Advanced C#

Mark Sapossnek

CS 594
Computer Science Department
Metropolitan College
Boston University

Prerequisites

- This module assumes that you understand the fundamentals of
  - Programming
    - Variables, statements, functions, loops, etc.
  - Object-oriented programming
    - Classes, inheritance, polymorphism, members, etc.
    - C++ or Java
  - Introduction to C#

Learning Objectives

- Advanced features of the C# language
  - Creating custom types with interfaces, classes and structs
  - Delegates and events
  - Miscellaneous topics

Agenda

- **Review Object-Oriented Concepts**
- Interfaces
- Classes and Structs
- Delegates
- Events
- Attributes
- Preprocessor Directives
- XML Comments
- Unsafe Code

Review
Key Object-Oriented Concepts

- Objects, instances and classes
- Identity
  - Every instance has a unique identity, regardless of its data
- Encapsulation
  - Data and function are packaged together
  - Information hiding
  - An object is an abstraction
    - User should NOT know implementation details

Review
Key Object-Oriented Concepts

- Interfaces
  - A well-defined contract
  - A set of function members
- Types
  - An object has a type, which specifies its interfaces and their implementations
  - A variable also can have a type
- Inheritance
  - Types are arranged in a hierarchy
    - Base/derived, superclass/subclass
  - Interface vs. implementation inheritance

Review
Key Object-Oriented Concepts

- Polymorphism
  - The ability to use an object without knowing its precise type
  - Three main kinds of polymorphism
    - Inheritance
    - Interfaces
    - Late binding
- Dependencies
  - For reuse and to facilitate development, systems should be loosely coupled
  - Dependencies should be minimized

Agenda

- Review Object-Oriented Concepts
- **Interfaces**
- Classes and Structs
- Delegates
- Events
- Attributes
- Preprocessor Directives
- XML Comments
- Unsafe Code

Interfaces

- An interface defines a contract
  - An interface is a type
  - Includes methods, properties, indexers, events
  - Any class or struct implementing an interface must support all parts of the contract
- Interfaces provide no implementation
  - When a class or struct implements an interface it must provide the implementation
- Interfaces provide polymorphism
  - Many classes and structs may implement a particular interface

Interfaces
Example

```
public interface IDelete {
  void Delete();
}
public class TextBox : IDelete {
  public void Delete() { ... }
}
public class Car : IDelete {
  public void Delete() { ... }
}
```

```
TextBox tb = new TextBox();
IDelete iDel = tb;
iDel.Delete();

Car c = new Car();
iDel = c;
iDel.Delete();
```

Interfaces
Multiple Inheritance

- Classes and structs can inherit from multiple interfaces
- Interfaces can inherit from multiple interfaces

```
interface IControl {
  void Paint();
}
interface IListBox: IControl {
  void SetItems(string[] items);
}
interface IComboBox: ITextBox, IListBox {
}
```

Interfaces
Explicit Interface Members

- If two interfaces have the same method name, you can explicitly specify interface + method name to disambiguate their implementations

```
interface IControl {
  void Delete();
}
interface IListBox: IControl {
  void Delete();
}
interface IComboBox: ITextBox, IListBox {
  void IControl.Delete();
  void IListBox.Delete();
}
```

Agenda

- Review Object-Oriented Concepts
- Interfaces
- **Classes and Structs**
- Delegates
- Events
- Attributes
- Preprocessor Directives
- XML Comments
- Unsafe Code

Classes and Structs
Similarities

- Both are user-defined types
- Both can implement multiple interfaces
- Both can contain
  - Data
    - Fields, constants, events, arrays
  - Functions
    - Methods, properties, indexers, operators, constructors
  - Type definitions
    - Classes, structs, enums, interfaces, delegates

Classes and Structs
Differences

Class	Struct
Reference type	Value type
Can inherit from any non-sealed reference type	No inheritance (inherits only from `System.ValueType`)
Can have a destructor	No destructor
Can have user-defined parameterless constructor	No user-defined parameterless constructor

Classes and Structs
C# Structs vs. C++ Structs

- Very different from C++ struct

C++ Struct	C# Struct
Same as C++ class, but all members are `public`	User-defined value type
Can be allocated on the heap, on the stack or as a member (can be used as value or reference)	Always allocated on the stack or as a member
Members are always `public`	Members can be `public`, `internal` or `private`

