

Windows Applications Programming

Microsoft .NET Framework, C# Language

Microsoft .NET Framework, C# Language



C#

• url: https://www.microsoft.com/net, https://msdn.microsoft.com/en-us/library/67ef8sbd.aspx

Few words about me...



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Administrative issues

Evaluation

- Final exam 50%
 - similar to the OOP exam

- Seminar 50%
 - test 30%
 - project (mandatory) 20%

Administrative issues

Recommended Reading / Watching

- Slides, Examples, Books:
 - http://liviucotfas.ase.ro

Further Reading / Watching

- Courses on Microsoft Virtual Academy <u>mva.microsoft.com</u>
 - Free
- Courses on PluralSight www.pluralsight.com
 - Free trial
 - Free access (limited period) through <u>Microsoft DreamSpark</u>

Administrative issues

API reference and Source code

- API reference:
 - https://msdn.microsoft.com/en-us/library/
- .NET Framework source code:
 - http://referencesource.microsoft.com/#mscorlib/system/string.cs,8281103e6f23
 cb5c

Road map

- 1. .NET Framework and C# Language
- 2. Differences between C++ and .NET
- 3. System Data Types
- 4. Value Types and Reference Types
- 5. Boxing / Unboxing

.NET Framework and C# language

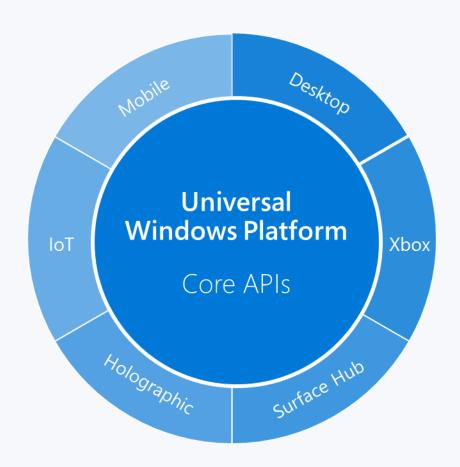
Why .NET? - Various types of apps

- desktop:
 - Universal Windows Platform (Windows 10);
 - Windows Runtime WinRT (Windows 8.0 / 8.1);
 - Windows Presentation Foundation WPF (Windows Vista +);
 - WinForms.
- mobile: Windows Phone, Android (Xamarin), iOS (Xamarin)
- web: ASP.NET MVC / ASP.NET WebAPI
- cloud: Windows Azure

.NET Framework and C# language

Why .NET?

- cross-platform;
- integrated in Windows;
- A comprehensive base class library;



Universal Windows Platform (Windows 10)

Building Blocks of the .NET Platform

From a programmer's point of view, .NET can be understood as a runtime environment and a comprehensive base class library.

The Base Class Libraries				
Database Access	Desktop GUI APIs	Security	Remoting APIs	
Threading	File I/O	Web APIs	(et al.)	
The Common Language Runtime				
Common Type System				
Common Language Specification				

Common Language Runtime

The **CLR** manages the code being executed and provides for a layer of abstraction between the code and the operating system. Built into the CLR are mechanisms for the following:

- Loading code into memory and preparing it for execution.
- Converting the code from the intermediate language to native code.
- Managing code execution.
- Managing code and user-level security.
- Automating deallocation and release of memory.
- Debugging and tracing code execution.
- Providing structured exception handling.

Common Type System and Common Language Specification

- Common Type System
 - describes all possible data types and all programming constructs supported by the runtime,
- Common Language Specification
 - Defines a subset of common types and programming constructs that all .NET programming languages can agree on.

Framework Base Class Library

- available to all .NET programming languages.
- define types that can be used to build any type of software application:
 - ASP.NET to build web sites,
 - WCF to build networked services,
 - WPF to build desktop GUI applications
- provide types to interact with XML documents, the local directory and file system on a given computer, communicate with a relational databases (via ADO.NET), and so forth.

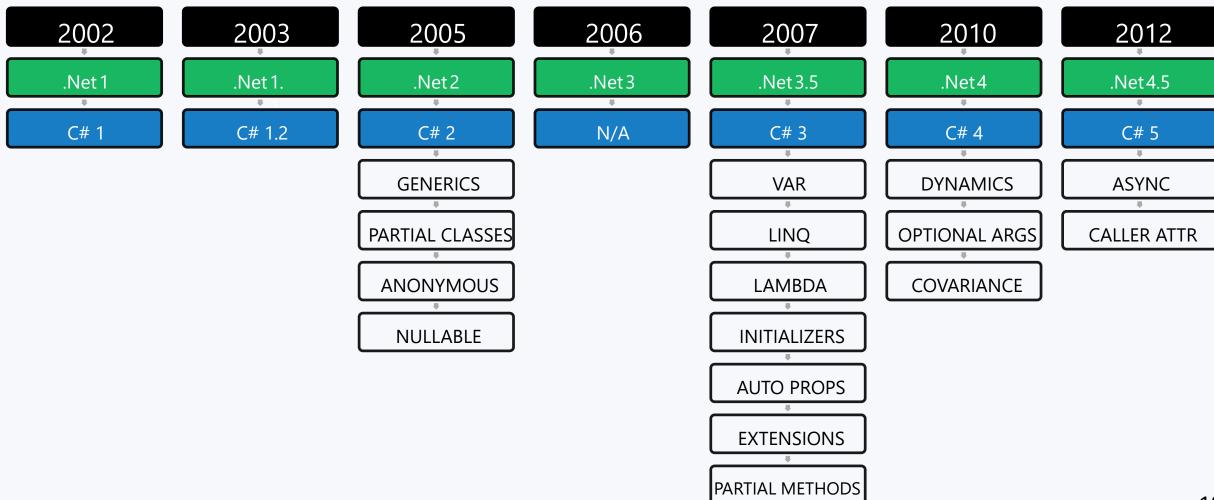
Managed languages

- Managed languages depend on services provided by a runtime environment.
- C# is one of many languages that compile into managed code.
- Managed code is executed by the Common Language Runtime (CLR).

Why use C#?

- C# (pronounced "C sharp") is a general-purpose, type-safe language, objectoriented programming language, designed for building a variety of applications
- Focused on developer productivity.
- C# syntax is based on the C & C++ syntax.
- Platform-neutral, but it was written to work well with the Microsoft .NET Framework.

Constantly evolving language



Compiling and Executing Managed Code

- When .NET code is compiled, it is converted into a .NET portable executable (PE) file. The compiler translates the source code into Microsoft intermediate language (MSIL) format.
- MSIL is CPU independent code, which means it needs to be further converted into native code before executing.

Decompiles: https://www.jetbrains.com/decompiler/

Compiling and Executing Managed Code

- Before the MSIL code in the PE file is executed, a .NET Framework just-in-time (JIT) compiler converts it into CPU-specific native code. To improve efficiency, the JIT compiler does not convert all the MSIL code into native code at the same time. MSIL code is converted on an as-needed basis. When a method is executed, the compiler checks to see if the code has already been converted and placed in cache. If it has, the compiled version is used; otherwise, the MSIL code is converted and stored in the cache for future calls.
- Because JIT compilers are written to target different CPUs and operating systems, developers are freed from needing to rewrite their applications to target various platforms.

