compile-time error. The corrected code is as follows:

```
class Token: IToken
{
    ...
}
```

4. Now that **Token** specifies **IToken** as a base interface, it must implement both methods declared in that interface. The C# compiler traps this bug as a compile-time error. The corrected code is as follows:

```
class Token: IToken
{
    public string Name( ) { ... }
    public int LineNumber( ) { ... }
    ...
}
```

5. The **Token.Main** method attempts to create an instance of the interface **IToken**. However, you cannot create an instance of an interface. The C# compiler traps this bug as a compile-time error. The corrected code is as follows:

```
class Token: IToken
{
    ...
    static void Main( )
    {
        IToken t = new Token( );
        ...
    }
}
```

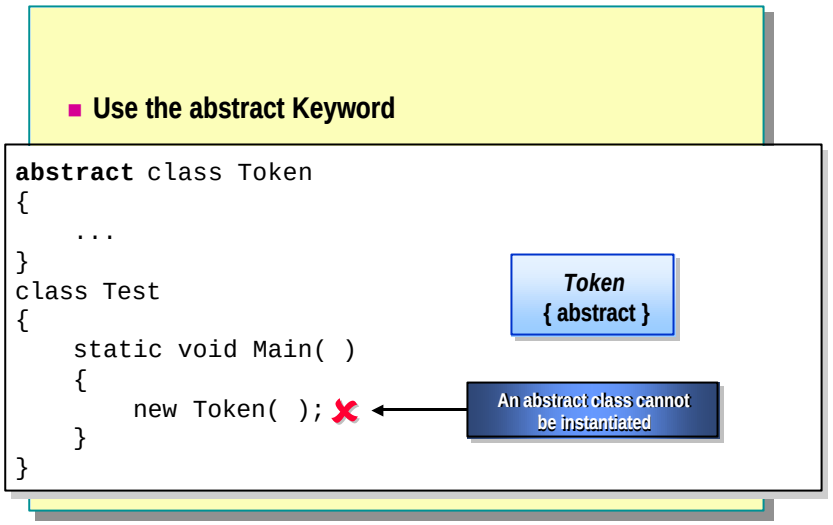
Using Abstract Classes

- Declaring Abstract Classes
- Using Abstract Classes in a Class Hierarchy
- Comparing Abstract Classes to Interfaces
- Implementing Abstract Methods
- Working with Abstract Methods
- Quiz: Spot the Bugs

Abstract classes are used to provide partial class implementations that can be completed by derived concrete classes. Abstract classes are particularly useful for providing a partial implementation of an interface that can be reused by multiple derived classes.

This section describes the syntax for declaring an abstract class, presents some examples of how you can use abstract classes in a class hierarchy, and introduces abstract methods.

Declaring Abstract Classes



You declare an abstract class by using the keyword **abstract**, as is shown on the slide.

The rules governing the use of an abstract class are almost exactly the same as those governing a non-abstract class. The only differences between using abstract and non-abstract classes are:

- You cannot create an instance of an abstract class.

  In this sense, abstract classes are like interfaces.
- You can create an abstract method in an abstract class.

  An abstract class can declare an abstract method, but a non-abstract class cannot.

Common features of abstract classes and non-abstract classes are:

- Limited extensibility

  An abstract class can extend at most one other class or abstract class. Note that an abstract class can extend a non-abstract class, whereas the converse is not true.
- Multiple interfaces

  An abstract class can implement multiple interfaces.
- Inherited interface methods

  An abstract class must implement all inherited interface methods.

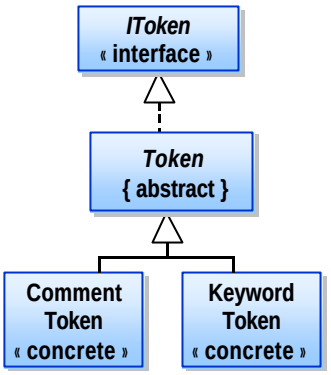
Using Abstract Classes in a Class Hierarchy

Example 1

```
interface IToken
{
    string Name( );
}

abstract class Token: IToken
{
    string IToken.Name( )
    {   ...
    }
    ...
}

class CommentToken: Token
{   ...
}
class KeywordToken: Token
{   ...
}
```



The role of abstract classes in a classic three-tier hierarchy, consisting of an interface, an abstract class, and a concrete class, is to provide a complete or partial implementation of an interface.

An Abstract Class Implementing an Interface

Consider Example 1, which appears on the slide. In this example, the abstract class implements an interface. It is an explicit implementation of the interface method. The explicit implementation is not virtual and therefore cannot be overridden in the further derived classes, such as **CommentToken**

However, it is possible for **CommentToken** to re-implement the **IToken** interface as follows:

```
interface IToken
{
    string Name( );
}

abstract class Token: IToken
{
    string IToken.Name( ) { ... }
}

class CommentToken: Token, IToken
{
    public virtual string Name( ) { ... }
}
```

Note that in this case it is not necessary to mark **CommentToken.Name** as a **new** method. This is because a derived class method can hide only a visible base class method, but the explicit implementation of **Name** in **Token** is not directly visible in **CommentToken**.

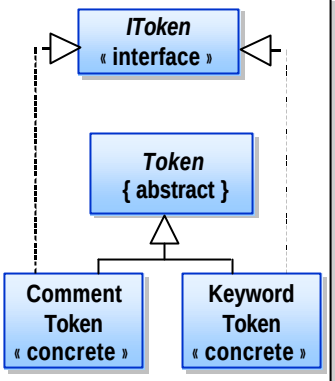
Using Abstract Classes in a Class Hierarchy *(continued)*

- **Example 2**

```
interface IToken
{
    string Name( );
}

abstract class Token
{
    public virtual string Name( )
    {   ...
    }
    ...
}

class CommentToken: Token, IToken
{   ...
}
class KeywordToken: Token, IToken
{   ...
}
```



To continue the discussion of the role played by abstract classes in a classic three-tier hierarchy, another example is presented in the slide.

