Introduction to C#

The New Language for Microsoft .net

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Advanced C#

References:

- B.Albahari, P.Drayton, B.Merrill: **C# Essentials**. O'Reilly, 2001
- S.Robinson et al: **Professional C#**, Wrox Press, 2001
- Online documentation on the .NET SDK CD

Features of C#

Very similar to Java

70% Java, 10% C++, 5% Visual Basic, 15% new

As in Java

- Object-orientation (single inheritance)
- Interfaces
- Exceptions
- Threads
- Namespaces (like Packages)
- Strong typing
- Garbage Collection
- Reflection
- Dynamic loading of code
- ...

As in C++

- (Operator) Overloading
- Pointer arithmetic in unsafe code
- Some syntactic details

New Features in C#

Really new (compared to Java)

- Reference and output parameters
- Objects on the stack (structs)
- Rectangular arrays
- Enumerations
- Unified type system
- goto
- Versioning

"Syntactic Sugar"

- Component-based programming
  - Properties
  - Events
- Delegates
- Indexers
- Operator overloading
- foreach statements
- Boxing/unboxing
- Attributes
- ...

Hello World

File Hello.cs

```
using System;

class Hello {

    static void Main() {
        Console.WriteLine("Hello World");
    }

}
```

- uses the namespace *System*
- entry point must be called *Main*
- output goes to the console
- file name and class name need *not* be identical

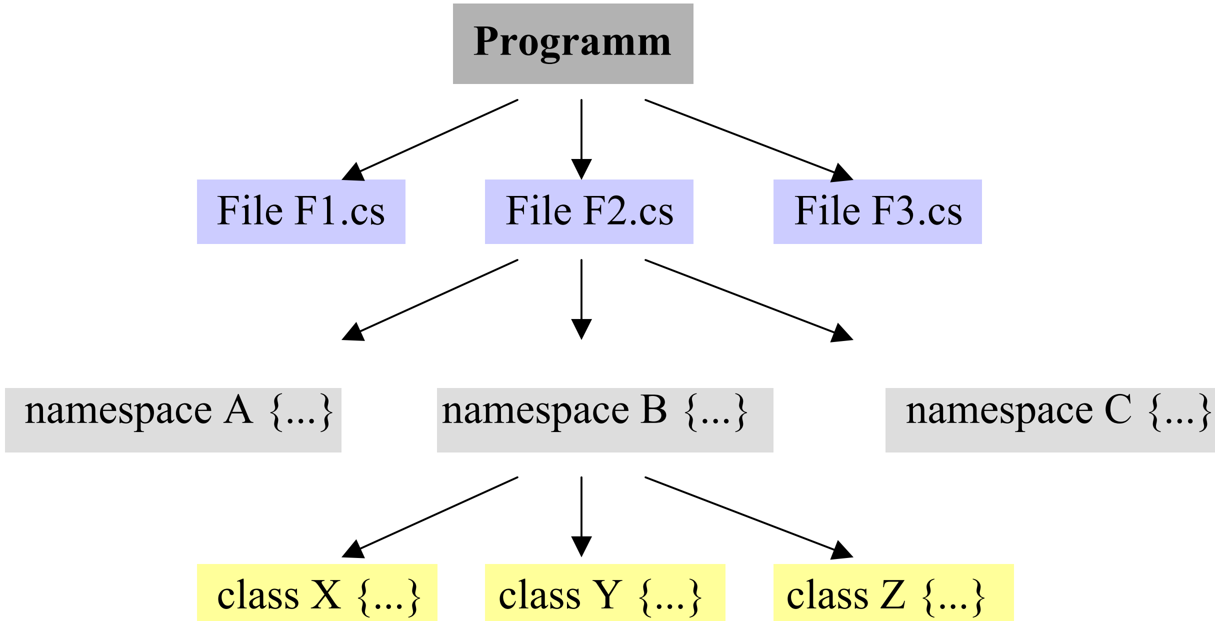
Compilation (in the Console window)

```
csc Hello.cs
```

Execution

```
Hello
```

Structure of C# Programs



- If no namespace is specified => anonymous default namespace
- Namespaces may also contain structs, interfaces, delegates and enums
- Namespace may be "reopened" in other files
- Simplest case: single class, single file, default namespace

A Program Consisting of 2 Files

Counter.cs

```
class Counter {
    int val = 0;
    public void Add (int x) { val = val + x; }
    public int Val () { return val; }
}
```

Prog.cs

```
using System;

class Prog {

    static void Main() {
        Counter c = new Counter();
        c.Add(3); c.Add(5);
        Console.WriteLine("val = " + c.Val());
    }
}
```