Compiling and Executing Managed Code

Because the source code for the various .NET-compliant languages is compiled into the same MSIL and metadata format based on a common type system, the .NET platform supports language integration. With .NET language integration, a class written in VB could inherit a class written in C#.

Differences between C++ and .NET

Globals

■ In C#, **global** methods and variables are **not supported**. Methods and variables must be contained within a class or struct.

Further reading: <u>link</u>

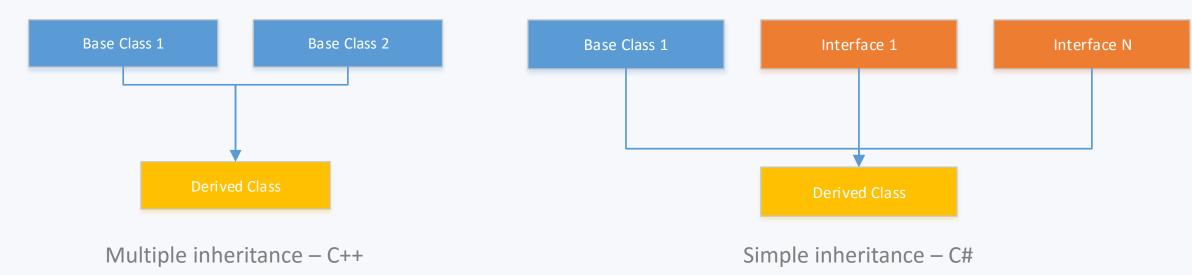
```
using System; //referenced namespace
namespace NameSpaceProgram
       internal class Program
               private static void Main(string[] args)
                       //HelloWorld application
                       Console.WriteLine ("Hello World!");
                       Console.ReadLine();
               } //end main
       }//end class
} //end namespace
```

Main

- The Main method in C# is declared differently from the main function in C++. In C# it is capitalized, and always static.
- Support for processing of command-line arguments is much more robust in C#.

Inheritance

- C# classes can implement any number of interfaces, but can inherit from only one base class => Multiple Inheritance is not supported!
- C# structs do not support inheritance, and do not support explicit default constructors (one is provided by default).



Inheritance

```
class DepositAccount: Account, IComparable, IComparable<Account>, ICloneable
         public int CompareTo(object obj)
                  throw new NotImplementedException();
         public int CompareTo(Account other)
                  throw new NotImplementedException();
         public object Clone()
                  throw new NotImplementedException();
```

Pointers

Pointers are allowed in C#, but only in unsafe mode.

Further reading: <u>link</u>

Strings

- In C++ a string is simply an array of characters. In C#, strings are objects that support robust searching methods.
- The C# string class is located in the System namespace (**System.String**).
 - Sealed the class cannot be inherited
 - Immutable after the initial value is assigned to a string object, the character data cannot be changed. A brand new string is created each time we modify the initial string
- Further reading: <u>link</u>

Garbage Collection

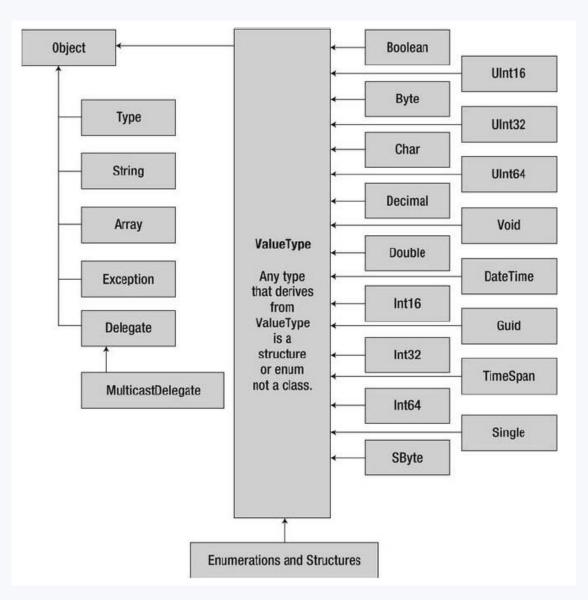
- Memory management: C++ is not a garbage collected language; memory that
 is not explicitly release remains allocated until the process terminates.
- C# is a garbage collected language.
- Further reading: <u>link</u>

Further reading

More differences: https://msdn.microsoft.com/en-us/library/yyaad03b%28v=vs.90%29.aspx

System Data Types

Inheritance between the System Data Types



System Data Types

Type

Foundational building block is a Type:

- Metadata about space allocation
- Metadata for compile-time type checking

System Data Types

Object

- All types have a common base Object
 - defines four base methods that will be available for any type
 - any type variable can be cast to Object (upcast).

Name	Description
Equals(Object)	Determines whether the specified object is equal to the current object.
GetHashCode()	Serves as the default hash function.
GetType()	Gets the <u>Type</u> of the current instance.
ToString()	Returns a string that represents the current object.

Object

```
public class Object
      public Object();
      public extern Type GetType();
      public virtual bool Equals (object obj);
      public static bool Equals (object objA, object objB);
      public static bool ReferenceEquals (object objA, object objB);
      public virtual int GetHashCode();
      public virtual string ToString();
      protected virtual void Finalize();
      protected extern object MemberwiseClone();
```

System Data Types

Categories

- Categories of standard types:
 - Value types variables directly store values
 - Reference types or objects, store a reference to data
 - Pointer types –only available in unsafe code

System Data Types

Value types

- structure, enum, primitive types (derived from System.ValueType)
- allocated: on the stack;
- lifetime: can be created and destroyed very quickly, as its lifetime is determined by the defining scope;

System Data Types

Reference types

- class, delegate, interface
- allocated: in the heap;
- lifetime: has a lifetime that is determined by a large number of factors

Comparison between Value Types and Reference Types

	Value type	Reference Type
Where are objects allocated?	Allocated on the stack.	Allocated on the managed
		heap.
How is a variable represented?	Value type variables are local copies.	Reference type variables are pointing to the memory occupied by the allocated instance.
What is the base type?	Implicitly extends	Can derive from any other
	System.ValueType.	type (except System.ValueType), as long as that type is not "sealed".
Can this type function as a base to other types?	No. Value types are always sealed and cannot be inherited from.	Yes. If the type is not sealed, it may function as a base to other types.
Default parameter passing behavior	Variables are passed by value (i.e., a copy of the variable is passed into the called function).	For value types, the object is copied-by-value. For reference types, the reference is copied-by- value.
Own constructor for this type	Yes, but the default constructor is reserved (i.e., the custom constructors must all have arguments).	Yes
When do variables of this type die?	When they fall out of the defining scope.	When the object is garbage collected.

System Data Types

String / StringBuilder

Url: https://drive.google.com/open?id=0B1H3r-YAWOyOQU1tZFlyMmZvanM

Section: Working with Strings

System Data Types

Array

Url: https://drive.google.com/open?id=0B1H3r-YAWOyOQU1tZFlyMmZvanM

Section: Arrays

Classes

Syntax

```
[attributes]
[internal / public] [abstract] [sealed] [static] [partial] class ClassName [:BaseClass, Interface1, ...
InterfaceN]
{
...
}
```

```
[Serializable]

public class Employee : Person, IComparable < Person >

{
    ...
}
```

Class - [accessModifier]

internal

 without specifying public the class is implicitly internal. This means that the class is only visible inside the same assembly.

public

the class is visible outside the assembly (project).