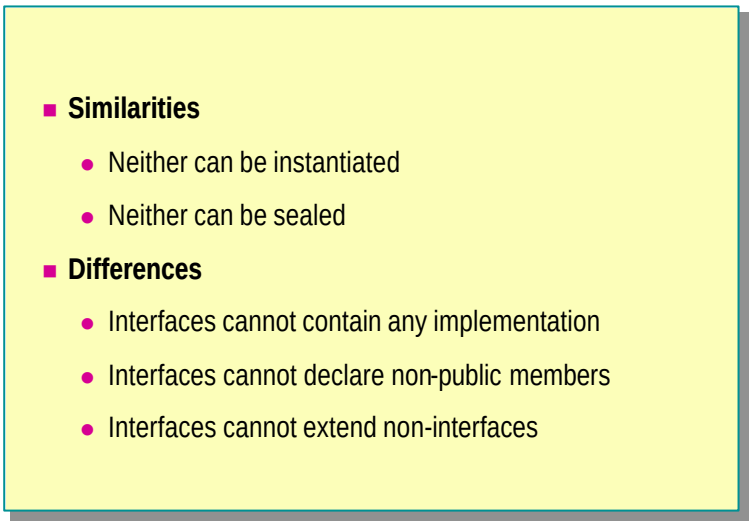
An Abstract Class That Does Not Implement an Interface

Consider Example 2, which appears on the slide. In this example, the abstract class does not implement the interface. This means that the only way it can supply an interface implementation to a further derived concrete class is by providing a public method. The method definition in the abstract class is optionally virtual, so it can be overridden in the classes as shown in the following code:

```
interface IToken
{
    string Name( );
}
abstract class Token
{
    public virtual string Name( ) { ... }
}
class CommentToken: Token, IToken
{
    public override string Name( ) { ... } // Okay
}
```

This shows that a class can inherit its interface and its implementation of that interface from separate branches of the inheritance.

Comparing Abstract Classes to Interfaces



Both abstract classes and interfaces exist to be derived from (or implemented). However, a class can extend at most one abstract class, so you need to be more careful when deriving from an abstract class than you need to be when deriving from an interface. Reserve the use of abstract classes for implementing true "is a" relationships.

The similarities between abstract classes and interfaces are that they:

- Cannot be instantiated.

  This means that they cannot be used directly to create objects.
- Cannot be sealed.

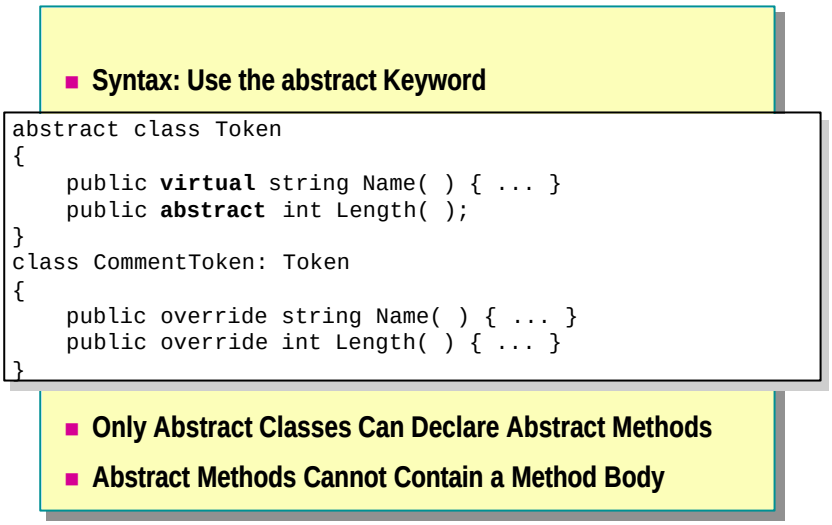
  This is acceptable because if an interface is sealed, it cannot not be implemented.

The differences between abstract classes and interfaces are summarized in the following table.

Interfaces	Abstract classes
Cannot contain implementation	Can contain implementation
Cannot declare non-public members	Can declare non-public members
Can extend only other interfaces	Can extend other classes, which can be non-abstract

When comparing the similarities and differences between abstract classes and interfaces, think of abstract classes as unfinished classes that contain plans for what needs to be finished.

Implementing Abstract Methods



You declare an abstract method by adding the **abstract** modifier to the method declaration. The syntax of the **abstract** modifier is displayed on the slide.

Only abstract classes can declare abstract methods. Following is an example:

```
interface IToken
{
    public abstract string Name( ); // Compile-time error
}
class CommentToken
{
    public abstract string Name( ); // Compile-time error
}
```

Note C++ developers can consider abstract methods to be the same as pure virtual methods in C++.

Abstract Methods Cannot Contain a Method Body

Abstract methods cannot contain any implementation. This is highlighted in the following code:

```
abstract class Token
{
    public abstract string Name( ) { ... }
    // Compile-time error
}
```

Working with Abstract Methods

- **Abstract Methods Are Virtual**
- **Override Methods Can Override Abstract Methods in Further Derived Classes**
- **Abstract Methods Can Override Base Class Methods Declared As Virtual**
- **Abstract Methods Can Override Base Class Methods Declared As Override**

When implementing abstract methods, you need to be aware of the following:

- Abstract methods are virtual.
- Override methods can override abstract methods in further derived classes.
- Abstract methods can override base class methods that are declared as virtual.
- Abstract methods can override base class methods that are declared as override.