Compilation

```
csc Counter.cs Prog.cs
=> generates Prog.exe
```

Execution

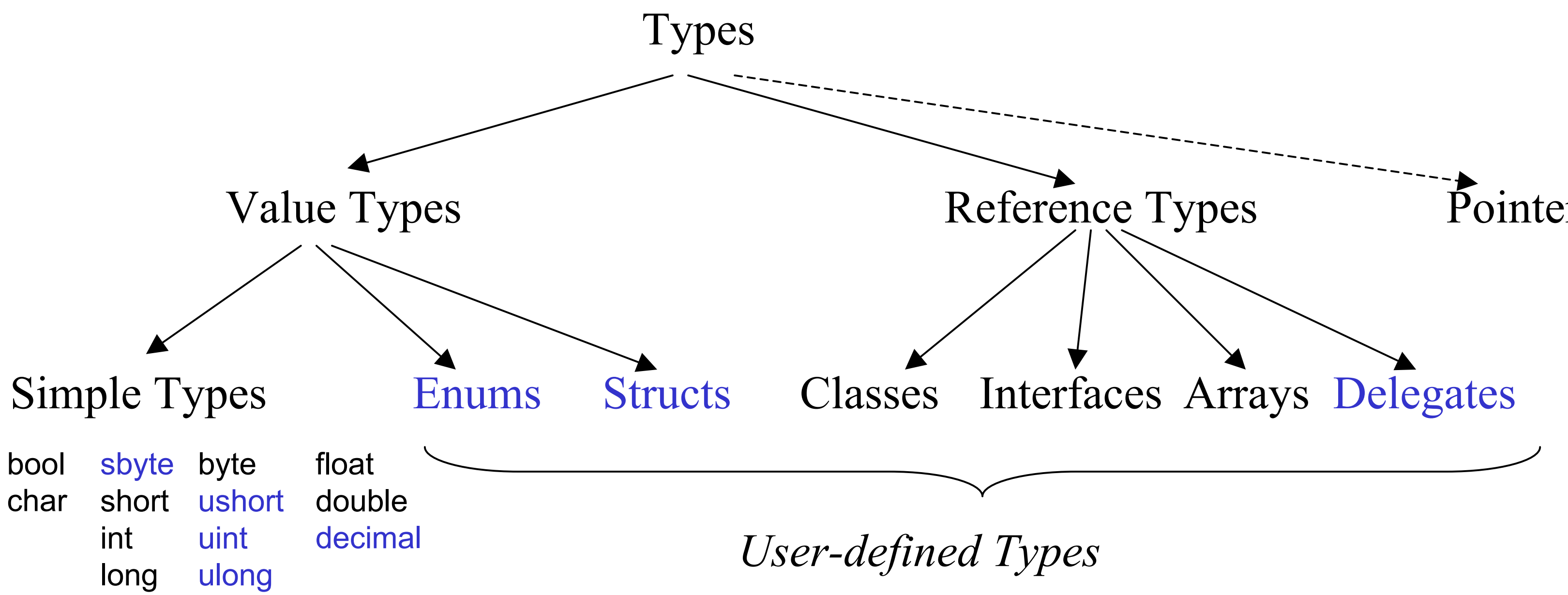
```
Prog
```

Working with DLLs

```
csc /target:library Counter.cs
=> generates Counter.dll

csc /reference:Counter.dll Prog.cs
=> generates Prog.exe
```

Types

Unified Type System

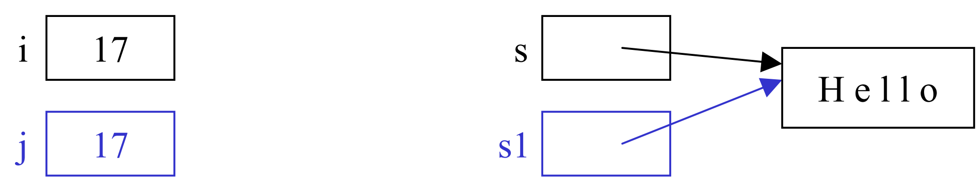


All types are compatible with *object*

- can be assigned to variables of type *object*
- all operations of type *object* are applicable to them