Classes and Structs
Class

```
public class Car : Vehicle {
  public enum Make { GM, Honda, BMW }
  Make make;
  string vid;
  Point location;
  Car(Make m, string vid; Point loc) {
    this.make = m;
    this.vid = vid;
    this.location = loc;
  }
  public void Drive() {
    Console.WriteLine("vroom"); }
}
```

```
Car c =
  new Car(Car.Make.BMW,
          "JF3559QT98",
          new Point(3,7));
c.Drive();
```

Classes and Structs
Struct

```
public struct Point  {
  int x, y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  public int X { get { return x; }
                 set { x = value; } }
  public int Y { get { return y; }
                 set { y = value; } }
}
```

```
Point p = new Point(2,5);
p.X += 100;
int px = p.X;     // px = 102
```

Classes and Structs
Static vs. Instance Members

- By default, members are per instance
  - Each instance gets its own fields
  - Methods apply to a specific instance
- Static members are per type
  - Static methods can't access instance data
  - No `this` variable in static methods
- Don't abuse static members
  - They are essentially object-oriented global data and global functions

Classes and Structs
Access Modifiers

- Access modifiers specify who can use a type or a member
- Access modifiers control encapsulation
- Top-level types (those directly in a namespace) can be `public` or `internal`
- Class members can be `public`, `private`, `protected`, `internal`, or `protected internal`
- Struct members can be `public`, `private` or `internal`

Classes and Structs
Access Modifiers

If the access modifier is	Then a member defined in type T and assembly A is accessible
`public`	to everyone
`private`	within T only (the default)
`protected`	to T or types derived from T
`internal`	to types within A
`protected internal`	to T or types derived from T or to types within A

Classes and Structs
Abstract Classes

- An abstract class is one that cannot be instantiated
- Intended to be used as a base class
- May contain abstract and non-abstract function members
- Similar to an interface
- Cannot be sealed

Classes and Structs
Sealed Classes

- A sealed class is one that cannot be used as a base class
- Sealed classes can't be abstract
- All structs are implicitly sealed
- Why seal a class?
  - To prevent unintended derivation
  - Code optimization
    - Virtual function calls can be resolved at compile-time

Classes and Structs
`this`

- The `this` keyword is a predefined variable available in non-static function members
  - Used to access data and function members unambiguously

```
class Person {
  string name;
  public Person(string name) {
    this.name = name;
  }
  public void Introduce(Person p) {
    if (p != this)
      Console.WriteLine("Hi, I'm " + name);
  }
}
```

Classes and Structs
base

- The `base` keyword is used to access class members that are hidden by similarly named members of the current class

```
class Shape {
  int x, y;
  public override string ToString() {
    return "x=" + x + ",y=" + y;
  }
}
class Circle : Shape {
  int r;
  public override string ToString() {
    return base.ToString() + ",r=" + r;
  }
}
```

Classes and Structs
Constants

- A constant is a data member that is evaluated at compile-time and is implicitly static (per type)
  - e.g. `Math.PI`

```
public class MyClass {
  public const string version = “1.0.0”;
  public const string s1 = “abc” + “def”;
  public const int i3 = 1 + 2;
  public const double PI_I3 = i3 * Math.PI;
  public const double s = Math.Sin(Math.PI);  //ERROR
  ...
}
```

Classes and Structs
Fields

- A field is a member variable
- Holds data for a class or struct
- Can hold:
  - a class instance (a reference),
  - a struct instance (actual data), or
  - an array of class or struct instances (an array is actually a reference)

Classes and Structs
Readonly Fields

- Similar to a const, but is initialized at run-time in its declaration or in a constructor
  - Once initialized, it cannot be modified
- Differs from a constant
  - Initialized at run-time (vs. compile-time)
    - Don’t have to re-compile clients
  - Can be static or per-instance

```
public class MyClass {
  public static readonly double d1 = Math.Sin(Math.PI);
  public readonly string s1;
  public MyClass(string s) { s1 = s; }  }
```

Classes and Structs
Properties

- A property is a virtual field
- Looks like a field, but is implemented with code

```
public class Button: Control {
   private string caption;
   public string Caption {
      get { return caption; }
      set { caption = value;
            Repaint(); }
   }
}
```

- Can be read-only, write-only, or read/write

```
Button b = new Button();
b.Caption = "OK";
String s = b.Caption;
```

