Java and C# in depth

Carlo A. Furia, Marco Piccioni, Bertrand Meyer

C#: introduction to object-oriented features
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C# classes and objects
Classes and objects

- The basic encapsulation unit is the **class**
  - as in every object-oriented language
- A class is made of a number of features (or members)
  - fields (instance variables)
  - methods
- Classes and features have different levels of **visibility**
- **Objects** are class instances
  - and classes are sets of objects
    - or blueprints for creating objects
  - **constructors** are special methods to create new objects
  - in C#, objects are automatically destroyed when no longer referenced (**garbage collection**)
    - **destructor** syntax exists, but to create finalizer methods
A simple class example

```csharp
namespace JavaCsharpInDepth
{
    using System;

    public class MainClass {
        /// <author> John H. Doe </author>
        // 'Main' must be capitalized!
        public static void Main(String[] args) {
            Game myGame = new Game();
            Console.WriteLine("Game starts!");
            myGame.startGame();
        }
    }
}
```
Main method

In C#, the `Main static` method can be:

- with argument `String[] args`
- without arguments
- returning `void`
- returning `int`

This is different than in Java, where the format of `main` is fixed.
Fields (instance variables)

- Relate to a class instance

- Declared within the class curly brackets, outside any method

- Visible at least within the class scope, within any method of the class

- Automatically initialized to the default values
  - 0 or 0.0 for numeric types, \'\0\' for chars, null for references, false for booleans, the value associated with 0 for enum, a default initialization of members for struct

- Warning: in standard C# parlance, “attributes” denote a kind of annotation, not fields
Methods (instance methods)

- Relate to an instance and are declared within the class curly brackets

- May have arguments
- Must have return type (possibly \texttt{void})

- Constructors are “special” (more on this later)

- Also special members in C#:
  - \texttt{properties, delegate, event}
  - They don’t exist in Java as such
  - More on these later
Information hiding (a.k.a. access modifiers)

Field and method visibility

- **public**: visible everywhere
- **protected**: visible within the class and in subclasses
- **internal**: visible in the same assembly (basically, the same compiled CIL file)
  - this is the default visibility for top-level types
- **internal protected**: class, subclasses, and in the same assembly
- **private**: visible only within the class
  - this is the default visibility for class members

Class visibility

- Classes can use all access modifiers except protected
The static modifier

When applied to fields and methods

- Relates to a specific class, not to a class instance
- Shared by every object of a certain class
- Accessed without creating any class object

When applied to a class

- The class must contain only static fields and methods
- The class cannot be instantiated
Constructors

- Same name as the class
- No return type (not even `void`)
- An argumentless constructor is provided by default if no other constructor is explicitly given
Local variables

- Declared within a method’s scope (denoted by curly brackets)
- Visible only within the method’s scope
- De-allocated at method end
- Not automatically initialized
- Must be initialized before usage
  - compiler checks this in a conservative way
The keyword **this**

Refers to the current object

```java
public class Card {

    private int value;

    // this is a property
    public int Value {
        get { return value; }
        set { this.value = value; }
    }
}
```
Nested classes

It’s a class defined inside another class

Less expressive than Java’s nested inner classes: in C#, the nesting controls visibility only, not behavior. Hence:

- There need not be a relation between instances of the nested class and instances of the containing class
- In general, the nested class cannot access members of the containing class
- A nested class can’t be anonymous

C#’s delegates replace one of the main usages of Java’s (anonymous) inner classes: pieces of code handling events
Nested classes: example usages

Nested classes may be used to:

- Declare helper classes used by the containing class but whose details are irrelevant to clients of the containing class.

  ```csharp
  class PersonList : IEnumerable<Person> {
      // implementation of the list
      private class PersonEnumerator : IEnumerator<Person> {
          // enumerator customized for Persons
          } // clients only know about the interface
      public IEnumerator<Person> GetEnumerator() {
          return new PersonEnumerator(this);
      }
  }
  ```

- Group together a number of tightly related variants of the containing class and dispatch them to clients with static methods (as in the factory design pattern).
Method overloading

- Using the same name with different argument list
  - list can differ in length, argument type, or both

- Example: constructors

- Method signature: name + arguments list
  - The return type is not part of the signature

- Tip: overloading may reduce readability: don’t abuse it
Method overloading with subtypes

When a method name is overloaded with argument types that are related by inheritance, method resolution selects the “closest” available type.

Example: Student is a subtype of Person

```java
class X {
    // v1
    void foo (Person p) { }
    // v2
    void foo (Student p) { }
}
X x = new X();
x.foo(new Person()); // Executes v1
x.foo(new Student()); // Executes v2
```
Method overloading with subtypes

When a method name is overloaded with argument types that are related by inheritance, method resolution selects the “closest” available type.