Fields

```
class ClassName
{
      [accessModifier] [static] [new] [readonly] type field;
}
```

```
class Person
{
     private int _age;
}
```

Modifiers:

- access: private (default), public, protected, internal, protected internal
- **static**: static
- read-only: readonly
- inheritance: new

Fields - Access Modifiers

- public: the type or member can be accessed by any other code in the same assembly or another assembly that references it.
- private: the type or member can be accessed only by code in the same class or struct.
- protected: the type or member can be accessed only by code in the same class or struct, or in a class that is derived from that class.
- internal: the type or member can be accessed by any code in the same assembly, but not from another assembly.

Fields - Access Modifiers

• protected internal: the type or member can be accessed by any code in the assembly in which it is declared, or from within a derived class in another assembly. Access from another assembly must take place within a class declaration that derives from the class in which the protected internal element is declared, and it must take place through an instance of the derived class type.

Fields - static

- declare a member, which belongs to the type itself rather than to a specific object.
- a static member cannot be referenced through an instance. Instead, it is referenced through the type name.
- It is not possible to use this to reference static methods or property accessors.

Fields - readonly

 assignments to the fields can only occur as part of the declaration or in a constructor in the same class

```
class Age
  readonly int _year;
  Age(int year)
    _year = year;
  void ChangeYear()
    //_year = 1967; // Compile error if uncommented.
```

Fields - const

- constant fields aren't variables and may not be modified. Constants can be numbers, Boolean values, strings, or a null reference.
- assignments to the fields can only occur as part of the declaration

```
class SampleClass
{
    public const int c1 = 5;
    public const int c2 = c1 + 5;
}
```

Fields – readonly & const

- The **readonly** keyword is different from the <u>const</u> keyword. A **const** field can only be initialized at the declaration of the field. A **readonly** field can be initialized either at the declaration or in a constructor.
- Therefore, readonly fields can have different values depending on the constructor used.

Methods

Modifiers:

- access: private (default), public, protected, internal, protected internal
- **static**: static
- inheritance: new, virtual, abstract, override, sealed
- partial: partial

Constructors

- run initialization code on a class or struct.
- a constructor is defined like a method, except that the method name and return type are reduced to the name of the enclosing type

```
public class Wine
         public decimal Price;
         public int Year;
         public Wine (decimal price) { Price = price; }
         public Wine (decimal price, int year) : this (price) { Year = year; }
var wine = new Wine(10);
var wine = new Wine(10, 2010);
```

Constructors

 Constructors do not need to be public. A common reason to have a nonpublic constructor is to control instance creation via a static method call. The static method could be used to return an object from a pool rather than necessarily creating a new object.

this Reference

- the **this** reference refers to the instance itself.
- the **this** reference also disambiguates a local variable or parameter from a field:

```
public class Test
{
      string name;
      public Test (string name) { this.name = name; }
}
```

Properties

A property is a member that provides a flexible mechanism to read, write, or compute the value of a private field. Properties can be used as if they are public data members, but they are actually special methods called accessors.

Modifiers:

- access: private (default), public, protected, internal, protected internal
- **static**: static
- inheritance: new, virtual, abstract, override, sealed

Properties

Encapsulation using accessor methods:

```
#region Accessor Methods
private int _age;
public int GetAge()
{
        return _age; // "this._age" is implicit
}
public void SetAge(int value)
{
        _age = value; // "this._age" is implicit
}
#endregion
```

Properties

```
#region Name - Using properties
private string _name;
//Read/Write property
public string Name
        get { return _name; }
        set { _name = value; }
//Readonly property
public string Name2
        get { return _name; }
#endregion
```

Auto-property

 The get and set accessors can have different access levels. The typical use case for this is to have a public property with an internal or private access modifier on the setter

```
#region Occupation - Using auto-property
public OccupationEnum Occupation { get; set; }
#endregion

#region Occupation - Using auto-property
public OccupationEnum Occupation { get; private set; }
#endregion
```

CLR property implementation

C# property accessors internally compile to methods called get_XXX and set_XXX:

```
public decimal CurrentPrice {get;set;}
```

```
public decimal get_CurrentPrice {...}
public void set_CurrentPrice (decimal value) {...}
```

Sealed class

- prevents other classes from inheriting from it
- can also be used on methods or properties that overrides a virtual method or property in a base class. Classes can be derived from the base class, but they are prevented from overriding specific virtual methods or properties.

```
public sealed class String : IComparable, ICloneable, I....
{
}
```

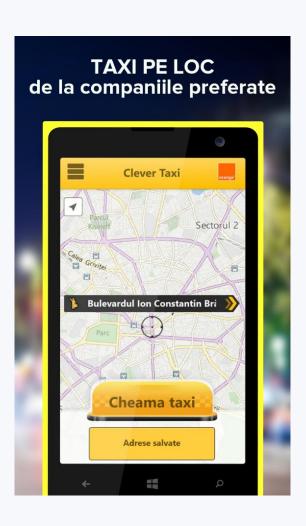
Static class

- has the static modifier in the class declaration. All the members of the class need to be static.
- can be used as a convenient container for sets of methods that just operate on input parameters and do not have to get or set any internal instance fields.
- a static class cannot be instantiated.
- further reading: <u>link</u>

Static class

```
/// <summary>
/// Contains device hardware related methods
/// </summary>
public static class DeviceInfo
           public static string GetDeviceUniqueId()
                     var token = HardwareIdentification.GetPackageSpecificToken(null);
                     return hashedString;
           public static String GetDeviceName()
                     var deviceInfo = new EasClientDeviceInformation();
                     return String.Format("{0} {1} {2}", deviceInfo.SystemManufacturer, deviceInfo.SystemProductName,
deviceInfo.FriendlyName);
```

Static class



Operators

Operators

Overloading

can be overload by defining static member functions using the <u>operator</u> keyword.

not all operators can be overloaded and others have restrictions

further reading: <u>link</u>

List of operators

Operators	Overloadability
<u>+</u> , <u>-</u> , <u>!</u> , <u>~</u> , <u>++</u> , <u></u> , <u>true</u> , <u>false</u>	These unary operators can be overloaded.
<u>+</u> , -, <u>*</u> , <u>/</u> , <u>%</u> , <u>&</u> , <u> </u> , <u>^</u> , <u><<</u> , <u>>></u>	These binary operators can be overloaded.
<u>==, !=, <, >, <=, >=</u>	The comparison operators can be overloaded
<u>&&</u> , <u> </u>	The conditional logical operators cannot be overloaded, but they are
	evaluated using & and , which can be overloaded.
П	The array indexing operator cannot be overloaded, but you can
	define indexers.
<u>(T)x</u>	The cast operator cannot be overloaded, but you can define new
	conversion operators (see <u>explicit</u> and <u>implicit</u>).
<u>+=, -=, *=, /=, %=, &=, =, ^=, <<=</u> ,	Assignment operators cannot be overloaded, but +=, for example, is
<u>>>=</u>	evaluated using +, which can be overloaded.
=, ., <u>?:</u> , <u>??</u> , <u>-></u> , <u>=></u> , <u>f(x)</u> , <u>as</u> , <u>checked</u> ,	These operators cannot be overloaded.
unchecked, default, delegate, is,	
new, sizeof, typeof	