Classes and Structs
Indexers

- An indexer lets an instance behave as a virtual array
- Can be overloaded (e.g. index by `int` and by `string`)

```
public class ListBox: Control {
   private string[] items;
   public string this[int index] {
      get { return items[index]; }
      set { items[index] = value;
            Repaint(); }
   }
}
```

- Can be read-only, write-only, or read/write

```
ListBox listBox = new ListBox();
listBox[0] = "hello";
Console.WriteLine(listBox[0]);
```

Classes and Structs
Methods

- All code executes in a method
  - Constructors, destructors and operators are special types of methods
  - Properties and indexers are implemented with get/set methods
- Methods have argument lists
- Methods contain statements
- Methods can return a value
  - Only if return type is not `void`

Classes and Structs
Method Argument Passing

- By default, data is passed by value
- A copy of the data is created and passed to the method
- For value types, variables cannot be modified by a method call
- For reference types, the instance can be modified by a method call, but the variable itself cannot be modified by a method call

Classes and Structs
Method Argument Passing

- The `ref` modifier causes arguments to be passed by reference
- Allows a method call to modify a variable
- Have to use `ref` modifier in method definition and the code that calls it
- Variable has to have a value before call

```
void RefFunction(ref int p) {
  p++;
}
```

```
int x = 10;
RefFunction(ref x);
// x is now 11
```

Classes and Structs
Method Argument Passing

- The `out` modifier causes arguments to be passed out by reference
- Allows a method call to initialize a variable
- Have to use `out` modifier in method definition and the code that calls it
- Argument has to have a value before returning

```
void OutFunction(out int p) {
  p = 22;
}
```

```
int x;
OutFunction(out x);
// x is now 22
```

Classes and Structs
Overloaded Methods

- A type may overload methods, i.e. provide multiple methods with the same name
- Each must have a unique signature
- Signature is based upon arguments only, the return value is ignored

```
void Print(int i);
void Print(string s);
void Print(char c);
void Print(float f);
int Print(float f);  // Error: duplicate signature
```

Classes and Structs
Parameter Arrays

- Methods can have a variable number of arguments, called a parameter array
- `params` keyword declares parameter array
- Must be last argument

```
int Sum(params int[] intArr) {
  int sum = 0;
  foreach (int i in intArr)
    sum += i;
  return sum;
}
```

```
int sum = Sum(13,87,34);
```

Classes and Structs
Virtual Methods

- Methods may be virtual or non-virtual (default)
- Non-virtual methods are not polymorphic
  - They cannot be overridden
- Non-virtual methods cannot be abstract

```
class Foo {
  public void DoSomething(int i) {
    ...
  }
}
```

```
Foo f = new Foo();
f.DoSomething();
```

Classes and Structs
Virtual Methods

- Defined in a base class
- Can be overridden in derived classes
  - Derived classes provide their own specialized implementation
- May contain a default implementation
  - Use abstract method if no default implementation
- A form of polymorphism
- Properties, indexers and events can also be virtual

Classes and Structs
Virtual Methods

```
class Shape {
  public virtual void Draw() { ... }
}
class Box : Shape {
  public override void Draw() { ... }
}
class Sphere : Shape {
  public override void Draw() { ... }
}
```

```
void HandleShape(Shape s) {
   s.Draw();
   ...
}
```

```
HandleShape(new Box());
HandleShape(new Sphere());
HandleShape(new Shape());
```

Classes and Structs
Abstract Methods

- An abstract method is virtual and has no implementation
- Must belong to an abstract class
- Intended to be implemented in a derived class

Classes and Structs
Abstract Methods

```
abstract class Shape {
  public abstract void Draw();
}
class Box : Shape {
  public override void Draw() { ... }
}
class Sphere : Shape {
  public override void Draw() { ... }
}
```

```
void HandleShape(Shape s) {
   s.Draw();
   ...
}
```

```
HandleShape(new Box());
HandleShape(new Sphere());
HandleShape(new Shape()); // Error!
```

Classes and Structs
Method Versioning

- Must explicitly use `override` or `new` keywords to specify versioning intent
- Avoids accidental overriding
- Methods are non-virtual by default
- C++ and Java product fragile base classes – cannot specify versioning intent