Each of these is described in detail in the following topics.

Abstract Methods Are Virtual

Abstract methods are considered implicitly virtual but cannot be explicitly marked as virtual, as shown in the following code:

```
abstract class Token
{
    public virtual abstract string Name( ) { ... }
    // Compile-time error
}
```

Override Methods Can Override Abstract Methods in Further Derived Classes

Because they are implicitly virtual, you can override abstract methods in derived classes. Following is an example:

```
class CommentToken: Token
{
    public void override string Name( );
}
```

Abstract Methods Can Override Base Class Methods Declared As Virtual

Overriding a base class method declared as virtual forces a further derived class to provide its own method implementation and makes the original implementation of the method unavailable. Following is an example:

```
class Token
{
    public virtual string Name( ) { ... }
}
abstract class Force: Token
{
    public abstract override string Name( );
}
```

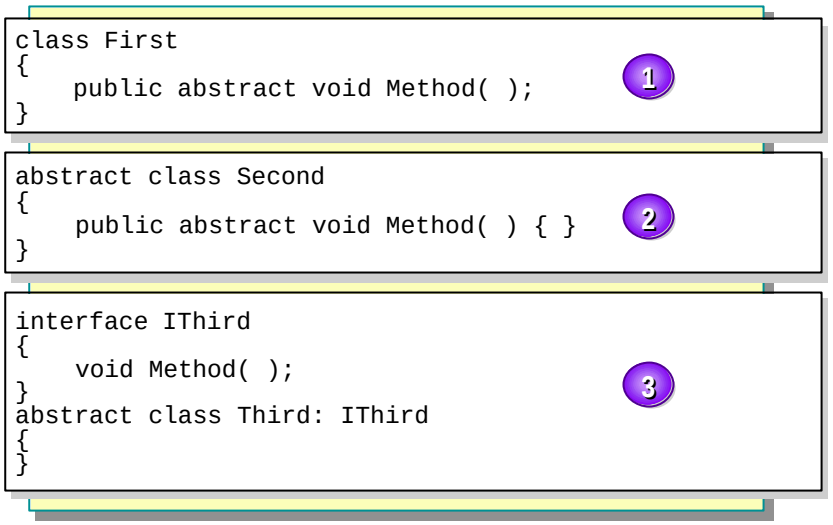
Abstract Methods Can Override Base Class Methods Declared As Override

Overriding a base class method declared as override forces a further derived class to provide its own method implementation and makes the original implementation of the method unavailable. Following is an example:

```
class Token
{
    public virtual string Name( ) { ... }
}
class AnotherToken: Token
{
    public override string Name( ) { ... }
}
abstract class Force: AnotherToken
{
    public abstract override string Name( );
}
```

This page intentionally left blank.

Quiz: Spot the Bugs



In this quiz, you can work with a partner to spot the bugs in the code on the slide. To see the answers to this quiz, turn the page.

Answers

The following bugs occur in the code on the slide:

1. You can only declare an abstract method in an abstract class. The C# compiler traps this bug as a compile-time error. You can fix the code by rewriting it as follows:

```
abstract class First
{
    public abstract void Method( );
}
```

2. An abstract method cannot declare a method body. The C# compiler traps this bug as a compile-time error. You can fix the code by rewriting it as follows:

```
abstract class Second
{
    public abstract void Method( );
}
```

3. The C# compiler traps this as a compile-time error. An abstract class must provide for the implementation of all methods in interfaces that it implements in much the same way as a concrete class. The main difference is that when you use an abstract class this can be achieved directly or indirectly. You can fix the code by rewriting it as follows:

```
abstract class Third: IThird
{
    public virtual void Method( ) { ... }
}
```

   Alternatively, if you do not want to implement the body of **Method** in an abstract class, you can declare it abstract and thus ensure that a derived class will implement it:

```
abstract class Third: IThird
{
    public abstract void Method( );
}
```

Lab 10: Using Inheritance to Implement an Interface

Objectives

After completing this lab, you will be able to:

- Define and use interfaces, abstract classes, and concrete classes.
- Implement an interface in a concrete class.
- Know how and when to use the **virtual** and **override** keywords.
- Define an abstract class and use it in a class hierarchy.
- Create sealed classes to prevent inheritance.

Prerequisites

Before working on this lab, you must be able to:

- Create classes in C#.
- Define methods for classes.

Estimated time to complete this lab: 75 minutes

Exercise 1
Converting a C# Source File into a Color Syntax HTML File

Frameworks are extremely useful because they provide an easy-to-use, flexible body of code. Unlike a library, which you use by directly calling a method, you use a framework by creating a new class that implements an interface. The framework code can then polymorphically call the methods of your class by means of the interface operations. Hence, a well-designed framework can be used in many different ways, unlike a library method, which can only be used in one way.