Value Types versus Reference Types

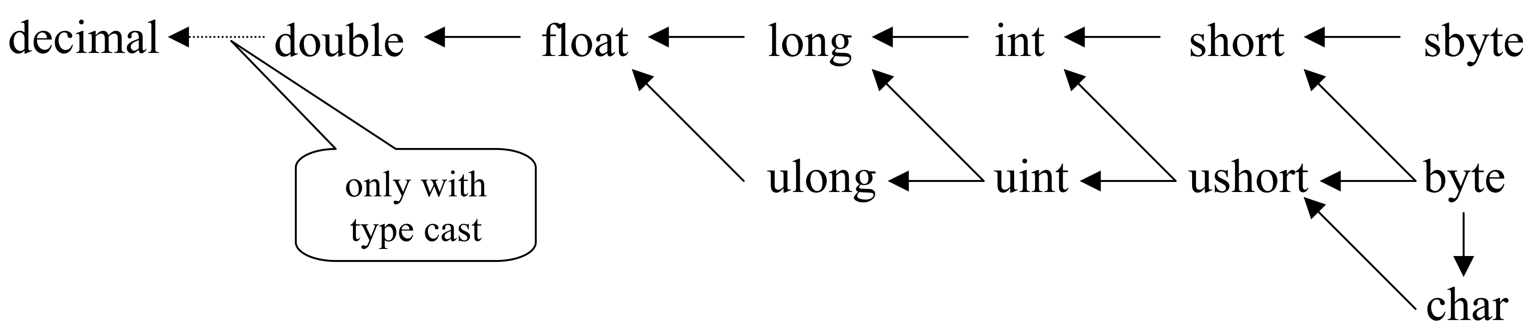
	Value Types	Reference Types
variable contains	value	reference
stored on	stack	heap
initialisation	0, false, '\0'	null
assignment	copies the value	copies the reference
example	int i = 17; int j = i;	string s = "Hello"; string s1 = s;



Simple Types

	Long Form	in Java	Range
sbyte	System.SByte	byte	-128 .. 127
byte	System.Byte	---	0 .. 255
short	System.Int16	short	-32768 .. 32767
ushort	System.UInt16	---	0 .. 65535
int	System.Int32	int	-2147483648 .. 2147483647
uint	System.UInt32	---	0 .. 4294967295
long	System.Int64	long	-2^{63} .. $2^{63}-1$
ulong	System.UInt64	---	0 .. $2^{64}-1$
float	System.Single	float	±1.5E-45 .. ±3.4E38 (32 Bit)
double	System.Double	double	±5E-324 .. ±1.7E308 (64 Bit)
decimal	System.Decimal	---	±1E-28 .. ±7.9E28 (128 Bit)
bool	System.Boolean	boolean	true, false
char	System.Char	char	Unicode character

Compatibility Between Simple Types



Enumerations

List of named constants

Declaration (directly in a namespace)

```
enum Color {red, blue, green}    // values: 0, 1, 2
enum Access {personal=1, group=2, all=4}
enum Access1 : byte {personal=1, group=2, all=4}
```

Use

```
Color c = Color.blue;     // enumeration constants must be qualified

Access a = Access.personal | Access.group;
if ((Access.personal & a) != 0) Console.WriteLine("access granted");
```

Operations on Enumerations

Compare	`if (c == Color.red) ...` `if (c > Color.red && c <= Color.green) ...`
+, -	`c = c + 2;`
++, --	`c++;`
&	`if ((c & Color.red) == 0) ...`
|	`c = c | Color.blue;`
~	`c = ~ Color.red;`

The compiler does not check if the result is a valid enumeration value.

Note

- Enumerations cannot be assigned to *int* (except after a type cast).
- Enumeration types inherit from *object* (*Equals*, *ToString*, ...).
- Class *System.Enum* provides operations on enumerations
  (*GetName*, *Format*, *GetValues*, ...).

Arrays

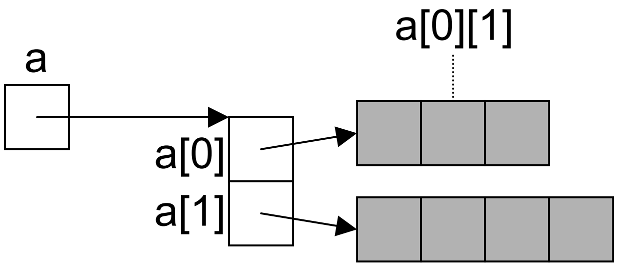
One-dimensional Arrays

```
int[] a = new int[3];
int[] b = new int[] {3, 4, 5};
int[] c = {3, 4, 5};
SomeClass[] d = new SomeClass[10];   // Array of references
SomeStruct[] e = new SomeStruct[10];  // Array of values (directly in the array)

int len = a.Length;   // number of elements in a
```

Multidimensional Arrays

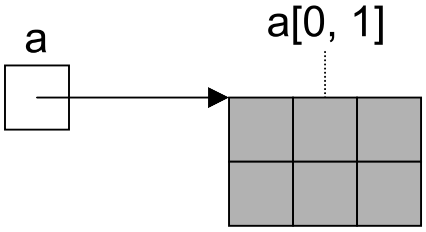
Jagged (like in Java)

```
int[][] a = new int[2][];
a[0] = new int[3];
a[1] = new int[4];

int x = a[0][1];
int len = a.Length;  // 2
len = a[0].Length;   // 3
```