Classes and Structs
Method Versioning

```
class Base {                        // version 2
   public virtual void Foo() {
      Console.WriteLine("Base.Foo");
   }
}
```

```
class Derived: Base {               // version 2b
   public override void Foo() {
      base.Foo();
      Console.WriteLine("Derived.Foo");
   }
}
```

Classes and Structs
Constructors

- Instance constructors are special methods that are called when a class or struct is instantiated
- Performs custom initialization
- Can be overloaded
- If a class doesn't define any constructors, an implicit parameterless constructor is created
- Cannot create a parameterless constructor for a struct
  - All fields initialized to zero/null

Classes and Structs
Constructor Initializers

- One constructor can call another with a constructor initializer
- Can call `this(...)` or `base(...)`
- Default constructor initializer is `base()`

```
class B {
  private int h;
  public B() { }
  public B(int h) { this.h = h; }
}
class D : B {
  private int i;
  public D() : this(24) { }
  public D(int i) { this.i = i; }
  public D(int h, int i) : base(h) { this.i = i; }
}
```

Classes and Structs
Static Constructors

- A static constructor lets you create initialization code that is called once for the class
- Guaranteed to be executed before the first instance of a class or struct is created and before any static member of the class or struct is accessed
- No other guarantees on execution order
- Only one static constructor per type
- Must be parameterless

Classes and Structs
Destructors

- A destructor is a method that is called before an instance is garbage collected
- Used to clean up any resources held by the instance, do bookkeeping, etc.
- Only classes, not structs can have destructors

```
class Foo {
  ~Foo() {
     Console.WriteLine(“Destroyed {0}”, this);
  }
}
```

Classes and Structs
Destructors

- Unlike C++, C# destructors are non-deterministic
- They are not guaranteed to be called at a specific time
- They are guaranteed to be called before shutdown
- Use the `using` statement and the `IDisposable` interface to achieve deterministic finalization

Classes and Structs
Operator Overloading

- User-defined operators
- Must be a static method

```
class Car {
  string vid;
  public static bool operator ==(Car x, Car y) {
    return x.vid == y.vid;
  }
}
```

Classes and Structs
Operator Overloading

- Overloadable unary operators

+	-	!	~
true	false	++	--

- Overloadable binary operators

+	-	*	/	!	~
%	&	|	^	==	!=
<<	>>	<	>	<=	>=

Classes and Structs
Operator Overloading

- No overloading for member access, method invocation, assignment operators, nor these operators: `sizeof`, `new`, `is`, `as`, `typeof`, `checked`, `unchecked`, `&&`, `||`, and `?:`
- The `&&` and `||` operators are automatically evaluated from `&` and `|`
- Overloading a binary operator (e.g. `*`) implicitly overloads the corresponding assignment operator (e.g. `*=`)

Classes and Structs
Operator Overloading

```
struct Vector {
  int x, y;
  public Vector(x, y) { this.x = x; this.y = y; }
  public static Vector operator +(Vector a, Vector b) {
    return Vector(a.x + b.x, a.y + b.y);
  }
  ...
}
```

Classes and Structs
Conversion Operators

- User-defined explicit and implicit conversions

```
class Note {
  int value;
  // Convert to hertz – no loss of precision
  public static implicit operator double(Note x) {
    return ...;
  }
  // Convert to nearest note
  public static explicit operator Note(double x) {
    return ...;
  }
}
```

```
Note n = (Note)442.578;
double d = n;
```

Classes and Structs
Implementing Interfaces

- Classes and structs can implement multiple interfaces
- A class or struct that inherits from an interface must implement all function members defined in that interface

Classes and Structs
Implementing Interfaces

```
public interface IDelete {
  void Delete();
}
public class TextBox : IDelete {
  public void Delete() { ... }
}
public class Car : IDelete {
  public void Delete() { ... }
}
```

```
TextBox tb = new TextBox();
IDelete iDel = tb;
iDel.Delete();

Car c = new Car();
iDel = c;
iDel.Delete();
```

Classes and Structs
Implementing Interfaces

- Explicit interface implementation
- Handles name collisions

```
public interface IDelete {
  void Delete();
}
public interface IFoo {
  void Delete();
}
public class TextBox : IDelete, IFoo {
  public void IDelete.Delete() { ... }
  public void IFoo.Delete() { ... }
}
```