Scenario

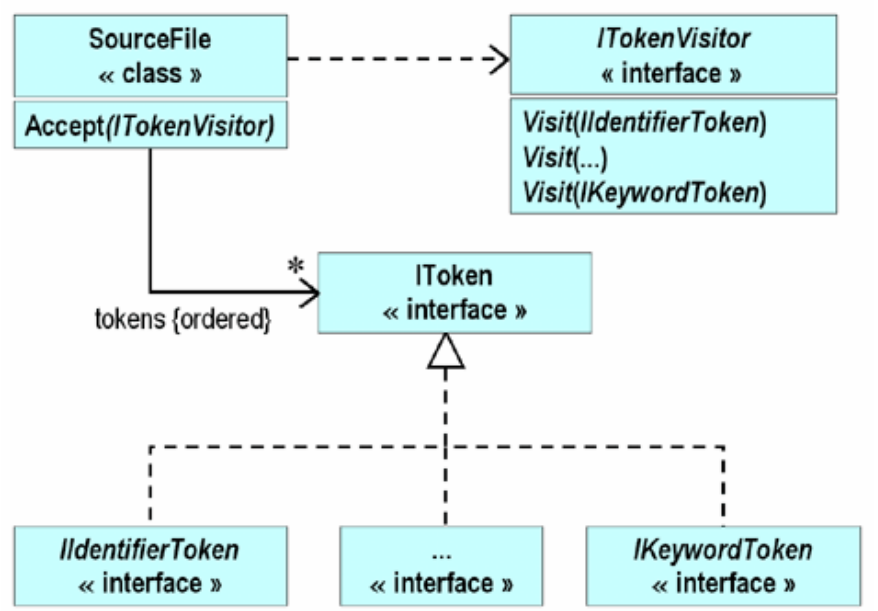
This exercise uses a pre-written hierarchy of interfaces and classes that form a miniature framework. The framework tokenizes a C# source file and stores the different kinds of tokens in a collection held in the **SourceFile** class. An **ITokenVisitor** interface with **Visit** operations is also provided, which in combination with the **Accept** method of **SourceFile** allows every token of the source file to be *visited* and processed in sequence. When you visit a token, your class can perform whatever processing it requires by using that token.

An abstract class called **NullTokenVisitor** has been created that implements all the **Visit** methods in **ITokenVisitor** by using empty methods. If you do not want to implement every method in **ITokenVisitor**, you can derive a class from **NullTokenVisitor** instead and override only the **Visit** methods that you want.

In this exercise, you will derive an **HTMLTokenVisitor** class from the **ITokenVisitor** interface. You will implement each overloaded **Visit** method in this derived class to output to the console the token bracketed by Hypertext Markup Language (HTML) and markers. You will run a simple batch file, which will run the created executable and redirect console output to create an HTML page that uses a cascading style sheet. You will then open the HTML page in Internet Explorer to see the original source file displayed with color-coded syntax.

↙ To familiarize yourself with the interfaces

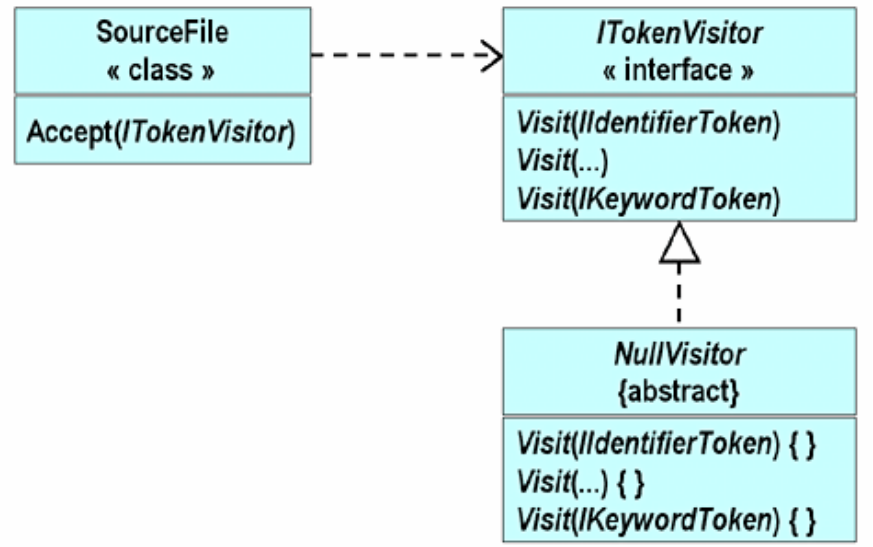
1. Open the ColorTokeniser.sln project in the *install folder*\Labs\Lab10\Starter\ColorTokeniser folder.
2. Study the classes and interfaces in the files Itoken.cs, Itoken_visitor.cs and source_file.cs. These collaborate in the following hierarchy:



↙ To create an abstract NullTokenVisitor class

1. Open the null_token_visitor.cs file.

   Notice that **NullTokenVisitor** is derived from the **ITokenVisitor** interface, yet it does not implement any of the operations specified in the interface. You will implement all of the inherited operations to be empty methods in order to enable **HTMLTokenVisitor** to be built incrementally.



2. Add a public virtual method called **Visit** to the **NullTokenVisitor** class. This method will return **void** and accept a single **ILineStartToken** parameter. The body of the method will be empty. The method will look as follows:

```
public class NullTokenVisitor : ITokenVisitor
{
   public virtual void Visit(ILineStartToken t) { }
   ...
}
```

3. Repeat step 2 for all other overloaded **Visit** methods declared in the **ITokenVisitor** interface.

   Implement all **Visit** methods in **NullTokenVisitor** as empty bodies.

4. Save your work.
5. Compile null_token_visitor.cs.

   If you have implemented all of the **Visit** operations from the **ITokenVisitor** interface, the compilation will be successful. If you have omitted any operations, the compiler will issue an error message.

6. Add a private static void method called **Test** to the **NullTokenVisitor** class.

   This method will expect no parameters. The body of this method should contain a single statement that creates a **new NullTokenVisitor** object. This statement will verify that the **NullTokenVisitor** class has implemented all of the **Visit** operations and that **NullTokenVisitor** instances can be created. The code for this method will be as follows:

```
public class NullTokenVisitor : ITokenVisitor
{
   ...
   static void Test( )
   {
       new NullTokenVisitor( );
   }
}
```

7. Save your work.
8. Compile null_token_visitor.cs and correct any errors.
9. Change the definition of **NullTokenVisitor**.

   Since the purpose of the **NullTokenVisitor** class is not to be instantiated but to be derived from, you need to change the definition so that it is an abstract class.