Rectangular (more compact, more efficient access)

```
int[,] a = new int[2, 3];

int x = a[0, 1];
int len = a.Length;       // 6
len = a.GetLength(0); // 2
len = a.GetLength(1); // 3
```



Class System.String

Can be used as standard type *string*

```
string s = "Alfonso";
```

Note

- Strings are immutable (use *StringBuilder* if you want to modify strings)
- Can be concatenated with +: `"Don " + s`
- Can be indexed: `s[i]`
- String length: `s.Length`
- Strings are reference types => reference semantics in assignments
- but their values can be compared with == and != : `if (s == "Alfonso") ...`
- Class *String* defines many useful operations:
  CompareTo, *IndexOf*, *StartsWith*, *Substring*, ...

Structs

Declaration

```
struct Point {
    public int x, y;                                        // fields
    public Point (int x, int y) { this.x = x; this.y = y; } // constructor
    public void MoveTo (int a, int b) { x = a; y = b; }     // methods
}
```

Use

```
Point p = new Point(3, 4);   // constructor initializes object on the stack
p.MoveTo(10, 20);            // method call
```

Classes

Declaration

```
class Rectangle {
	Point origin;
	public int width, height;
	public Rectangle() { origin = new Point(0,0); width = height = 0; }
	public Rectangle (Point p, int w, int h) { origin = p; width = w; height = h; }
	public void MoveTo (Point p) { origin = p; }
}
```

Use

```
Rectangle r = new Rectangle(new Point(10, 20), 5, 5);
int area = r.width * r.height;
r.MoveTo(new Point(3, 3));
```

Differences Between Classes and Structs

Classes	Structs
Reference Types (objects stored on the heap)	Value Types (objects stored on the stack)
support inheritance (all classes are derived from *object*)	no inheritance (but compatible with *object*)
can implement interfaces	can implement interfaces
may have a destructor	no destructors allowed

Boxing and Unboxing

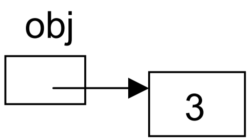
Value types (int, struct, enum) are also compatible with *object*!

Boxing

The assignment

```
object obj = 3;
```

wraps up the value 3 into a heap object



Unboxing

The assignment

```
int x = (int) obj;
```

unwraps the value again

Boxing/Unboxing

Allows the implementation of generic container types

```
class Queue {
	...
	public void Enqueue(object x) {...}
	public object Dequeue() {...}
	...
}
```

This *Queue* can then be used for reference types <u>and</u> value types

```
Queue q = new Queue();

q.Enqueue(new Rectangle());
q.Enqueue(3);

Rectangle r = (Rectangle) q.Dequeue();
int x = (int) q.Dequeue();
```

Expressions

Operators and their Priority

- Primary: (x) x.y f(x) a[x] x++ x-- new typeof sizeof checked unchecked
- Unary: + - ~ ! ++x --x (T)x
- Multiplicative: * / %
- Additive: + -
- Shift: << >>
- Relational: < > <= >= is as
- Equality: == !=
- Logical AND: &
- Logical XOR: ^
- Logical OR: |
- Conditional AND: &&
- Conditional OR: ||
- Conditional: c?x:y
- Assignment: = += -= *= /= %= <<= >>= &= ^= |=

Operators on the same level are evaluated from left to right

Overflow Check

Overflow is not checked by default

```
int x = 1000000;
x = x * x;   // -727379968, no error
```

Overflow check can be turned on

```
x = checked(x * x);  // ➔ System.OverflowException

checked {
	...
	x = x * x;	// ➔ System.OverflowException
	...
}
```

Overflow check can also be turned on with a compiler switch

```
csc /checked Test.cs
```

typeof and sizeof

typeof

- Returns the *Type* descriptor for a given type
  (the *Type* descriptor of an object *o* can be retrieved with *o.GetType()*).

```
Type t = typeof(int);
Console.WriteLine(t.Name);    // → Int32
```

sizeof

- Returns the size of a type in bytes.
- Can only be applied to value types.
- Can only be used in an unsafe block (the size of structs may be system dependent).
  Must be compiled with   csc /unsafe xxx.cs

```
unsafe {
    Console.WriteLine(sizeof(int));
    Console.WriteLine(sizeof(MyEnumType));
    Console.WriteLine(sizeof(MyStructType));
}
```

Declarations

Declaration Space

The program area to which a declaration belongs

Entities can be declared in a ...