operator == and operator!=

```
public sealed class String: IComparable, ICloneable, I....
         public static bool operator == (String a, String b) {
                  return String.Equals(a, b);
         public static bool operator != (String a, String b) {
                  return !String.Equals(a, b);
```

operator+, operator*, cast

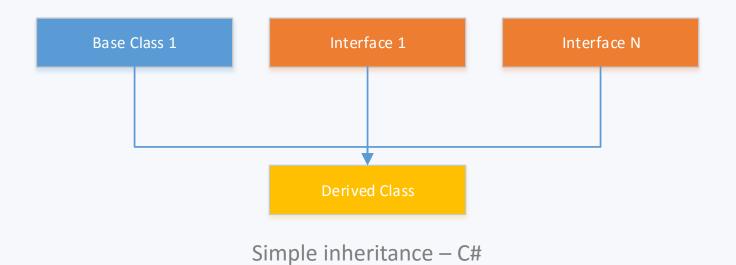
```
class Fraction
  // overload operator +
  public static Fraction operator +(Fraction a, Fraction b) {
     return new Fraction(a.num * b.den + b.num * a.den,
       a.den * b.den);
  // overload operator *
  public static Fraction operator *(Fraction a, Fraction b) {
     return new Fraction(a.num * b.num, a.den * b.den);
  // user-defined conversion from Fraction to double
  public static implicit operator double(Fraction f) {
     return (double)f.num / f.den;
```

Inheritance

Simple Inheritance

C# implements Inheritance in two ways:

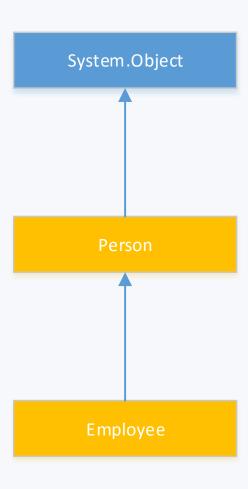
- a class may inherit from a single base class
- a class may implement zero or more Interfaces



Example

```
internal class Person
        public string Name { get; set; }
        public int Age { get; set; }
internal abstract class Employee: Person
        public double Wage { get; set; }
```

Example – Inheritance Chain



Upcasting

```
private static void Main()
 var employee = new Employee();
 Person person = employee; // Upcast
 Console.WriteLine (person == employee); // True
 Console.WriteLine (person.Name); // OK
 Console.WriteLine (person.Wage); // Error: Wage undefined
```

Downcasting

```
Private is testian explication dest because it can potentially fail at runtime. If a downcast fails, an
{ InvalidCastException is thrown.
  var employee = new Employee();
  Person person = employee; // Upcast
  Employee employee2 = (Employee) person; // Downcast
  Console.WriteLine (employee2.Wage); // <No error>
  Console.WriteLine (person == employee); // True
  Console.WriteLine (person == employee2); // True
```

The as operator

 performs a downcast that evaluates to null (rather than throwing an exception) if the downcast fails:

```
System.Object
var e = new Employee();
// Contract and Employee are derived from Person
Contractor c = a as Contractor; // c is null; no exception thrown
                                                                                Person
test whether the result is null
if (c!=null){
         Console.WriteLine(c.Rate)
                                                                                              Contractor
```

The is operator

- tests whether a reference conversion would succeed (whether an object derives from a specified class or implements an interface)
- it is often used to test before downcasting

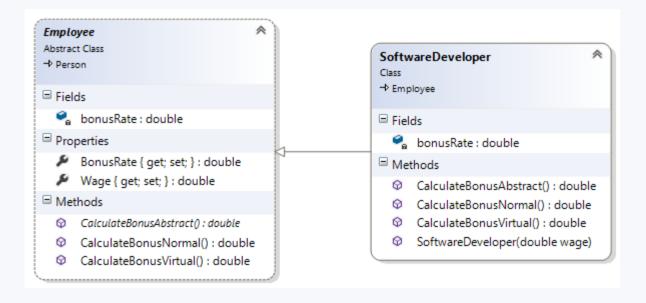
Abstract classes

- can never be instantiated. Instead, only its concrete subclasses can be instantiated.
- are able to define abstract members. Abstract members are like virtual members, except they don't provide a default implementation. That implementation must be provided by the subclass, unless that subclass is also declared abstract.

Abstract classes

```
internal abstract class Employee : Person{
        private static double bonusRate = 1.1;
        public double Wage { get; set; }
        public abstract double CalculateBonusAbstract(); //Abstract method
        public double CalculateBonusNormal(){//Normal method
                 Console.WriteLine("Employee - CalculateBonusNormal");
                 return bonusRate * Wage;
        public virtual double CalculateBonusVirtual() {//Virtual method
                 Console.WriteLine("Employee - CalculateBonusVirtual");
                 return bonusRate * Wage;
```

Virtual Function Members



Virtual Function Members

```
internal class Software Developer: Employee
        private static double bonusRate = 1.2;
        public override double CalculateBonusAbstract()
                 Console.WriteLine("SoftwareDeveloper - CalculateBonusAbstract");
                 return bonusRate * Wage;
        public override double CalculateBonusVirtual() {
                 Console.WriteLine("Employee - CalculateBonusVirtual");
                 return bonusRate * Wage;
```

Hiding Inherited Members

- using the new modifier;
- We can hide attributes, methods and properties.

```
internal class SoftwareDeveloper : Employee{
    private static double bonusRate = 1.2;

public new double CalculateBonusNormal()
    {
        Console.WriteLine("SoftwareDeveloper - CalculateBonusNormal");
        return bonusRate * Wage;
    }
}
```

Abstract / Hide / Virtual

```
private static void AbstractNormalVirtualMethods () {
         var softwareDeveloper = new SoftwareDeveloper(2000);
         //Abstract method
         Console.WriteLine("\n###Abstract");
         Console. WriteLine (software Developer. Calculate Bonus Abstract ()):
         Console.WriteLine(((Employee)softwareDeveloper).CalculateBonusAbstract());
         //Normal method
         Console.Write("\n###Hide");
         Console.WriteLine(softwareDeveloper.CalculateBonusNormal());
         Console.WriteLine(((Employee)softwareDeveloper).CalculateBonusNormal());
         //Virtual method
         Console.Write("\n###Override");
         Console.WriteLine(softwareDeveloper.CalculateBonusVirtual());
         Console.WriteLine(((Employee)softwareDeveloper).CalculateBonusVirtual());
```

Abstract / Hide / Virtual

```
C:\WINDOWS\system32\cmd.exe
###Abstract
SoftwareDeveloper - CalculateBonusAbstract
2400
SoftwareDeveloper - CalculateBonusAbstract
2400
###HideSoftwareDeveloper - CalculateBonusNormal
2400
Employee - CalculateBonusNormal
2200
###OverrideEmployee - CalculateBonusVirtual
2400
Employee - CalculateBonusVirtual
2400
Press any key to continue . . . _
```