10. Compile null_token_visitor.cs again.

    Also, verify that the **new** statement inside the **Test** method now causes an error, as you cannot create instances of an abstract class.

11. Delete the **Test** method.
12. **NullTokenVisitor** should now look like this:

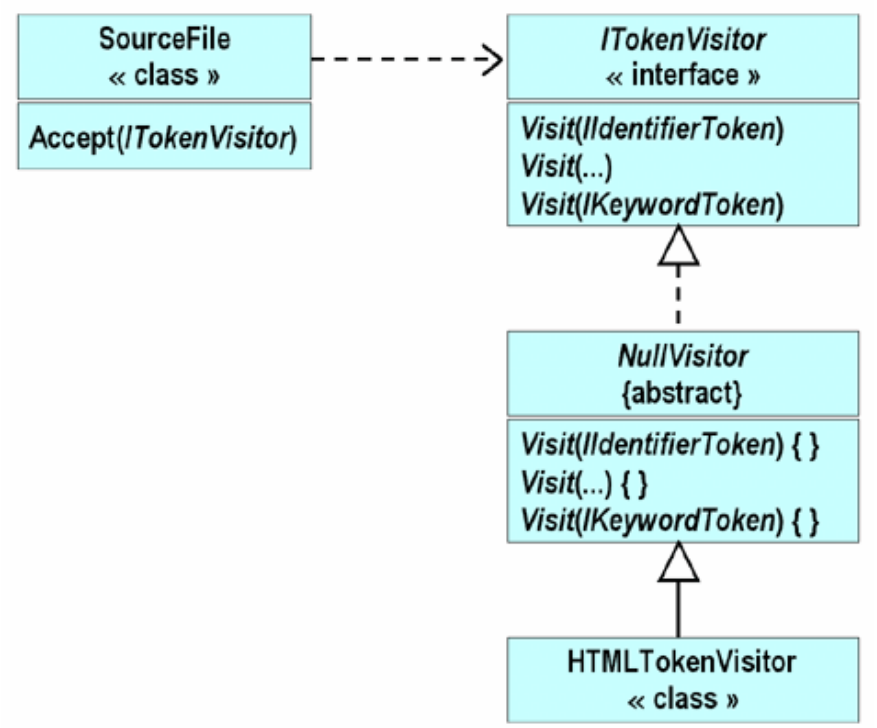
```
public abstract class NullTokenVisitor : ITokenVisitor
{
   public virtual void Visit(ILineStartToken t) { }
   public virtual void Visit(ILineEndToken   t) { }

   public virtual void Visit(ICommentToken    t) { }
   public virtual void Visit(IDirectiveToken  t) { }
   public virtual void Visit(IIdentifierToken t) { }
   public virtual void Visit(IKeywordToken    t) { }
   public virtual void Visit(IWhiteSpaceToken t) { }

   public virtual void Visit(IOtherToken t) { }
}
```

↙ To create an HTMLTokenVisitor class

1. Open the html_token_visitor.cs file.
2. Change the **HTMLTokenVisitor** class so that it derives from the **NullTokenVisitor** abstract class.



3. Open the main.cs file, and add two statements to the static **InnerMain** method.
   a. The first statement will declare a variable called *visitor* of type **HTMLTokenVisitor** and initialize it with a newly created **HTMLTokenVisitor** object.
   b. The second statement will pass *visitor* as the parameter to the **Accept** method being called on the already declared *source* variable.
4. Save your work.
5. Compile the program and correct any errors.

   Run the program from the command line, passing the name of a .cs source file from the *install folder*\Labs\Lab10\Starter\ColorTokeniser\bin\debug folder as the command-line argument.

   Nothing will happen, because you have not yet defined any methods in **HTMLTokenVisitor** class!

6. Add a public non-static **Visit** method to the **HTMLTokenVisitor** class. This method will return **void** and accept a single **ILineStartToken** parameter called **line**.

   Implement the body of the method as a single statement that calls **Write** (*not* **WriteLine**), displaying the value of **line.Number( )** to the console. Note that **Number** is an operation declared in the **ILineStartToken** interface. Do not qualify the method with a **virtual** or **override** keyword. This is shown in the following code:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   public void Visit(ILineStartToken line)
   {
       Console.Write(line.Number( )); // Not WriteLine
   }
}
```

7. Save your work.
8. Compile the program.

   Run the program again, as before. Nothing will happen, because the **Visit** method in **HTMLTokenVisitor** is hiding the **Visit** method in the base class **NullTokenVisitor**.

9. Change **HTMLTokenVisitor.Visit(ILineStartToken)** so that it overrides **Visit** from its base class.

   This will make **HTMLTokenVisitor.Visit** polymorphic, as shown in the following code:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   public override void Visit(ILineStartToken line)
   {
       Console.Write(line.Number( ));
   }
}
```

10. Save your work.
11. Compile the program and correct any errors.

    Run the program as before. Output will be displayed. It will contain ascending numbers with no intervening white space. (The numbers are generated line numbers for the file that you specified.)

12. In **HTMLTokenVisitor**, define an overloaded public non-static **Visit** method that returns **void** and accepts a single **ILineEndToken** parameter.

    This revision adds a new line between lines of output tokens. Notice that this operation is declared in the **ITokenVisitor** interface. Implement the body of this method to print a single new line to the console, as shown. (Note that this method uses **WriteLine**, not **Write**.)

```
public class HTMLTokenVisitor : NullTokenVisitor
{
    ...
    public override void Visit(ILineEndToken t)
    {
        Console.WriteLine( );  // Not Write
    }
}
```

13. Save your work.

14. Compile the program and correct any errors.

    Run the program as before. This time each line number is terminated with a separate line.