Example: **Student** is a subtype of **Person**

class Y { void foo (Person p) { ... } }
class Z { void foo (Student p) { ... } }

Y y = new Y();
y.foo(new Person()); // OK
y.foo(new Student()); // OK

Z z = new Z();
z.foo(new Person()); // Error
z.foo(new Student()); // OK
Operator overloading

- Operator overloading is possible with the `operator` keyword

```java
public class Complex {

    private int re, im;

    public Complex(int re, int im) {
        this.re = re;
        this.im = im;
    }

    public static Complex operator +(Complex c1, Complex c2) {
        return new Complex(c1.re + c2.re, c1.im + c2.im);
    }
}
```
Operator overloading (cont’d)

The following operators can be overloaded:

- **Unary:** + - ! ~ ++ -- true false
- **Binary:** + - * / % & | ^ << >> == != > < >= <=

- If you overload a binary operator +, the += operator is implicitly overloaded, too
  - Same for – and -=, * and *=, etc.
- Cast operators are also overloaded by defining conversion operations
- At least one argument of the overloaded operator must belong to the class where the overloading definition occurs
- Operators don’t have to be static and can have side effects
  - but think twice before relying on this feature!
C# supports two argument passing semantics

- by value (the default)
- by reference (with the `ref` keyword)
- the “output parameter semantics” (with the `out` keyword) is a variant of the reference semantics
By-value argument passing

This is the default (no keywords)

- All the primitive types are passed by value
  - Inside the method body we work with a local copy
  - We return information using the `return` keyword

- (Object) Reference types are passed by value too, but:
  - What is passed by value is the reference (i.e., an object address)
  - Consequently, a method can change the state of the object attached to the actual arguments through the reference
By-value argument passing

This is the default (no keywords)

```java
public void no_swap(int i, int j) {
    int tmp = i;
    i = j;
    j = tmp;
}
...
int a, b;
a = 3; b = 5;
no_swap(a, b);
// a == 3 && b == 5
```
By-reference argument passing

With the `ref` keyword

- The method can modify directly the value of the actual argument in the caller
  - The caller must use the `ref` keyword too
    (rationale: it enhances the clarity of what’s going on)
- If a reference type is passed by reference the method can change the value of the reference itself in the caller
By-reference argument passing

With the `ref` keyword

```csharp
public void swap(ref int i, ref int j) {
    int tmp = i;
    i = j;
    j = tmp;
}
...
int a, b;
a = 3; b = 5;
swap(ref a, ref b);
// a == 5 && b == 3
```
Output arguments

With the `out` keyword

- This is meant to mark arguments used as “additional returned values”

- In practice, it achieves a semantics which is very similar to the `ref` keyword

- The differences:
  - a `ref` argument must be initialized by the caller before calling the method
  - an `out` argument must be written by the callee before the method returns
Variable number of arguments

To pass a variable number of arguments to a method:

- Use a collection (including arrays)
- Use a `params` argument

```csharp
public void write(params String[] someStrings) {
    foreach (String aString in someStrings) {
        Console.Write(aString);
    }
}
```

- This is just syntactic sugar for an array
  - You can pass an array as actual
- The `params` parameter must be the only one of its kind and the last one in the signature
Static constructors

- Similar to “static block initializers” in Java
- No arguments, no return type, no visibility specifiers
- The code within them is executed before the first instance of the class is created or any static member is referenced
Any class $\texttt{C}$ may include a destructor method:

\[
\sim \texttt{C} ()
\]

which is syntactic sugar for overriding $\texttt{Object.Finalize}$ in any class.

The destructor method is called just sometime after an object becomes inaccessible

- The destructor may not be called at all (e.g. if running process terminates first)
- No guarantee on when a destructor is called during garbage collection

What’s for: do some final clean-up upon object disposal

- E.g.: resources not properly released beforehand

It is not meant for general release of resources
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Inheritance, polymorphism, and dynamic dispatching
Inheritance

- We can explicitly inherit from one class only
  - A class C inheriting from D:
    ```java
    public class C : D
    ```
  - Otherwise, every class implicitly inherits from `Object`

- Visible (i.e., `public` and `protected`) inherited fields and methods are available in the heir
Overriding and dynamic dispatching

Overriding: method redefinition in a subclass

Overriding rule:

- overriding method must have the same signature and return type as in the superclass
- covariant return types are not allowed in C#
  (Something similar can be obtained with genericity)

Unlike Java: static dispatching applies by default.
Overriding and dynamic dispatching

There are two types of method redefinition in C#:

- **With the `new` keyword (hiding/shadowing)**
  - dynamic dispatching does not apply
  - if you don’t write `new` you get a warning but hiding semantic is assumed
  - can change the visibility of the method

- **With the `override` keyword (overriding)**
  - dynamic dispatching does apply
  - only allowed if method is declared as `virtual` in parent class
  - cannot change the visibility of the method

- **An `override` method implicitly remains virtual until it is declared as `sealed`**
Overriding and dynamic dispatching

```java
public class A { public virtual void Do() { } }
// virtual; hence both types of redefinition are possible

public class B : A { public new void Do() { } }
// non-polymorphic redefinition

public class C : A { public override void Do() { } }
// polymorphic redefinition

A x = new B(); x.Do(); // static dispatching
B y = new B(); y.Do(); // static dispatching
A z = new C(); z.Do(); // dynamic dispatching
```
Casting and Polymorphism

Casting is C++/Java/C# jargon to denote polymorphic assignments.

