Module 01

"Advanced Types and Methods"

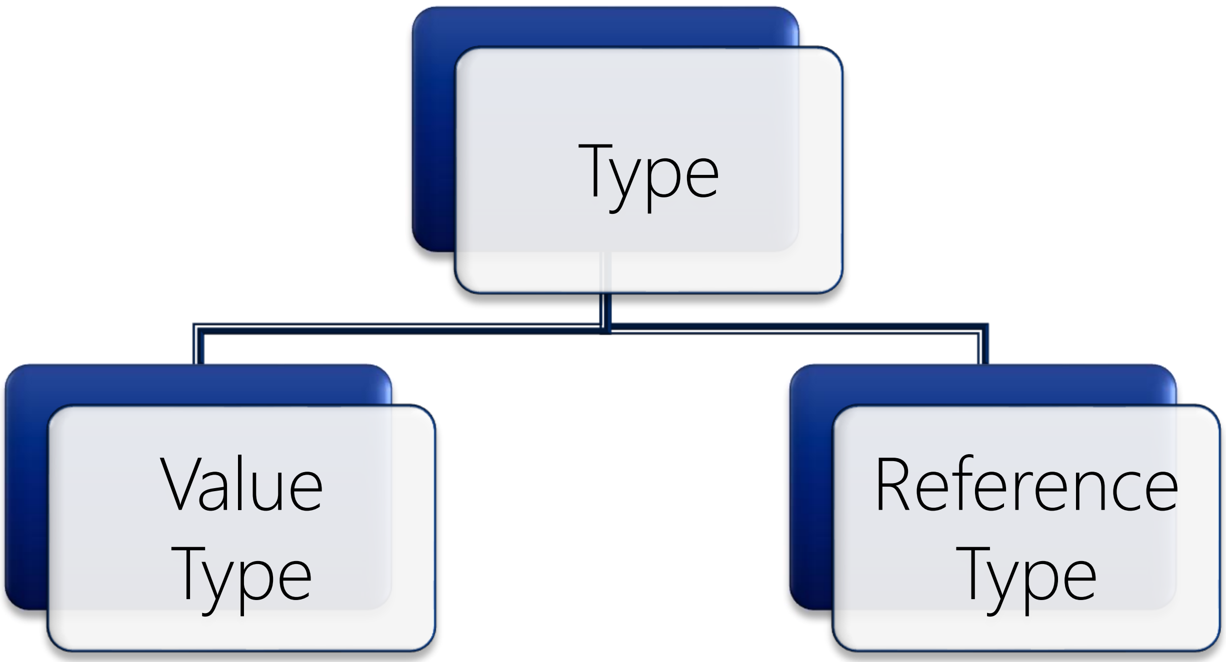
TEKNOLOGISK
INSTITUT

Agenda

- **Common Type System**
- Collections and Generics
- Iterators
- Anonymous Types
- Tuples and Other Types
- Methods
- Extension Methods
- Lab 1
- Discussion and Review

Anatomy of the Common Type System

- Every variable has a type
- C# is statically typed



Value Types vs. Reference Types

Value Types	Reference Types

Value Types

- Directly contain data
- Allocated on the stack
- Have to be initialized
- Each copy has its own data

Reference Types

- Store references to data ("objects")
- Stored on the heap
- Has a default value of `null`
- Several references can refer to same data

Examples of Types

Value Types	Reference Types

Value Types

- `bool`
- `int`
- `float`
- `decimal`
- `struct`
- `enum`
- `DateTime`
- …

Reference Types

- `class`
- `string`
- `Array`
- `Exception`
- …

Implicitly Typed Variables

- You can define <u>local</u> implicitly typed variables using the **`var`** keyword

```
var myInteger = 87;
var myBoolean = true;
var myString = "Hello, there...";
```

- The compiler infers the type of the local variable!
- Everything is still completely type-safe

```
var i = 87;
i = 112;
int j = i + 42;
i = "Forbidden!";
```

- Must be assigned a value when declared

```
var myInteger;
myInteger = 87;
```

Nullable Types

- Can assume the values of the underlying value type as well as `null`

```
int? i = 87;
int? j = null;
if( i.HasValue )
{
   int k = i.Value + j.GetValueOrDefault( 42 );
   Console.WriteLine( k );
}
```

```
int k = i.Value + ( j ?? 42 );
```

- The `??` operator is an elegant shorthand

Characteristics of Nullable Types

- Make no mistake about it:
  - Nullable types are **value types**!
- Only value types can be nullable!

- `int?` is actually generically defined as

```
Nullable<int> i = 42;
```

Recursive Types

- Classes are allowed to be recursive, i.e refer to instances of the same class
- A classic examples is the Linked List

```
public class Node
{
   public object Data { get; set; }
   public Node Next { get; set; }

   ...
}
```

- Note: Structs are **not** allowed to be recursive!