The base Keyword

- access an overridden function member from the subclass
- calling a base-class constructor

Constructors and Inheritance

• A subclass must declare its own constructors. The base class's constructors are accessible to the derived class, but are never automatically inherited.

```
public class Baseclass
{
public int X;
public Baseclass () { }
public Baseclass (int x) { this.X = x; }
}
public class Subclass : Baseclass { }
```

the following is illegal:

```
Subclass s = new Subclass (123);
```

Constructors and Inheritance

```
public class Subclass : Baseclass
{
     public Subclass (int x) : base (x)
     {
      }
}
```

Implicit calling of the parameterless base-class constructor

 If a constructor in a subclass omits the base keyword, the base type's parameterless constructor is implicitly called

```
public class BaseClass
{
         public int X;
         public BaseClass() { X = 1; }
}
public class Subclass : BaseClass
{
         public Subclass() { Console.WriteLine (X); } // 1
}
```

Constructor and field initialization order

When an object is instantiated, initialization takes place in the following order:

- 1. From subclass to base class:
 - a) Fields are initialized.
 - b) Arguments to base-class constructor calls are evaluated.
- 2. From base class to subclass:
 - a) Constructor bodies execute.

Constructor and field initialization order

```
public class B{
         int x = 1; // Executes 3rd
         public B (int x)
                   ... // Executes 4th
public class D : B{
         int y = 1; // Executes 1st
         public D (int x)
                   : base (x + 1) // Executes 2nd
                  ... // Executes 5th
```

Interfaces

Interfaces

- An interface declaration is like a class declaration, but it provides no implementation for its members, since all its members are implicitly abstract.
 These members will be implemented by the classes and structs that implement the interface.
- An interface can contain only methods, properties, events, and indexers.

```
public interface IComparable<in T>
{
    int CompareTo(T other);
}
```

```
var p1 = new Person("Name3", 42);
var p2 = new Person("Name1", 23);
var p3 = new Person("Name2", 32);

var pArray = new Person[] { p1, p2, p3 };

Array.Sort(pArray);
```

IComparable<T>

- Defines a generalized comparison method that a value type or class implements to create a type-specific comparison method for ordering or sorting its instances.
- CompareTo(T) method must return an Int32

Value	Meaning
Less than zero	This object precedes the object specified by the CompareTo method in the sort order.
Zero	This current instance occurs in the same position in the sort order as the object specified by the CompareTo method argument.
Greater than zero	This current instance follows the object specified by the CompareTo method argument in the sort order.

IComparable<T>

```
internal class Person : IComparable<Person>
      #region Properties
      public string Name { get; set; }
      #endregion
      public int CompareTo(Person other)
            return Name.CompareTo(other.Name);
```

Question: why is it possible to call Name.CompareTo(...)?

Custom interfaces

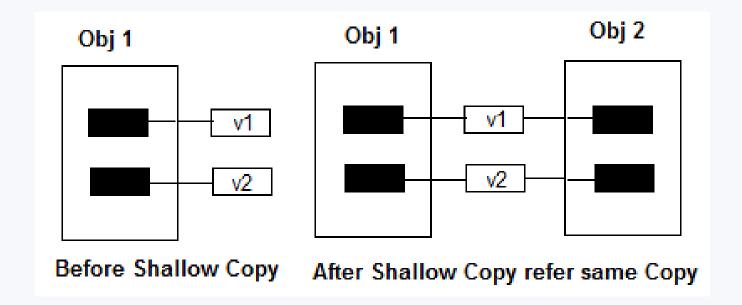
```
internal interface IKnownProgrammingLanguages
{
    //Property
    string[] KnownProgrammingLanguages { get; set; }

    //Method
    bool Knows(string language);
}
```

Shallow Copy and Deep Copy

Shallow Copy

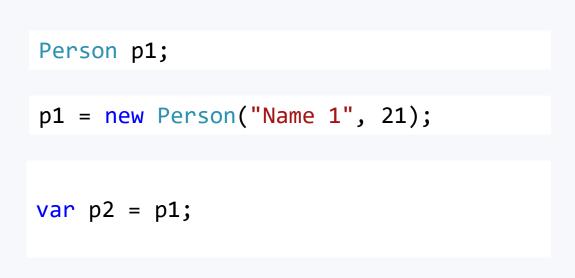
copying an object's value type fields into the target object and the object's reference types are copied as references into the target object but not the referenced object itself. It copies the types bit by bit. The result is that both instances are cloned and the original will refer to the same object.

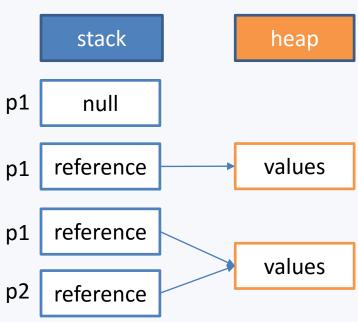


Shallow Copy

Operator=

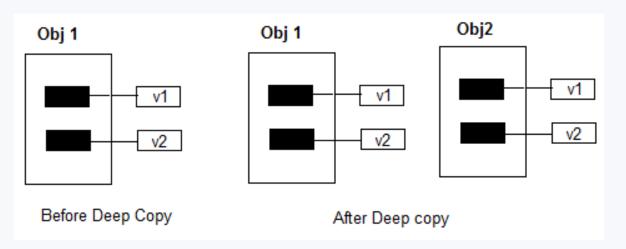
- Copies the reference and not the object (ex: ReferenceTypeAssignment implemented during the seminar)
- Works fine for a Value Type (ex: ValueTypeAssignment implemented during the seminar)





Deep Copy

- used to make a complete deep copy of the internal reference types
- If a field is a value type, a bit by bit copy of the field is performed. If a field is a reference type, a new copy of the referred object is performed.
- A deep copy of an object is a new object with entirely new instance variables, it does not share objects with the old.



Shallow Copy and Deep Copy

Deep Copy

- Implemented using:
 - Copy Constructor
 - ICloneable interface (most frequently)

Copy Constructor

```
//Copy Constructor
public Person(Person person): this(person.Name, person.Age)
//Constructor
public Person(string name, int age)
      Name = name;
      Age = age;
```

Copy Constructor

```
heap
                                                             stack
Person p1;
                                                       p1
                                                              null
p1 = new Person("Name 1", 21);
                                                           reference
                                                       p1
                                                                             values
                                                           reference
                                                       p1
                                                                             values
var p2 = new Person(p1);
                                                       p2
                                                                             values
                                                           reference
```

 Supports cloning, which creates a new instance of a class with the same value as an existing instance.

```
public interface ICloneable
{
     // Interface does not need to be marked with the serializable attribute
     // Make a new object which is a copy of the object instanced.
     // This object may be either deep copy or a shallow copy depending on
     // the implementation of clone.
     // The default Object support for clone does a shallow copy.

Object Clone();
}
```