- **namespace**: Declaration of classes, interfaces, structs, enums, delegates
- **class**, **interface, struct**: Declaration of fields, methods, properties, events, indexers, ...
- **enum**: Declaration of enumeration constants
- **block**: Declaration of local variables

Scoping rules

- A name must not be declared twice in the same declaration space.
- Declarations may occur in arbitrary order.
  Exception: local variables must be declared before they are used

Visibility rules

- A name is only visible within its declaration space
  (local variables are only visible after their point of declaration).
- The visibility can be restricted by modifiers (private, protected, ...)

Namespaces

File: X.cs

```
namespace A {
    ... Classes ...
    ... Interfaces ...
    ... Structs ...
    ... Enums ...
    ... Delegates ...
    namespace B {  // full name: A.B
        ...
    }
}
```

File: Y.cs

```
namespace A {
    ...
    namespace B {...}
}
```

```
namespace C {...}
```

Equally named namespaces in different files constitute a single declaration space.

Nested namespaces constitute a declaration space on their own.

Using Other Namespaces

Color.cs

```
namespace Util {
    public enum Color {...}
}
```

Figures.cs

```
namespace Util.Figures {
    public class Rect {...}
    public class Circle {...}
}
```

Triangle.cs

```
namespace Util.Figures {
    public class Triangle {...}
}
```

```
using Util.Figures;

class Test {
    Rect r;         // without qualification (because of using Util.Figures)
    Triangle t;
    Util.Color c;   // with qualification
}
```

Foreign namespaces

- must either be imported (e.g. *using Util;)*
- or specified in a qualified name (e.g. *Util.Color*)

Most programs need the namespace System => using System;

Blocks

Various kinds of blocks

```
void foo (int x) {                  // method block
    ... local variables ...

    {                               // nested block
        ... local variables ...
    }

    for (int i = 0; ...) {          // structured statement block
        ... local variables ...
    }
}
```

Note

- The declaration space of a block includes the declaration spaces of nested blocks.
- Formal parameters belong to the declaration space of the method block.
- The loop variable in a for statement belongs to the block of the for statement.
- The declaration of a local variable must precede its use.

Declaration of Local Variables

```
void foo(int a) {
	int b;
	if (...) {
		int b;			// error: b already declared in outer block
		int c;			// ok so far, but wait ...
		int d;
		...
	} else {
		int a;			// error: a already declared in outer block
		int d;			// ok: no conflict with d from previous block
	}
	for (int i = 0; ...) {...}
	for (int i = 0; ...) {...}	// ok: no conflict with i from previous loop
	int c;				// error: c already declared in this declaration space
}
```

Statements

Simple Statements

Empty statement

```
;                                   // ; is a terminator, not a separator
```

Assigment

```
x = 3 * y + 1;
```

Method call

```
string s = "a,b,c";
string[] parts = s.Split(',');      // invocation of an object method (non-static)

s = String.Join(" + ", parts);  // invocation of a class method (static)
```

if Statement

```
if ('0' <= ch && ch <= '9')
	val = ch - '0';
else if ('A' <= ch && ch <= 'Z')
	val = 10 + ch - 'A';
else {
	val = 0;
	Console.WriteLine("invalid character {0}", ch);
}
```

switch Statement

```
switch (country) {
	case "Germany": case "Austria": case "Switzerland":
		language = "German";
		break;
	case "England": case "USA":
		language = "English";
		break;
	case null:
		Console.WriteLine("no country specified");
		break;
	default:
		Console.WriteLine("don't know language of {0}", country);
		break;
}
```

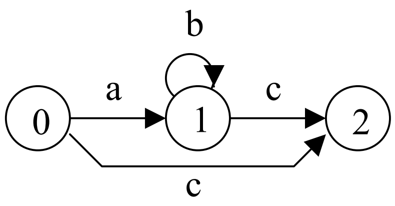
Type of switch expression
numeric, char, enum or <u>string</u> (null ok as a case label).

No fall-through!
Every statement sequence in a case must be terminated with break (or return, goto, throw).