Classes and Structs
Nested Types

- Declared within the scope of another type
- Nesting a type provides three benefits:
  - Nested type can access all the members of its enclosing type, regardless of access modifer
  - Nested type can be hidden from other types
  - Accessing a nested type from outside the enclosing type requires specifying the type name
- Nested types can be declared `new` to hide inherited types
- Unlike Java inner classes, nested types imply no relationship between instances

Classes and Structs
`is` Operator

- The `is` operator is used to dynamically test if the run-time type of an object is compatible with a given type

```
static void DoSomething(object o) {
  if (o is Car)
    ((Car)o).Drive();
}
```

- Don't abuse the `is` operator: it is preferable to design an appropriate type hierarchy with polymorphic methods

Classes and Structs
`as` Operator

- The `as` operator tries to convert a variable to a specified type; if no such conversion is possible the result is `null`

```
static void DoSomething(object o) {
  Car c = o as Car;
  if (c != null) c.Drive();
}
```

- More efficient than using `is` operator: test and convert in one operation
- Same design warning as with the `is` operator

Classes and Structs
`typeof` Operator

- The `typeof` operator returns the `System.Type` object for a specified type
- Can then use reflection to dynamically obtain information about the type

```
Console.WriteLine(typeof(int).FullName);
Console.WriteLine(typeof(System.Int).Name);
Console.WriteLine(typeof(float).Module);
Console.WriteLine(typeof(double).IsPublic);
Console.WriteLine(typeof(Car).MemberType);
```

Agenda

- Review Object-Oriented Concepts
- Interfaces
- Classes and Structs
- **Delegates**
- Events
- Attributes
- Preprocessor Directives
- XML Comments
- Unsafe Code

Delegates
Overview

- A delegate is a reference type that defines a method signature
- A delegate instance holds one or more methods
  - Essentially an “object-oriented function pointer”
  - Methods can be static or non-static
  - Methods can return a value
- Provides polymorphism for individual functions
- Foundation for event handling

Delegates
Overview

```
delegate double Del(double x);      // Declare

static void DemoDelegates() {
  Del delInst = new Del(Math.Sin);  // Instantiate
  double x = delInst(1.0);          // Invoke
}
```

Delegates
Multicast Delegates

- A delegate can hold and invoke multiple methods
  - Multicast delegates must contain only methods that return `void`, else there is a run-time exception
- Each delegate has an invocation list
  - Methods are invoked sequentially, in the order added
- The `+=` and `-=` operators are used to add and remove delegates, respectively
- `+=` and `-=` operators are thread-safe

Delegates
Multicast Delegates

```
delegate void SomeEvent(int x, int y);
static void Foo1(int x, int y) {
  Console.WriteLine("Foo1");
}
static void Foo2(int x, int y) {
  Console.WriteLine("Foo2");
}
public static void Main() {
  SomeEvent func = new SomeEvent(Foo1);
  func += new SomeEvent(Foo2);
  func(1,2);              // Foo1 and Foo2 are called
  func -= new SomeEvent(Foo1);
  func(2,3);              // Only Foo2 is called
}
```

Delegates
and Interfaces

- Could always use interfaces instead of delegates
- Interfaces are more powerful
  - Multiple methods
  - Inheritance
- Delegates are more elegant for event handlers
  - Less code
  - Can easily implement multiple event handlers on one class/struct

Agenda

- Review Object-Oriented Concepts
- Interfaces
- Classes and Structs
- Delegates
- **Events**
- Attributes
- Preprocessor Directives
- XML Comments
- Unsafe Code

Events
Overview

- Event handling is a style of programming where one object notifies another that something of interest has occurred
  - A publish-subscribe programming model
- Events allow you to tie your own code into the functioning of an independently created component
- Events are a type of “callback” mechanism

Events
Overview

- Events are well suited for user-interfaces
  - The user does something (clicks a button, moves a mouse, changes a value, etc.) and the program reacts in response
- Many other uses, e.g.
  - Time-based events
  - Asynchronous operation completed
  - Email message has arrived
  - A web session has begun

Events
Overview

- C# has native support for events
- Based upon delegates
- An event is essentially a field holding a delegate
- However, public users of the class can only register delegates
  - They can only call += and -=
  - They can't invoke the event's delegate
- Multicast delegates allow multiple objects to register with the same event

Events
Example: Component-Side

- Define the event signature as a delegate

```
public delegate void EventHandler(object sender,
                                  EventArgs e);
```