Agenda

- Common Type System
- **Collections and Generics**
- Iterators
- Anonymous Types
- Tuples and Other Types
- Methods
- Extension Methods
- Lab 1
- Discussion and Review

TEKNOLOGISK INSTITUT

System.Collections.Stack

- **Stack** is a container with last-in, first-out behavior based on **object**

Member of **Stack**	Meaning
Push()	Adds an object to the top of the stack
Pop()	Removes the object at the top of the stack
Peek()	Returns the object at the top of the stack without removing it

```
Stack stack = new Stack();
stack.Push( new Car( "Fred", 90 ) );
stack.Push( new Car( "Mary", 100 ) );
Car top = stack.Peek() as Car;
Car removed = stack.Pop() as Car;
foreach( Car c in stack )
{
   Console.WriteLine( c.PetName );
}
```

Annoying Problems

- You can insert anything into a **`Stack`**!

```
Stack stack = new Stack();
stack.Push( new Car( "Fred", 90 ) );
stack.Push( new Car( "Mary", 100 ) );
stack.Push( "Hello, World" );
stack.Push( 87 );

Car top = stack.Peek() as Car;
Car removed = stack.Pop() as Car;

foreach( Car c in stack )
{
   Console.WriteLine( c.PetName );
}
```

- The problem is that type-safety is missing

TEKNOLOGISK INSTITUT

Wouldn’t It Be Nice If…

- … we only needed to construct each type once?
- … and it had no (un)boxing performance hit?

```
class Stack<T>
{
   public Stack { ... }
   public T Peek() { ... }
   public void Push( T t ) { ... }
   public T Pop() { ... }
   ...
}
```

- I.e. “generic” types!

The Classes of the `System.Collections.Generic` Namespace

- Type-safe, reusable, and efficient collection classes

Class	Meaning
`List<T>`	Dynamically sized list of elements of type T
`Dictionary<K,V>`	Values of type V indexed by an element key of type K
`SortedDictionary<K,V>`	Values of type V indexed and sorted by keys of type K
`Queue<T>`	First-in, first-out queue of elements of type T
`Stack<T>`	Last-in, first-out queue of elements of type T
`HashSet<T>`	Set of elements of type T
`SortedSet<T>`	Sorted set of elements of type T

- These implement the generic interfaces on the previous slide
- <u>Never</u> use the non-generic collections!

Using Generic Types

- Substitute T with a concrete type whenever it is used

```
List<int> list = new List<int>();
list.Add( 42 );
list.Add( 87 );
list.Add( 112 );

foreach( int i in list )
{
   Console.WriteLine( i );
}
```

```
List<string> list = new
List<string>();
list.Add( "Hello" );
list.Add( "World" );

foreach( string s in list )
{
   Console.WriteLine( s );
}
```

Queue<T>

- **Queue<T>** is a type-safe container ensuring first-in, first-out behavior

Member of **Queue<T>**	Meaning
Dequeue()	Removes and returns the element at beginning of queue
Enqueue()	Adds an element to the end of queue
Peek()	Returns the element at the beginning

```
Queue<Car> queue = new Queue<Car>();
queue.Enqueue( new Car( "Fred", 90 ) );
queue.Enqueue( new Car( "Mary", 100 ) );
Car first = queue.Peek();
Car removed = queue.Dequeue();
foreach( Car c in queue )
{
   Console.WriteLine( c.PetName );
}
```

Dictionary<K,V>

- **Dictionary<K,V>** is a container of values of type V indexed by an element key of type K

Member of **Dictionary<K,V>**	Meaning
Add()	Adds an key-value pair to the dictionary
Remove()	Removes the element with the specified key

- Iterate dictionaries by using **KeyValuePair<K,V>**

```
Dictionary<int, string> dict = new Dictionary<int, string>();
dict.Add( 11, "Peter Graulund" );
dict.Add( 7, "Stephan Petersen" );
Console.WriteLine( "Number 11 is {0}", dict[ 11 ] );

foreach( KeyValuePair<int, string> kv in dict )
{
   Console.WriteLine( "Player {0} is {1}", kv.Key, kv.Value );
}
```

HashSet<T>

- **HashSet<T>** is a set of values of type T

Member of **HashSet<T>**	Meaning
Add()	Adds an element to the set
Remove()	Removes the specified element in the set

- There is also a **SortedSet<T>**
  - Needs **IComparer<T>**

```
HashSet<int> set = new HashSet<int>();
set.Add( 42 );
set.Add( 87 );
set.Add( 42 );
set.Remove( 42 );

foreach( int i in set )
{
   Console.WriteLine( i );
}
```

Collection Initializers

- Collections can be conveniently initialized via *collection initializer syntax*

```
List<int> list = new List<int> { 42, 87, 112 };
```

```
List<string> list = new List<string> { "Hello", "World" };
```

```
SortedSet<int> set = new SortedSet<int> { 87, 42, 112, 176 };
```

- Note: Only works for those collection classes with an **Add()** method, i.e. not
  - Stack<T>
  - Queue<T>
  - LinkedList<T>
  - …

Agenda

- Common Type System
- Collections and Generics
- **Iterators**
- Anonymous Types
- Tuples and Other Types
- Methods
- Extension Methods
- Lab 1
- Discussion and Review