If no case label matches ➔ default
If no default specified ➔ continuation after the switch statement

switch with Gotos

E.g. for the implementation of automata




```
int state = 0;
int ch = Console.Read();
switch (state) {
    case 0:  if (ch == 'a') { ch = Console.Read(); goto case 1; }
             else if (ch == 'c') goto case 2;
             else goto default;
    case 1:  if (ch == 'b') { ch = Console.Read(); goto case 1; }
             else if (ch == 'c') goto case 2;
             else goto default;
    case 2:  Console.WriteLine("input valid");
             break;
    default: Console.WriteLine("illegal character {0}", ch);
             break;
}
```

Loops

while

```
while (i < n) {
	sum += i;
	i++;
}
```

do while

```
do {
	sum += a[i];
	i--;
} while (i > 0);
```

for

```
for (int i = 0; i < n; i++)
	sum += i;
```

Short form for

```
int i = 0;
while (i < n) {
    sum += i;
    i++;
}
```

foreach Statement

For iterating over collections and arrays

```
int[] a = {3, 17, 4, 8, 2, 29};
foreach (int x in a) sum += x;
```

```
string s = "Hello";
foreach (char ch in s) Console.WriteLine(ch);
```

```
Queue q = new Queue();
q.Enqueue("John"); q.Enqueue("Alice"); ...
foreach (string s in q) Console.WriteLine(s);
```

Jumps

`break;`	For exiting a loop or a switch statement. There is no break with a label like in Java (use *goto* instead).
`continue;`	Continues with the next loop iteration.
`goto case 3:`	Can be used in a switch statement to jump to a case label.

```
myLab:
...
goto myLab;
```

Jumps to the label *myLab*.

Restrictions:

- no jumps into a block
- no jumps out of a finally block of a try statement

return Statement

Returning from a void method

```
void f(int x) {
    if (x == 0) return;
    ...
}
```

Returning a value from a function method

```
int max(int a, int b) {
    if (a > b) return a; else return b;
}

class C {
    static int Main() {
        ...
        return errorCode;       // The Main method can be declared as a function;
    }                           // the returned error code can be checked with the
                                // DOS variable errorlevel
}
```

Classes and Structs

Contents of Classes or Structs

```
class C {
    ... fields, constants ...                      // for object-oriented programming
    ... methods ...
    ... constructors, destructors ...

    ... properties ...                             // for component-based programming
    ... events ...

    ... indexers ...                               // for amenity
    ... overloaded operators ...

    ... nested types (classes, interfaces, structs, enums, delegates) ...
}
```

Classes

```
class Stack {
    int[] values;
    int top = 0;

    public Stack(int size) { ... }

    public void Push(int x) {...}
    public int Pop() {...}
}
```

- Objects are allocated on the heap (classes are reference types)
- Objects must be created with *new*

```
Stack s = new Stack(100);
```

- Classes can inherit from *one* other class (single code inheritance)
- Classes can implement multiple interfaces (multiple type inheritance)

Structs

```
struct Point {
    int x, y;
    public Point(int x, int y) { this.x = x; this.y = y; }
    public MoveTo(int x, int y) {...}
}
```

- Objects are allocated on the stack not on the heap (structs are value types)
  + efficient, low memory consumption, no burden for the garbage collector.
  - live only as long as their container (not suitable for dynamic data structures)
- Can be allocated with new

```
Point p;            // fields of p are not yet initialized
Point q = new Point();
```

- Fields must not be initialized at their declaration

```
struct Point {
    int x = 0;      // compilation error
}
```

- Parameterless construcors cannot be declared
- Can neither inherit nor be inherited, but can implement interfaces

Visibility Modifiers (excerpt)

public visible where the declaring namespace is known

- Members of interfaces and enumerations are public by default.
- Types in a namespace (classes, structs, interfaces, enums, delegates) have default visibility *internal* (visible in the declaring assembly)

private only visible in declaring class or struct

- Members of classes and structs are private by default (fields, methods, properties, ..., nested types)

Example

```
public class Stack {
    private int[] val;          // private is also default
    private int top;            // private is also default
    public Stack() {...}
    public void Push(int x) {...}
    public int Pop() {...}
}
```

Fields and Constants

```
class C {
```

```
int value = 0;
```

Field
- Initialization is optional
- Initialization must not access other fields or methods of the same type
- Fields of a struct must not be initialized

```
const long size = ((long)int.MaxValue + 1) / 4;
```

Constant
- Value must be computable at compile time

```
readonly DateTime date;
```

Read Only Field
- Must be initialized in their declaration or in a constructor
- Value needs not be computable at compile time
- Consumes a memory location (like a field)

```
}
```

Access within C

... value ... size ... date ...

Access from other classes

```
C c = new C();
... c.value ... c.size ... c.date ...
```

Static Fields and Constants

Belong to a class, not to an object

```
class Rectangle {
	static Color defaultColor;	// once per class
	static readonly int scale;	// -- " –
	// static constants are not allowed
	int x, y, width,height;		// once per object
	...
}
```

Access within the class

... defaultColor ... scale ...

Access from other classes

... Rectangle.defaultColor ... Rectangle.scale ...