- Define the event and firing logic

```
public class Button {
  public event EventHandler Click;

  protected void OnClick(EventArgs e) {
    // This is called when button is clicked
    if (Click != null) Click(this, e);
  }
}
```

Events
Example: User-Side

- Define and register an event handler

```
public class MyForm: Form {
  Button okButton;

  static void OkClicked(object sender, EventArgs e) {
    ShowMessage("You pressed the OK button");
  }

  public MyForm() {
    okButton = new Button(...);
    okButton.Caption = "OK";
    okButton.Click += new EventHandler(OkClicked);
  }
}
```

Agenda

- Review Object-Oriented Concepts
- Interfaces
- Classes and Structs
- Delegates
- Events
- **Attributes**
- Preprocessor Directives
- XML Comments
- Unsafe Code

Attributes
Overview

- It's often necessary to associate information (metadata) with types and members, e.g.
  - Documentation URL for a class
  - Transaction context for a method
  - XML persistence mapping
  - COM ProgID for a class
- Attributes allow you to decorate a code element (assembly, module, type, member, return value and parameter) with additional information

Attributes
Overview

```
[HelpUrl("http://SomeUrl/APIDocs/SomeClass")]
class SomeClass {
  [Obsolete("Use SomeNewMethod instead")]
  public void SomeOldMethod() {
    ...
  }

  public string Test([SomeAttr()] string param1) {
    ...
  }
}
```

Attributes
Overview

- Attributes are superior to the alternatives
  - Modifying the source language
  - Using external files, e.g., .IDL, .DEF
- Attributes are extensible
  - Attributes allow to you add information not supported by C# itself
  - Not limited to predefined information
- Built into the .NET Framework, so they work across all .NET languages
  - Stored in assembly metadata

Attributes
Overview

- Some predefined .NET Framework attributes

Attribute Name	Description
`Browsable`	Should a property or event be displayed in the property window
`Serializable`	Allows a class or struct to be serialized
`Obsolete`	Compiler will complain if target is used
`ProgId`	COM Prog ID
`Transaction`	Transactional characteristics of a class

Attributes
Overview

- Attributes can be
  - Attached to types and members
  - Examined at run-time using reflection
- Completely extensible
  - Simply a class that inherits from `System.Attribute`
- Type-safe
  - Arguments checked at compile-time
- Extensive use in .NET Framework
  - XML, Web Services, security, serialization, component model, COM and P/Invoke interop, code configuration…

Attributes
Querying Attributes

```
[HelpUrl("http://SomeUrl/MyClass")]
class Class1 {}
[HelpUrl("http://SomeUrl/MyClass"),
 HelpUrl("http://SomeUrl/MyClass", Tag="ctor")]
class Class2 {}
```

```
Type type = typeof(MyClass);
foreach (object attr in type.GetCustomAttributes() ) {
  if ( attr is HelpUrlAttribute )  {
    HelpUrlAttribute ha = (HelpUrlAttribute) attr;
    myBrowser.Navigate( ha.Url );
  }
}
```

Agenda

- Review Object-Oriented Concepts
- Interfaces
- Classes and Structs
- Delegates
- Events
- Attributes
- **Preprocessor Directives**
- XML Comments
- Unsafe Code

Preprocessor Directives
Overview

- C# provides preprocessor directives that serve a number of functions
- Unlike C++, there is not a separate preprocessor
  - The "preprocessor" name is preserved only for consistency with C++
- C++ preprocessor features removed include:
  - `#include`: Not really needed with one-stop programming; removal results in faster compilation
  - Macro version of `#define`: removed for clarity

Preprocessor Directives
Overview

Directive	Description
`#define`, `#undef`	Define and undefine conditional symbols
`#if`, `#elif`, `#else`, `#endif`	Conditionally skip sections of code
`#error`, `#warning`	Issue errors and warnings
`#region`, `#end`	Delimit outline regions
`#line`	Specify line number

Preprocessor Directives
Conditional Compilation

```
#define Debug
public class Debug {
  [Conditional("Debug")]
  public static void Assert(bool cond, String s) {
    if (!cond) {
      throw new AssertionException(s);
    }
  }
  void DoSomething() {
    ...
    // If Debug is not defined, the next line is
    // not even called
    Assert((x == y), "X should equal Y");
    ...
  }
}
```