↙ To use HTMLTokenVisitor to display C# source file tokens

1. Add a public non-static **Visit** method to the **HTMLTokenVisitor** class. This method will return **void** and accept a single **IIdentifierToken** parameter called **token**. It should override the corresponding method in the **NullTokenVisitor** base class.

2. Implement the body of the method as a single statement that calls **Write**, displaying **token** to the console as a **string**. Open the IToken.cs file and note that **IIdentifierToken** is derived from **IToken** and that **IToken** declares a **ToString** method. This is shown in the following code:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
    ...
    public override void Visit(IIdentifierToken token)
    {
        Console.Write(token.ToString( ));
    }
}
```

3. Save your work.

4. Compile the program and correct any errors.

    Run the program as before. This time the output includes all of the identifiers.

5. Repeat steps 1 through 3, adding four more overloaded **Visit** methods to **HTMLTokenVisitor**.

    Each of these will expect a single parameter of type **ICommentToken**, **IKeywordToken**, **IWhiteSpaceToken**, and **IOtherToken**, respectively. The bodies of these methods will all be exactly as described in step 2.

↙ To convert a C# source file into an HTML file

1. In the *install folder*\Labs\Lab10\Starter\ColorTokeniser\bin\debug folder, there is a batch script called generate.bat. This script executes the ColorTokeniser program, using a command-line parameter that you pass to it. It also performs some pre-processing and post-processing of the tokenized file that is produced. It performs this processing by using a cascading style sheet (code_style.css) to convert the output into HTML.

   From the command prompt, run the program by using the generate batch file, passing in token.cs file as a parameter. (This is actually a copy of part of the source code for your program, but it will work as an example .cs file.) Capture the output to another file that has an .html suffix. Following is an example:

   ```
   generate token.cs > token.html
   ```

2. Use Internet Explorer to display the .html file that you just created (token.html in the example in the previous step). You can do this by typing **token.html** at the command prompt.

   The displayed result will not be pretty! Line numbers greater than 9 are all indented differently from the lines with numbers less than 10. This is because numbers less than 10 have a single digit, whereas numbers greater than 9 have two digits. Notice also that the line numbers are in the same color as the source file tokens, which is not helpful.

↙ To find and fix the line number and indentation problems

1. Change the definition of the **Visit(ILineStartToken)** method as follows to add some output that fixes both of these problems. This is shown in the following code:

   ```
   public class HTMLTokenVisitor : NullTokenVisitor
   {
      public override void Visit(ILineStartToken line)
      {
          Console.Write("<span class=\"line_number\">");
          Console.Write("{0,3}", line.Number( ));
          Console.Write("</span>");
      }
      ...
   }
   ```

2. Save your work.
3. Compile the program and correct any errors.
4. Re-create the token.html file from the token.cs source file from the command line as before:

   ```
   generate token.cs > token.html
   ```

5. Open token.html in Internet Explorer.

   There is still a problem. Compare the appearance of token.html in Internet Explorer to the original token.cs file. Notice that the first comment in token.cs (`/// <summary>`) appears in the browser as "///". The `<summary>` has been lost. The problem is that in HTML some characters have a special meaning. To display the left angle bracket (<), the HTML source must be **<** and to display the right angle bracket (>) the HTML source must be **>**. To display the ampersand (&), the HTML source must be **&**.

↙ To make the changes required to correctly display the angle bracket and ampersand characters

1. Add to **HTMLTokenVisitor** a private non-static method called **FilteredWrite** that returns **void** and expects a single parameter of type **IToken** called **token**.

   This method will create a **string** called **dst** from **token** and iterate through each character in **dst**, applying the transformations described above. The code will look as follows:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   ...
   private void FilteredWrite(IToken token)
   {
       string src = token.ToString( );
       for (int i = 0; i != src.Length; i++) {
           string dst;
           switch (src[i]) {
           case '<' :
               dst = "&lt;"; break;
           case '>' :
               dst = "&gt;"; break;
           case '&' :
               dst = "&amp;"; break;
           default :
               dst = new string(src[i], 1); break;
           }
           Console.Write(dst);
       }
   }
}
```

2. Change the definition of **HTMLTokenVisitor.Visit(ICommentToken)** to use the new **FilteredWrite** method instead of **Console.Write**, as follows:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   public override void Visit(ICommentToken token)
   {
       FilteredWrite(token);
   }
   ...
}
```

3. Change the definition of **HTMLTokenVisitor.Visit(IOtherToken)** to use the new **FilteredWrite** method instead of **Console.Write**, as follows:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   public override void Visit(IOtherToken token)
   {
       FilteredWrite(token);
   }
   ...
}
```

4. Save your work.
5. Compile the program and correct any errors.
6. Re-create the token.html file from the token.cs source file from the command line as before:

```
generate token.cs > token.html
```

7. Open token.html in Internet Explorer and verify that the angle bracket and ampersand characters are now displayed correctly.

↙ To add color comments to the HTML file

1. Use Notepad to open the code_style.css style sheet in the *install folder*\Labs\Lab10\Starter\ColorTokeniser\bin\debug folder.