The MemberwiseClone method creates a shallow copy by creating a new object, and then copying the nonstatic fields of the current object to the new object. If a field is a value type, a bit-by-bit copy of the field is performed. If a field is a reference type, the reference is copied but the referred object is not; therefore, the original object and its clone refer to the same object.

```
stack
                                                                             heap
Person p1;
                                                       p1
                                                             null
p1 = new Person("Name 1", 21);
                                                          reference
                                                                            values
                                                       p1
                                                          reference
                                                                            values
                                                       p1
var p2 = p1.Clone();
                                                       p2
                                                          reference
                                                                            values
```

What happens if the class contains a reference type member (other than System.String)?

```
internal class PersonLuckyNumbers : Person, ICloneable
{
   public int[] LuckyNumbers { get; set; }
}
```

Copy Constructor

```
public PersonLuckyNumbers(PersonLuckyNumbers other)
// First call the copy constructor in the Person class
: base(other)
   Console.WriteLine("PersonLuckyNumbers - Copy Constructor");
   // Then fill in the gaps.
   LuckyNumbers = new int[other.LuckyNumbers.Length];
   for (var i = 0; i < other.LuckyNumbers.Length; i++)</pre>
      LuckyNumbers[i] = other.LuckyNumbers[i];
```

Question: Would we need to change the code if the members of the LuckyNumbers array would be a reference type?

```
public new object Clone()
      // First get a shallow copy.
      var newPerson = (PersonLuckyNumbers)MemberwiseClone();
      // Then fill in the gaps.
      newPerson.LuckyNumbers = new int[LuckyNumbers.Length];
      for (var i=0; i< LuckyNumbers.Length; i++)</pre>
             newPerson.LuckyNumbers[i] = LuckyNumbers[i];
      return newPerson;
```

System.Object

Boxing and Unboxing

■ **Boxing** is the act of converting a value-type instance to a reference-type instance.

```
int i = 123;
object o = i; // Box the int
```

 Unboxing reverses the operation, by casting the object back to the original value type.

```
int y = (int)o; // Unbox the int
```

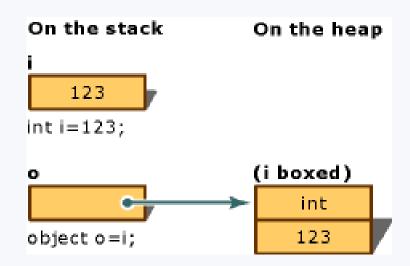
Boxing and Unboxing

```
int i = 123;
object o = i; // Box the int

int y = (int)o; // Unbox the int

long zLong = (long)o; // InvalidCastException
string zString = (string)o; // InvalidCastException

byte w = (byte)(int)o; //succeeds
```



Collections

Namespaces

Namespace	Contains
System.Collections	Nongeneric collection classes and interfaces
System.Collections.Specialized	Strongly typed nongeneric collection classes
System.Collections.Generic	Generic collection classes and interfaces
System.Collections.ObjectModel	Proxies and bases for custom collections
System.Collections.Concurrent	Thread-safe collections

System.Collections.ArrayList

 Implements the IList interface using an array whose size is dynamically increased as required.

```
var words = new ArrayList();
words.Add("melon");
words.Add("avocado");
string first = (string)words[0];
```

Warning: casts cannot be verified by the compiler; the following compiles successfully but then fails at runtime:

```
int first = (int)words[0];
```

Collections

ArrayList

- The ArrayList class is designed to hold heterogeneous collections of objects. However, it does not always offer the best performance. Instead, the following are recommend:
 - for a heterogeneous collection of objects, use the List<Object>;
 - for a homogeneous collection of objects, use the List<T> class.

System.Collections.Generic.List<T>

■ The List<T> class is the generic equivalent of the <u>ArrayList</u> class. It implements the <u>IList<T></u> generic interface by using an array whose size is dynamically increased as required.

```
var words = new List<string>(); // New string-typed list
words.Add("melon");
words.Add("avocado");
words.AddRange(new[] { "banana", "plum" });
words.Insert(∅, "lemon"); // Insert at start
words.InsertRange(∅, new[] { "peach", "nashi" }); // Insert at start
words.Remove("melon");
words.RemoveAt(3); // Remove the 4th element
words.RemoveRange(0, 2); // Remove first 2 elements
// Remove all strings starting in 'n':
words.RemoveAll(x => x.StartsWith("n"));
```

```
for (var i=0; i<words.Count; i++)</pre>
      Console.WriteLine(words[i]);
foreach (var word in words)
      Console.WriteLine(word);
```

```
public class List<T> : IList<T>, IReadOnlyList<T>
      public List ();
      public List (IEnumerable<T> collection);
      public List (int capacity);
      // Add+Insert
      public void Add (T item);
      public void AddRange (IEnumerable<T> collection);
      public void Insert (int index, T item);
      public void InsertRange (int index, IEnumerable<T> collection);
```

```
// Remove
public bool Remove (T item);
public void RemoveAt (int index);
public void RemoveRange (int index, int count);
public int RemoveAll (Predicate<T> match);
// Indexing
public T this [int index] { get; set; }
public List<T> GetRange (int index, int count);
public Enumerator<T> GetEnumerator();
```

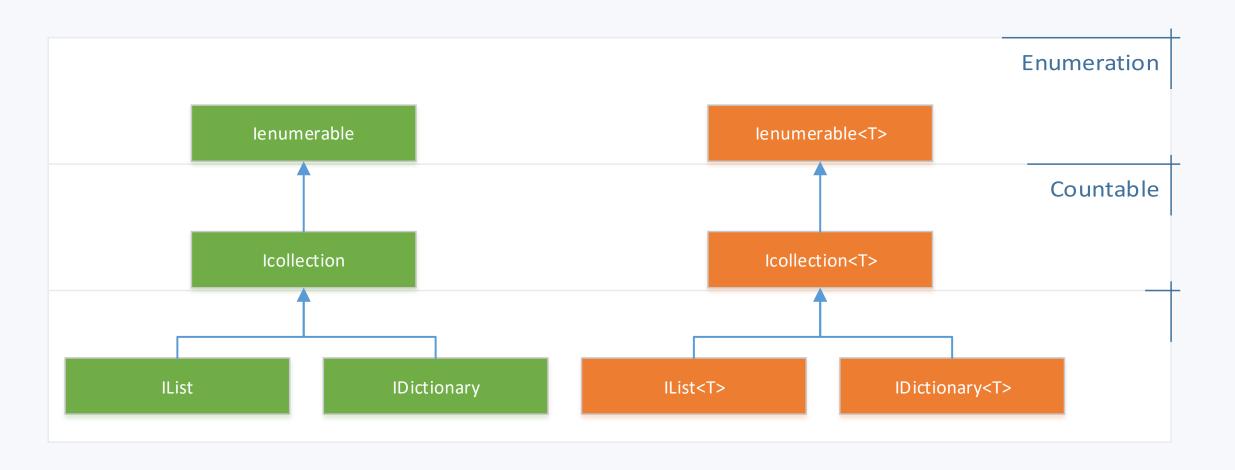
```
// Exporting, copying and converting:
public T[] ToArray();
public void CopyTo (T[] array);
public void CopyTo (T[] array, int arrayIndex);
public void CopyTo (int index, T[] array, int arrayIndex, int count);
public ReadOnlyCollection<T> AsReadOnly();
public List<TOutput> ConvertAll<TOutput> (Converter <T,TOutput> converter);
```

```
// Other:
public void Reverse(); // Reverses order of elements in list.
public int Capacity { get;set; } // Forces expansion of internal array.
public void TrimExcess(); // Trims internal array back to size.
public void Clear(); // Removes all elements, so Count=0.
```

List<T> and ArrayList

- Internally, List<T> and ArrayList work by maintaining an internal array of objects, replaced with a larger array upon reaching capacity.
- Appending elements is efficient (since there is usually a free slot at the end);
- Inserting elements can be slow (since all elements after the insertion point have to be shifted to make a free slot).