Methods

Examples

```
class C {
    int sum = 0, n = 0;

    public void Add (int x) {          // procedure
        sum = sum + x; n++;
    }

    public float Mean() {              // function (must return a value)
        return (float)sum / n;
    }
}
```

Access within the class

```
this.Add(3);
float x = Mean();
```

Access from other classes

```
C c = new C();
c.Add(3);
float x = c.Mean();
```

Static Methods

Operations on class data (static fields)

```
class Rectangle {
	static Color defaultColor;

	public static void ResetColor() {
		defaultColor = Color.white;
	}
}
```

Access within the class

ResetColor();

Access from other classes

Rectangle.ResetColor();

Parameters

Value Parameters (input values)

```
void Inc(int x) {x = x + 1;}
void f() {
    int val = 3;
    Inc(val); // val == 3
}
```

- "call by value"
- formal parameter is a copy of the actual parameter
- actual parameter is an expression

ref Parameters (transition values)

```
void Inc(ref int x) { x = x + 1; }
void f() {
    int val = 3;
    Inc(ref val); // val == 4
}
```

- "call by reference"
- formal parameter is an alias for the actual parameter (address of actual parameter is passed)
- actual parameter must be a variable

out Parameters (output values)

```
void Read (out int first, out int next) {
    first = Console.Read(); next = Console.Read();
}
void f() {
    int first, next;
    Read(out first, out next);
}
```

- similar to ref parameters but no value is passed by the caller.
- must not be used in the method before it got a value.

Variable Number of Parameters

Last n parameters may be a sequence of values of a certain type.

keyword *params*

array type

```
void Add (out int sum, params int[] val) {
      sum = 0;
      foreach (int i in val) sum = sum + i;
}
```

params cannot be used for *ref* and *out* parameters

Use

```
Add(out sum, 3, 5, 2, 9);  // sum == 19
```

Method Overloading

Methods of a class may have the same name
- if they have different numbers of parameters, or
- if they have different parameter types, or
- if they have different parameter kinds (value, ref/out)

Examples

```
void F (int x) {...}
void F (char x) {...}
void F (int x, long y) {...}
void F (long x, int y) {...}
void F (ref int x) {...}
```

Calls

```
int i; long n; short s;
F(i);       // F(int x)
F('a');     // F(char x)
F(i, n);    // F(int x, long y)
F(n, s);    // F(long x, int y);
F(i, s);    // cannot distinguish F(int x, long y) and F(long x, int y); => compilation error
F(i, i);    // cannot distinguish F(int x, long y) and F(long x, int y); => compilation error
```

Overloaded methods must not differ only in their function types, in the presence of *params* or in *ref* versus *out*!

Constructors for Classes

Example

```
class Rectangle {
    int x, y, width, height;
    public Rectangle (int x, int y, int w, int h) {this.x = x; this.y = y; width = x; height = h; }
    public Rectangle (int w, int h) : this(0, 0, w, h) {}
    public Rectangle () : this(0, 0, 0, 0) {}
    ...
}
```

```
Rectangle r1 = new Rectangle();
Rectangle r2 = new Rectangle(2, 5);
Rectangle r3 = new Rectangle(2, 2, 10, 5);
```

- Constructors can be overloaded.
- A construcor may call another constructor with *this*
  (specified in the constructor head, not in its body as in Java!).
- Before a construcor is called, fields are possibly initialized.

Default Constructor

If no constructor was declared in a class, the compiler generates a parameterless default constructor:

```
class C { int x; }
C c = new C();      // ok
```

The default constructor initializes all fields as follows:

numeric	0
enum	0
bool	false
char	'\0'
reference	null

If a constructor was declared, no default constructor is generated:

```
class C {
    int x;
    public C(int y) { x = y; }
}

C c1 = new C();    // compilation error
C c2 = new C(3);  // ok
```

Constructors for Structs

Example

```
struct Complex {
	double re, im;
	public Complex(double re, double im) { this.re = re; this.im = im; }
	public Complex(double re) : this (re, 0) {}
	...
}
```

```
Complex c0;                          // c0.re and c0.im are still uninitialized
Complex c1 = new Complex();          // c1.re == 0, c1.im == 0
Complex c2 = new Complex(5);         // c2.re == 5, c2.im == 0
Complex c3 = new Complex(10, 3);     // c3.re == 10, c3.im == 3
```

- For <u>every</u> struct the compiler generates a parameterless default constructor (even if there are other constructors).
  The default constructor zeroes all fields.

- Programmers must not declare a parameterless constructor for structs (for implementation reasons of the CLR).