   The cascading style sheet file called code_style.css will be used to add color to the HTML file. This file has already been created for you. The following is an example of its contents:

```
...
SPAN.LINE_NUMBER
{
   background-color: white;
   color: gray;
}
...
SPAN.COMMENT
{
   color: green;
   font-style: italic;
}
```

   The **HTMLTokenVisitor.Visit(ILineStartToken)** method already uses this style sheet:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   public override void Visit(ILineStartToken line)
   {
       Console.Write("<span class=\"line_number\">");
       Console.Write("{0,3}", line.Number( ));
       Console.Write("</span>");
   }
   ...
}
```

Notice that this method writes the words “span” and “ line_number,” and that the style sheet contains an entry for SPAN.LINE_NUMBER.

2. Change the body of **HTMLTokenVisitor.Visit(ICommentToken)** so that it takes the following pattern:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   public override void Visit(ICommentToken token)
   {
       Console.Write("<span class=\"comment\">");
       FilteredWrite(token);
       Console.Write("</span>");
   }
   ...
}
```

3. Save your work.
4. Compile the program and correct any errors.
5. Re-create the token.html file from the token.cs source file as before:

```
generate token.cs > token.html
```

6. Open token.html in Internet Explorer.

   Verify that the source file comments are now green and are italicized.

↙ To add color keywords to the HTML file

1. Notice that the code_style.css file contains the following entry:

```
...
SPAN.KEYWORD
{
   color: blue;
}
...
```

2. Change the body of **HTMLTokenVisitor.Visit(IKeywordToken)** to use the style specified in the style sheet, as follows:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   public override void Visit(IKeywordToken token)
   {
       Console.Write("<span class=\"keyword\">");
       FilteredWrite(token);
       Console.Write("</span>");
   }
   ...
}
```

3. Save your work.
4. Compile the program and correct any errors.
5. Re-create the token.html file from the token.cs source file by using the generate batch file as before:

```
generate token.cs > token.html
```

6. Open token.html in Internet Explorer and verify that the keywords are now in blue.

↙ To refactor the Visit methods to eliminate duplication

1. Notice the duplication in the two **Visit** methods. That is, both methods write span strings to the console.

   You can refactor the **Visit** methods to avoid this duplication. Define a new private non-static method called **SpannedFilteredWrite** that returns **void** and expects two parameters, a **string** called **spanName** and an **IToken** called **token**. The body of this method will contain three statements. The first statement will write the span string to the console by using the **spanName** parameter. The second statement will call the **FilteredWrite** method, passing **token** as the argument. The third statement will write the closing span string to the console. The code will look as follows:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   ...
   private void SpannedFilteredWrite(string spanName,
➥IToken token)
   {
       Console.Write("<span class=\"{0}\">", spanName);
       FilteredWrite(token);
       Console.Write("</span>");
   }
   ...
}
```

2. Change **HTMLTokenVisitor.Visit(ICommentToken)** to use this new method, as follows:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   ...
   public override void Visit(ICommentToken token)
   {
       SpannedFilteredWrite("comment", token);
   }
   ...
}
```

3. Change **HTMLTokenVisitor.Visit(IKeywordToken)** to use this new method, as follows:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
   ...
   public override void Visit(IKeywordToken token)
   {
       SpannedFilteredWrite("keyword", token);
   }
   ...
}
```

4. Change the **HTMLTokenVisitor.Visit(IIdentifierToken)** method body so that it calls the **SpannedFilteredWrite** method. You must do this because identifier tokens also have an entry in the code_style.css file:

```
public class HTMLTokenVisitor : NullTokenVisitor
{
    ...
    public override void Visit(IIdentifierToken token)
    {
        SpannedFilteredWrite("identifier", token);
    }
    ...
}
```

5. Save your work.
6. Compile the program and correct any errors.
7. Re-create the token.html file from the token.cs source file by using the generate batch file as before:

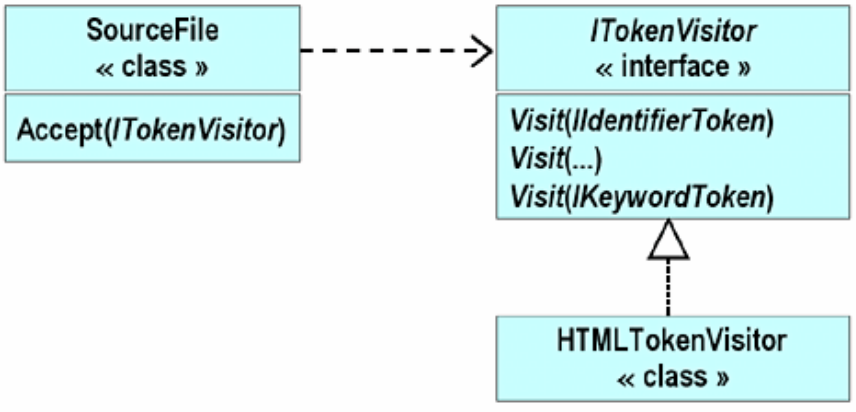
```
generate token.cs > token.html
```

8. Open token.html in Internet Explorer.

   Verify that the comments are still green and that the keywords are still blue.

↙ To implement HTMLTokenVisitor directly from ITokenVisitor

1. Open the html_token_visitor.cs file
2. Change the code so that the **HTMLTokenVisitor** class derives from the **ITokenVisitor** interface. Because you have implemented nearly all of the **Visit** methods in **HTMLTokenVisitor**, it no longer needs to inherit from the **NullTokenVisitor** abstract class (which provides a default empty implementation of every method in **ITokenVisitor**). It can be derived directly from the **ITokenVisitor** interface.



The class should look as follows:

```
public class HTMLTokenVisitor : ITokenVisitor
{
    ...
}
```

3. Save your work.
4. Compile the program.

   There will be many errors! The problem is that the **Visit** methods in **HTMLTokenVisitor** are still qualified as override, but you cannot override an operation in an interface.
5. Remove the keyword **override** from every **Visit** method definition.
6. Compile the program.

   There will still be an error. The problem this time is that **HTMLTokenVisitor** does not implement the **Visit(IDirectiveToken)** operation inherited from its **ITokenVisitor** interface. Previously, **HTMLTokenVisitor** inherited an empty implementation of this operation from **NullTokenVisitor**.
7. In **HTMLTokenVisitor**, define a public non-static method called **Visit** that returns **void** and expects a single parameter of type **IDirectiveToken** called *token*. This will fix the implementation problem.