Interfaces



Ienumerable and IEnumerable < T >

ICollection<T>

```
public interface ICollection<T> : IEnumerable<T>, IEnumerable
      int Count { get; }
      bool Contains (T item);
     void CopyTo (T[] array, int arrayIndex);
     bool IsReadOnly { get; }
     void Add(T item);
      bool Remove (T item);
     void Clear();
```

```
public interface IList<T> : ICollection<T>, IEnumerable<T>,
IEnumerable
{
    T this [int index] { get; set; }
    int IndexOf (T item);
    void Insert (int index, T item);
    void RemoveAt (int index);
}
```

```
public class MyCollection: IEnumerable
   int[] items;
   public MyCollection(){
      items = new int[5] \{12, 44, 33, 2, 50\};
   public MyEnumerator GetEnumerator(){
      return new MyEnumerator(this);
   // Implement the GetEnumerator() method:
   IEnumerator IEnumerable.GetEnumerator(){
      return GetEnumerator();
```

```
public class MyEnumerator: IEnumerator
      int nIndex;
     MyCollection collection;
      public MyEnumerator(MyCollection coll){
         collection = coll;
         nIndex = -1;
      public void Reset(){
         nIndex = -1;
```

```
public bool MoveNext() {nIndex++;
         return(nIndex < collection.items.GetLength(∅));</pre>
 public int Current
         get
            return(collection.items[nIndex]);
```

```
// The current property on the IEnumerator interface:
   object IEnumerator.Current
   {
      get
      {
         return(Current);
      }
   }
}
```

```
public class MainClass
   public static void Main(string [] args)
     MyCollection col = new MyCollection();
     Console.WriteLine("Values in the collection are:");
      // Display collection items:
      foreach (int i in col)
          Console.WriteLine(i);
```

Collections

Other Collections

- SortedList<TKey, TValue>
- LinkedList<T>
- Queue
- Stack<T>
- and many others: <u>link</u>

- A delegate is a reference type that can be used to encapsulate a named or an anonymous method.
- Delegates are similar to function pointers in C++; however, delegates are typesafe and secure.

```
public delegate void TestDelegate(string message);
public delegate int TestDelegate(MyType m, long num);
```

```
// This delegate can point to any method, taking
two integers and returning an integer.
public delegate int BinaryOp(int x, int y);

//
public class SimpleMath
{
    public static int Add(int x, int y)
        { return x + y; }
    public static int Subtract(int x, int y)
        { return x - y; }
}
```

 A delegate variable is assigned a method at runtime. This is useful for writing plugin methods.

Plug-in Methods with Delegates

```
public delegate int Transformer (int x);
class Util {
          public static void Transform (int[] values, Transformer t) {
                     for (int i = 0; i < values.Length; i++)</pre>
                     values[i] = t (values[i]);
class Test {
          static void Main() {
                     int[] values = { 1, 2, 3 };
                     Util.Transform (values, Square); // Hook in the Square method
                     foreach (int i in values)
                     Console.Write (i + " "); // 1 4 9
          static int Square (int x) { return x * x; }
```

Multicast Delegates

• All delegate instances have multicast capability. This means that a delegate instance can reference not just a single target method, but also a list of target methods. The + and += operators combine delegate instances.

```
SomeDelegate d = SomeMethod1;
d += SomeMethod2; //d = d + SomeMethod2;
```

■ The - and -= operators remove the right delegate operand from the left delegate operand.

```
d -= SomeMethod1;
```

Multicast Delegates

• If a multicast delegate has a nonvoid return type, the caller receives the return value from the last method to be invoked. The preceding methods are still called, but their return values are discarded. In most scenarios in which multicast delegates are used, they have void return types, so this subtlety does not arise.

Multicast Delegates

```
class Test{
         static void Main(){
                  ProgressReporter p = WriteProgressToConsole;
                  p += WriteProgressToFile;
                  Util.HardWork (p);
         static void WriteProgressToConsole (int percentComplete){
                  Console.WriteLine (percentComplete);
         static void WriteProgressToFile (int percentComplete){
                  System.IO.File.WriteAllText ("progress.txt",
percentComplete.ToString());
```

Multicast Delegates

• Further reading: <u>link</u>

Events

Events

- Events in the .NET Framework are based on the delegate model. The delegate model follows the **observer design pattern**, which enables a subscriber to register with, and receive notifications from, a provider. An event sender pushes a notification that an event has happened, and an event receiver receives that notification and defines a response to it.
- The broadcaster is a type that contains a delegate field. The broadcaster decides when to broadcast, by invoking the delegate
- The *subscribers* are the method target recipients. A subscriber decides when to start and stop listening, by calling += and -= on the broadcaster's delegate. A subscriber does not know about, or interfere with, other subscribers.

Events

- Events are a language feature that formalizes this pattern. An event is a construct that exposes just the subset of delegate features required for the broadcaster/subscriber model.
- The main purpose of events is to prevent subscribers from interfering with each other.

Example

```
public delegate void PriceChangedHandler (decimal oldPrice, decimal newPrice);
public class Stock {
          string symbol; decimal price;
          public Stock (string symbol) { this.symbol = symbol; }
          public event PriceChangedHandler PriceChanged;
          public decimal Price
                    get { return price; }
                    set{
                              if (price == value) return; // Exit if nothing has changed
                              decimal oldPrice = price;
                              price = value;
                              if (PriceChanged != null) // If invocation list not
                                        PriceChanged (oldPrice, price); // empty, fire event.
```

Example

```
private static void Main()
        var stock = new Stock("MSFT");
        stock.PriceChanged += Stock_PriceChanged;
        stock.Price = 30;
        stock.Price = 60;
        stock.Price = 90;
private static void Stock_PriceChanged(decimal oldPrice, decimal newPrice)
        Console.WriteLine("MSFT: {0} {1}", oldPrice, newPrice);
```

Example - Discussion

Without the **event** keyword, PriceChanged becomes an ordinary delegate field, making the Stock class less robust. Subscribers could do the following things to interfere with each other:

- replace other subscribers by reassigning PriceChanged (instead of using the += operator).
- clear all subscribers (by setting PriceChanged to null).
- broadcast to other subscribers by invoking the delegate.