Preprocessor Directives
Assertions

- By the way, assertions are an incredible way to improve the quality of your code
- An assertion is essentially a unit test built right into your code
- You should have assertions to test preconditions, postconditions and invariants
- Assertions are only enabled in debug builds
- Your code is QA'd every time it runs
- Must read: "*Writing Solid Code*", by Steve Maguire, Microsoft Press, ISBN 1-55615-551-4

Agenda

- Review Object-Oriented Concepts
- Interfaces
- Classes and Structs
- Delegates
- Events
- Attributes
- Preprocessor Directives
- **XML Comments**
- Unsafe Code

XML Comments
Overview

- Programmers don't like to document code, so we need a way to make it easy for them to produce quality, up-to-date documentation
- C# lets you embed XML comments that document types, members, parameters, etc.
  - Denoted with triple slash: `///`
- XML document is generated when code is compiled with `/doc` argument
- Comes with predefined XML schema, but you can add your own tags too
  - Some are verified, e.g. parameters, exceptions, types

XML Comments
Overview

XML Tag	Description
`<summary>, <remarks>`	**Type or member**
`<param>`	**Method parameter**
`<returns>`	**Method return value**
`<exception>`	**Exceptions thrown from method**
`<example>, <c>, <code>`	**Sample code**
`<see>, <seealso>`	**Cross references**
`<value>`	**Property**
`<paramref>`	**Use of a parameter**
`<list>, <item>, ...`	**Formatting hints**
`<permission>`	**Permission requirements**

XML Comments
Overview

```
class XmlElement {
   /// <summary>
   ///    Returns the attribute with the given name and
   ///    namespace</summary>
   /// <param name="name">
   ///    The name of the attribute</param>
   /// <param name="ns">
   ///    The namespace of the attribute, or null if
   ///    the attribute has no namespace</param>
   /// <return>
   ///    The attribute value, or null if the attribute
   ///    does not exist</return>
   /// <seealso cref="GetAttr(string)"/>
   ///
   public string GetAttr(string name, string ns) {
      ...
   }
}
```

Agenda

- Review Object-Oriented Concepts
- Interfaces
- Classes and Structs
- Delegates
- Events
- Attributes
- Preprocessor Directives
- XML Comments
- **Unsafe Code**

Unsafe Code
Overview

- Developers sometime need total control
  - Performance extremes
  - Dealing with existing binary structures
  - Existing code
  - Advanced COM support, DLL import
- C# allows you to mark code as unsafe, allowing
  - Pointer types, pointer arithmetic
  - `->`, `*` operators
  - Unsafe casts
  - No garbage collection

Unsafe Code
Overview

- Lets you embed native C/C++ code
- Basically “inline C”
- Must ensure the GC doesn’t move your data
  - Use `fixed` statement to pin data
  - Use `stackalloc` operator so memory is allocated on stack, and need not be pinned

```
unsafe void Foo() {
   char* buf = stackalloc char[256];
   for (char* p = buf; p < buf + 256; p++) *p = 0;
   ...
}
```

Unsafe Code
Overview

```
class FileStream: Stream {
  int handle;

  public unsafe int Read(byte[] buffer, int index,
                         int count) {
    int n = 0;
    fixed (byte* p = buffer) {
      ReadFile(handle, p + index, count, &n, null);
    }
    return n;
  }

  [dllimport("kernel32", SetLastError=true)]
  static extern unsafe bool ReadFile(int hFile,
    void* lpBuffer, int nBytesToRead,
    int* nBytesRead, Overlapped* lpOverlapped);
}
```

Unsafe Code
C# and Pointers

- Power comes at a price!
  - Unsafe means unverifiable code
  - Stricter security requirements
    - Before the code can run
    - Downloading code

More Resources

- http://msdn.microsoft.com
- http://windows.oreilly.com/news/hejlsberg_0800.html
- http://www.csharphelp.com/
- http://www.csharp-station.com/
- http://www.csharpindex.com/
- http://msdn.microsoft.com/msdnmag/issues/0900/csharp/csharp.asp
- http://www.hitmill.com/programming/dotNET/csharp.html
- http://www.c-sharpcorner.com/
- http://msdn.microsoft.com/library/default.asp?URL=/library/dotnet/csspec/vclrfcsharpspec_Start.htm