   The body of this method will call the **SpannedFilteredWrite** method, passing it two parameters: the **string** literal “directive” and the variable *token*.

```
public class HTMLTokenVisitor : ITokenVisitor
{
    ...
    public void Visit(IDirectiveToken token)
    {
        SpannedFilteredWrite("directive", token);
    }
    ...
}
```

8. Save your work.
9. Compile the program and correct any errors.
10. Re-create the token.html file from the token.cs source file by using the generate batch file as before:

```
generate token.cs > token.html
```

11. Open token.html in Internet Explorer.

    Verify that the comments are still green and that the keywords are still blue.

↙ To prevent the use of HTMLTokenVisitor as a base class

1. Declare **HTMLTokenVisitor** as a sealed class.

   Given that the methods of **HTMLTokenVisitor** are no longer virtual, it makes sense for **HTMLTokenVisitor** to be declared as a sealed class. This is shown in the following code:

   ```
   public sealed class HTMLTokenVisitor : ITokenVisitor
   {
      ...
   }
   ```

2. Compile the program and correct any errors.
3. Re-create the token.html file from the token.cs source file by using the generate batch file as before:

   ```
   generate token.cs > token.html
   ```

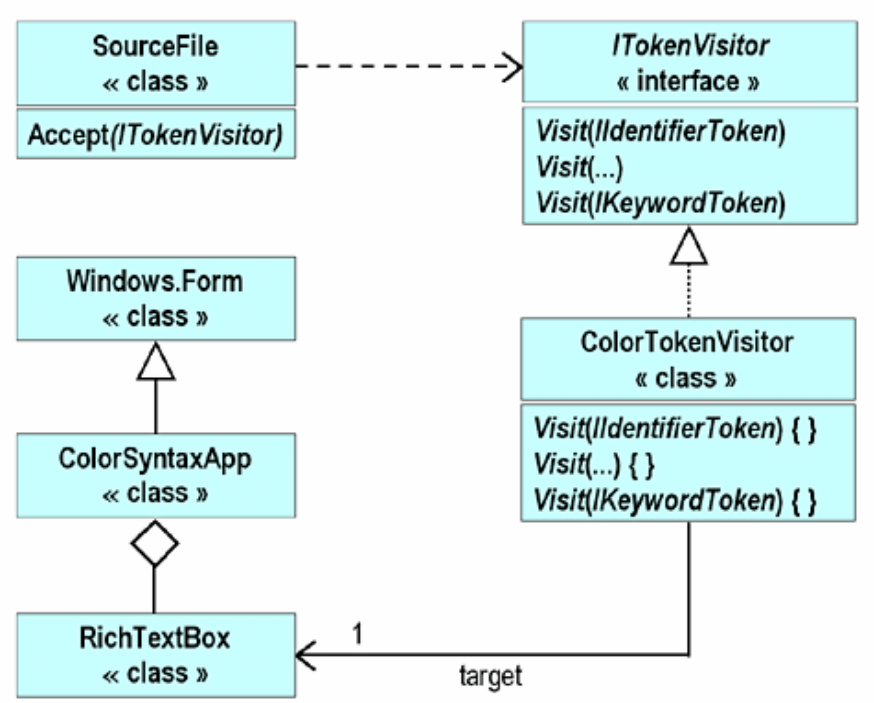
4. Open token.html in Internet Explorer, and verify that the comments are still green and that the keywords are still blue.

Exercise 2
Converting a C# Source File into a Color Syntax HTML File

In this exercise, you will examine a second application that uses the same C# tokenizer framework used in Exercise 1.

Scenario

In this application, the **ColorTokenVisitor** class derives from the **ITokenVisitor** interface. The **Visit** methods of this class write colored tokens to a **RichTextBox** inside a Microsoft Windows® Forms application. The collaborating classes form the following hierarchy:



↙ To familiarize yourself with the interfaces

1. Open the ColorSyntaxApp.sln project in the *install folder*\Labs\Lab10\Solution\ColourSyntaxApp folder.
2. Study the contents of the two .cs files. Notice that the **ColorTokenVisitor** class is very similar to the **HTMLTokenVisitor** class that you created in Exercise 1. The main difference is that **ColorTokenVisitor** writes the color tokens to a **RichTextBox** form component rather than to the console.
3. Build the project.
4. Run the application.
   a. Click **Open File**.
   b. In the dialog box that appears, click a .cs source file.
   c. Click **Open**.

      The contents of the selected .cs source file will appear, in color.

Review

- Deriving Classes
- Implementing Methods
- Using Sealed Classes
- Using Interfaces
- Using Abstract Classes

---

1. Create a class called **Widget** that declares two public methods. Create both methods so that they return **void** and so that they do not use parameters. Call the first method **First,** and declare it as virtual. Call the second method **Second**, and do not declare it as virtual. Create a class called **FancyWidget** that extends **Widget**, overriding the inherited **First** method and hiding the inherited **Second** method.

2. Create an interface called **IWidget** that declares two methods. Create both methods so that they return **void** and so that they do not use parameters. Call the first method **First**, and call the second method **Second**. Create a class called **Widget** that implements **IWidget**. Implement **First** as virtual, and implement **Second** explicitly.

3. Create an abstract class called **Widget** that declares a protected abstract method called **First** that returns **void** and does not use parameters. Create a class called **FancyWidget** that extends **Widget**, overriding the inherited **First** method.

4. Create a sealed class called **Widget** that implements the **IWidget** interface that you created in question 2. Create **Widget** so that it implements both inherited methods explicitly.