Standard Event Pattern

- The .NET Framework defines a standard pattern for writing events. Its purpose is to provide consistency across both Framework and user code. At the core of the standard event pattern is System.EventArgs
- EventArgs is a base class for conveying information for an event.

```
public class PriceChangedEventArgs : EventArgs
{
          public readonly decimal LastPrice;
          public readonly decimal NewPrice;
          public PriceChangedEventArgs(decimal lastPrice, decimal newPrice)
          {
                LastPrice = lastPrice;
                NewPrice = newPrice;
           }
}
```

Standard Event Pattern

```
public class Stock{
         private string symbol; private decimal price;
         public Stock(string symbol){ _symbol = symbol; }
         public event EventHandler<PriceChangedEventArgs> PriceChanged;
         protected virtual void OnPriceChanged(PriceChangedEventArgs e) {
                   if (PriceChanged != null) PriceChanged(this, e);
         public decimal Price
                   get { return price; }
                   set {
                            if ( price == value) return;
                            decimal oldPrice = _price; _price = value;
                            OnPriceChanged(new PriceChangedEventArgs(oldPrice, price));
```

Standard Event Pattern

```
private static void Stock_PriceChanged(decimal oldPrice, decimal newPrice)
         Console.WriteLine("MSFT: {0} {1}", oldPrice, newPrice);
private static void Stock_PriceChanged1(object sender, PriceChangedEventArgs e)
         Console.WriteLine("MSFT: {0} {1}", e.LastPrice, e.NewPrice);
```

Events

Further reading: <u>link</u>

Disposal and Garbage Collection

Disposal and Garbage Collection

- Some objects require explicit teardown code to release resources such as open files, database connections, operating system handles, and unmanaged objects. In .NET parlance, this is called disposal, and it is supported through the IDisposable interface.
- The managed memory occupied by unused objects must also be reclaimed at some point; this function is known as **garbage collection** and is performed by the CLR.

IDisposable, Dispose, and Close

- explicitly initiated;
- the .NET Framework defines a special interface for types requiring a tear-down method:

```
public interface IDisposable
{
      void Dispose();
}
```

using

provides a syntactic shortcut for calling Dispose on objects that implement
 IDisposable, using a try/finally block

```
using (FileStream fs = new FileStream ("myFile.txt", FileMode.Open)){
      // ... Write to the file ...
}
```

converted by the compiler into:

using

 the finally block ensures that the Dispose method is called even when an exception is thrown,1 or the code exits the block early.

IDisposable

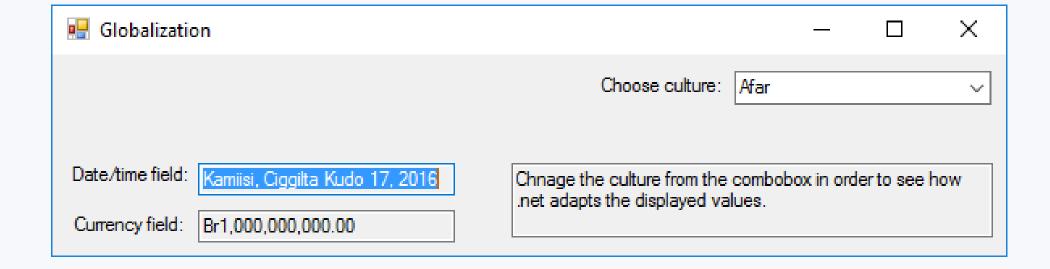
```
public interface IDisposable
{
     void Dispose();
}
```

```
sealed class Demo : IDisposable
{
    public void Dispose()
    {
        // Perform cleanup / tear-down.
        ...
    }
}
```

IDisposable

- 1. Once disposed, an object is beyond redemption. It **cannot be reactivated**, and calling its methods or properties throws an ObjectDisposedException.
- 2. Calling an object's Dispose method repeatedly causes no error.
- 3. If disposable **object x** contains or "wraps" or "possesses" disposable **object y**, **x's Dispose** method automatically calls **y's Dispose** method.

IDisposable



Automatic Garbage Collection

- The CLR frees the memory in the heap entirely automatically, via GC Garbage Collection.
- Garbage collection does not happen immediately after an object is orphaned.
 The CLR bases its decision on when to collect upon a number of factors, such as:
 - the available memory,
 - the amount of memory allocation,
 - and the time since the last collection.
- There's an indeterminate delay between an object being orphaned and being released from memory. This delay can range from nanoseconds to days.

Automatic Garbage Collection

```
internal class PersonLuckyNumbers{
         public int Age {get;set;} //int is a value type
         public string Name {get;set;} // System.String is a reference type
         public int[] LuckyNumbers { get; set; } // System.Array is a reference type
         public PersonLuckyNumbers(string name, int age, int[] luckyNumbers){
static void Main(){
                   var p = new PersonLuckyNumbers("Name1", 21, new []{13,26,39});
         //object is orphaned
```

Disposal and Garbage Collection

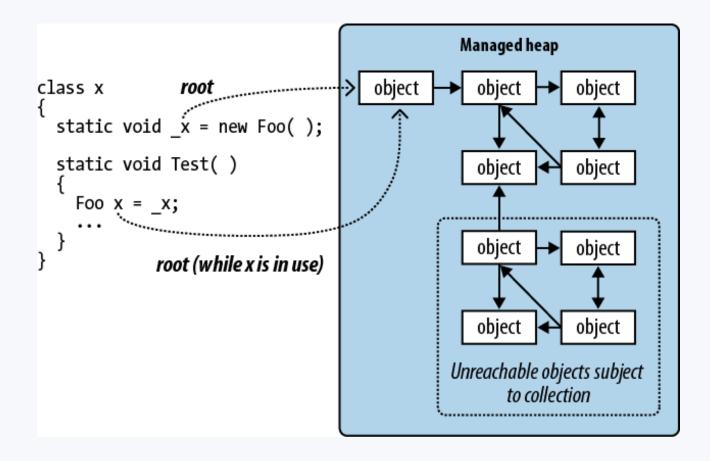
Roots

A root is one of the following:

- a local variable or parameter in an executing method (or in any method in its call stack)
- a static variable
- an object on the queue that stores objects ready for finalization (see next section)

Roots

• objects that cannot be accessed by following the arrows (references) from a root object are *unreachable* —and therefore subject to collection.



prior to an object being released from memory, its finalizer runs, if it has one.

 finalizers cannot be declared as public or static, cannot have parameters, and cannot call the base class

Garbage collection works in distinct phases:

- 1. the GC identifies the unused objects for deletion. Those without finalizers are deleted right away. Those with pending (unrun) finalizers are kept alive (for now) and are put onto a special queue. At that point, garbage collection is complete, and the program continues executing.
- 2. the *finalizer thread* kicks in and starts running in parallel to the program, picking objects off that special queue and running their finalization methods. Prior to each object's finalizer running, it's still very much alive—that queue acts as a root object. Once it's been dequeued and the finalizer executed, the object becomes orphaned and will get deleted in the next collection.

- Finalizers slow the allocation and collection of memory (the GC needs to keep track of which finalizers have run).
- Finalizers prolong the life of the object and any referred objects (they must all await the next garbage truck for actual deletion).
- It's impossible to predict in what order the finalizers for a set of objects will be called.
- You have limited control over when the finalizer for an object will be called.

- If code in a finalizer blocks, other objects cannot get finalized.
- Finalizers may be circumvented altogether if an application fails to unload cleanly.

Disposal and Garbage Collection

Dispose Pattern

• Further reading: <u>link</u>