Static Constructors

Both for classes and for structs

```
class Rectangle {
    ...
    static Rectangle() {
        Console.WriteLine("Rectangle initialized");
    }
}
```

```
struct Point {
    ...
    static Point() {
        Console.WriteLine("Point initialized");
    }
}
```

- Must be <u>parameterless</u> (also for structs) and have <u>no</u> *public* or *private* modifier.
- There must be <u>just one</u> static constructor per class/struct.
- Is invoked <u>once</u> before this type is used for the first time.

Destructors

```
class Test {

    ~Test() {
        ... finalization work ...
        // automatically calls the destructor of the base class
    }

}
```

- Correspond to finalizers in Java.
- Called for an object before it is removed by the garbage collector.
- No *public* or *private*.
- Is dangerous (object resurrection) and should be avoided.

Properties

Syntactic sugar for get/set methods

```
class Data {
    FileStream s;

    public string FileName {
        set {
            s = new FileStream(value, FileMode.Create);
        }
        get {
            return s.Name;
        }
    }
}
```

property type

property name

"input parameter" of the set method

Used as "smart fields"

```
Data d = new Data();

d.FileName = "myFile.txt";      // invokes set("myFile.txt")
string s = d.FileName;          // invokes get()
```

JIT compilers often inline get/set methods ➔ no efficiency penalty

Properties (continued)

get or set can be omitted

```
class Account {
    long balance;

    public long Balance {
        get { return balance; }
    }
}

x = account.Balance;          // ok
account.Balance = ...;        // compilation error
```

Why are properties a good idea?

- Interface and implementation of data may differ.
- Allows read-only and write-only fields.
- Can validate a field when it is assigned.
- Substitute for fields in interfaces.

Indexers

Programmable operator for indexing a collection

type of the indexed expression | name (always *this*) | type and name of the index value

```
class File {
    FileStream s;

    public int this [int index] {
        get {  s.Seek(index, SeekOrigin.Begin);
               return s.ReadByte();
            }
        set {  s.Seek(index, SeekOrigin.Begin);
               s.WriteByte((byte)value);
            }
    }
}
```

Use

```
File f = ...;
int x = f[10];          // calls f.get(10)
f[10] = 'A';            // calls f.set(10, 'A')
```

- get or set method can be omitted (write-only / read-only)
- Indexers can be overloaded with different index types

Indexers (other example)

```
class MonthlySales {
      int[] product1 = new int[12];
      int[] product2 = new int[12];
      ...
      public int this[int i] {                    // set method omitted => read-only
          get { return product1[i-1] + product2[i-1]; }
      }

      public int this[string month] {        // overloaded read-only indexer
          get {
              switch (month) {
                  case "Jan": return product1[0] + product2[0];
                  case "Feb": return product1[1] + product2[1];
                  ...
              }
          }
      }
}
```

```
MonthlySales sales = new MonthlySales();
...
Console.WriteLine(sales[1] + sales["Feb"]);
```

Overloaded Operators

Static method for implementing a certain operator

```
struct Fraction {
    int x, y;
    public Fraction (int x, int y) {this.x = x; this.y = y; }

    public static Fraction operator + (Fraction a, Fraction b) {
        return new Fraction(a.x * b.y + b.x * a.y, a.y * b.y);
    }
}
```

Use

```
Fraction a = new Fraction(1, 2);
Fraction b = new Fraction(3, 4);
Fraction c = a + b;    // c.x == 10, c.y == 8
```

- The following operators can be overloaded:
  - arithmetic: +, - (unary and binary), *, /, %, ++, --
  - relational: ==, !=, <, >, <=, >=
  - bit operators: &, |, ^
  - others: !, ~, >>, <<, true, false
- Must return a value

Conversion Operators

Implicit conversion

- If the conversion is always possible without loss of precision
- e.g. long = int;

Explicit conversion

- If a run time check is necessary or truncation is possible
- e.g. int = (int) long;

Conversion operators for custom types

```
class Fraction {
    int x, y;
    ...
    public static implicit operator Fraction (int x) { return new Fraction(x, 1); }
    public static explicit operator int (Fraction f) { return f.x / f.y; }
}
```

Use

```
Fraction f = 3;       // implicit conversion, f.x == 3, f.y == 1
int i = (int) f;      // explicit conversion, i == 3
```

Nested Types

```
class A {
    int x;
    B b = new B(this);
    public void f() { b.f(); }

    public class B {
        A a;
        public B(A a) { this.a = a; }
        public void f() { a.x = ...; ... a.f(); }
    }
}

class C {
    A a = new A();
    A.B b = new A.B(a);
}
```

For auxiliary classes that should be hidden

- Inner class can access all members of the outer class (even private members).
- Outer class can access only public members of the inner class.
- Other classes can access an inner class only if it is public.

Nested types can also be structs, enums, interfaces and delegates.