- Let S be an ancestor of T (that is, $T \rightarrow^* S$)
  - Upcasting: an object of type T is attached to a reference of type S
  - Downcasting: an object of type S is attached to a reference of type T

```java
class Vehicle;
class Car extends Vehicle;
Vehicle v = (Vehicle)new Car(); // upcasting
Car c = (Car)new Vehicle(); // downcasting
```
Casting in C#

- Upcasting is implicit
  - For primitive types, upcasting means assigning a “smaller” type to a “larger” compatible type
    - `byte` to `short` to `int` to `long` to `float` to `double`
    - (`long` to `float` may actually lose precision)
  - `char` to `int`
  - For reference types, upcasting means assigning a subtype to a supertype, that is:
    - a subclass to superclass
    - an implementation of an interface X to that interface X
    - an interface X to the implementation of an ancestor of X

- Downcasting must be explicit
  - can raise runtime exceptions if it turns out to be impossible
  - No casts are allowed for reference types outside the inheritance hierarchy
The **is** and **as** keywords

- The **is** keyword performs runtime checking of the dynamic type of a reference variable
  - Syntax: \( \text{aVariable} \text{ is aType} \)
  - Is the object attached to \( \text{aVariable} \) compatible with \( \text{aType} \)?
    - Compatible means of \( \text{aType} \) or one of its subtypes

- The **as** keyword performs a conversion; if the conversion fails, the reference takes value **null**
  - Syntax: \( \text{aVariable} \text{ as aType} \)
  - If \( \text{aVariable is aType} \) is the case, it is equivalent to: \( \text{(aType) aVariable} \)
  - Otherwise, it is equivalent to **null**
Shadowing

Variables with the same name and different (but overlapping) scopes:

- A local variable shadows a field with the same name: use `this` to access the field

- For fields, only shadowing redefinitions are allowed
  - use the `new` keyword to avoid warnings

- For methods, we’ve seen the two different types of redefinition
The **sealed** class modifier

- **sealed class**
  - Cannot be inherited from

- **sealed method or field**
  - Can’t have further **override** (but must itself be an **override**)
  - Further **new** redefinitions are still allowed

- To have constant (local) variables: use keyword **const**
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The object creation process
The keyword **base**

- Enables invocation of a superclass method or constructor from within an overriding method in a subclass
  - regardless of whether the overriding was with dynamic or static dispatching

- Can be used to explicitly invoke a constructor of the superclass (see next example)
Chained constructors

Any constructor implicitly starts by executing the argumentless constructor of the parent class, unless:

- A specific constructor of the superclass is invoked using `base(...)`

- Another specific constructor of the same class is invoked using `this(...)`

- `base(...)` or `this(...)` must occur after the signature of the constructor, separated by a colon
public class CreatureCard : Card {
    int value;
    public CreatureCard(String name) : base(name) {
        //specific initializations
        value = 7;
    }
    public CreatureCard(int value) : this("Big Monster") {
        //specific initializations
        this.value = value;
    }
}
Object creation process

```java
MyClass obj = new MyClass();
```
*(static members are initialized before)*

- `new` allocates memory for a `MyClass` instance (all attributes, including inherited ones)
- Initializes all attributes to default values

If constructor references `base` (explicitly or by default):

1. Execute `MyClass`'s initializers in their textual order
2. Recursive call to constructor of superclass

If constructor references `this` (another constructor X):

1. Recursive call to other constructor X
2. Execute rest of originally called constructor body

3. Execute constructor body
Object creation process: example

```java
public class Person {
    protected int age = 1;
}

public class Student : Person {
    protected double gpa;
    public Student() {
        age = 6;
        gpa = age/2 + 1.0;
    }
}

Person p1 = new Person();       // age = 1
Person p2 = new Student();      // age = 6, gpa = 4.0
```
Example (closer to intentions in Java)

```java
public class Person {
    protected int age;
    public Person() : this(1) {} 
    public Person(int age) { this.age = age; } 
}

public class Student : Person {
    protected double gpa;
    public Student() : base(6) {
        gpa = age/2 + 1.0;
    }
}

Person p2 = new Student(); // age = 6, gpa = 4.0
```