The `IEnumerable` Interface

- The **`IEnumerable`** interface states that the items of a class can be enumerated

```
using System.Collections;

public interface IEnumerable
{
   IEnumerator GetEnumerator();
}
```

```
public interface IEnumerator
{
   bool MoveNext ();
   object Current { get; }
   void Reset ();
}
```

- The **`IEnumerator`** interface provides an enumerator mechanism for the class
- Both are built into the .NET Framework base classes in the **`System.Collections`** namespace
- Arrays and collection types implement **`IEnumerable`** out-of-the-box

Implementing `IEnumerable`

- You can implement **`IEnumerable`** in your own types

```
Garage garage = new Garage();
foreach( Car c in garage )
{
   Console.WriteLine( c.PetName );
}
```

```
public class Garage : IEnumerable
{
   private Car[] carArray = new Car[ 4 ];
   public Garage()
   {
      carArray[ 0 ] = new Car( "FeeFee", 200 );
      carArray[ 1 ] = new Car( "Clunker", 90 );
      carArray[ 2 ] = new Car( "Zippy", 30 );
      carArray[ 3 ] = new Car( "Fred", 30 );
   }

   public IEnumerator GetEnumerator() { ... }
}
```

Building Iterators with `yield`

- C# provides powerful mechanisms for creating *iterator methods*

```
public IEnumerator GetEnumerator()
{
   foreach( Car c in carArray )
   {
      yield
   }
}
```

```
public IEnumerator GetEnumerator()
{
   yield return carArray[ 0 ];
   yield return carArray[ 1 ];
   yield retu
   yield retu
}
```

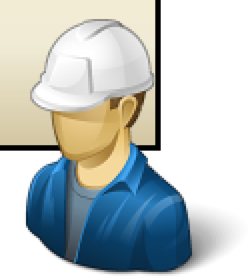
```
public IEnumerator GetEnumerator()
{
   int i = 0;
   while( true )
   {
      yield return carArray[ i++ ];
      if( i == 4 ) { yield break; }
   }
}
```

Named Iterators

- Multiple iterators can be built for a class with named iterators

```
public IEnumerable GetTheCars( bool returnReversed )
{
   if( returnReversed )
   {
      for( int i = carArray.Length; i != 0; i-- )
      { yield return carArray[i-1]; }
   }
   else
   {
      foreach( Car c in carArray ) { yield return c; }
   }
}
```

```
Garage garage = new Garage();
foreach( Car c in garage.GetTheCars( true ) )
{
   Console.WriteLine( c.PetName );
}
```



Implementing `IEnumerable<T>`

- There are generic versions of **`IEnumerable`** and **`IEnumerator`**

```
public interface IEnumerable<out T> : IEnumerable
{
   IEnumerator<T> GetEnumerator();
}
```

```
public interface IEnumerator<T>
{
   bool MoveNext ();
   T Current { get; }
   void Reset ();
}
```

- *Note: Slight trick involved when implementing **`IEnumerable<T>`***

- We will return to the "**`out`**" in Module 2

Agenda

- Common Type System
- Collections and Generics
- Iterators
- **Anonymous Types**
- Tuples and Other Types
- Methods
- Extension Methods
- Lab 1
- Discussion and Review

TEKNOLOGISK INSTITUT

Creating Anonymous Types

- Combining implicitly typed variables with object initializer syntax provides an excellent shorthand for defining simple classes called *anonymous types*

```
var myEquipment = new { Manufacturer = "Nintendo",
                        Make = "Wii",
                        Controllers = 4 };
Console.WriteLine( "I have a {0} {1} with {2} controllers",
   myEquipment.Manufacturer,
   myEquipment.Make,
   myEquipment.Controllers );
```

- The compiler autogenerates an anonymous class for us to use
- This class inherits from `object`
- Members are read-only!

Equality of Anonymous Types

- Anonymous types come with their own overrides of **`object`** methods
  - `ToString()`
  - `Equals()`
  - `GetHashCode()`
- The `==` and `!=` operators are however not overloaded with `Equals()`!
  - The exact references are still compared

TEKNOLOGISK INSTITUT

Restrictions to Anonymous Types

- Anonymous types can be nested arbitrarily

```
var myFancyEquipment = new
{
   Manufacturer = "Microsoft",
   Make = "Xbox 360",
   XboxLive = new { Name = "Komatoze",
                    Membership = MembershipType.Gold }
};
```

- Some restrictions do apply to anonymous types
  - Type name is auto-generated and cannot be changed
  - Always derive directly from `object`
  - Fields and properties of anonymous types are always read-only
  - Anonymous types are implicitly sealed
  - No possibility of custom methods, operators, overrides, or events

Agenda

- Common Type System
- Collections and Generics
- Iterators
- Anonymous Types
- **Tuples and Other Types**
- Methods
- Extension Methods
- Lab 1
- Discussion and Review

Tuples

- Tuples are <u>immutable</u> data values supporting 1 to 8 data items of any type named
  - `Item1`, `Item2`, …
- Carry no semantic meaning

```
Tuple<int, int> point = Tuple.Create( 1, 3 );
Console.WriteLine( "The point is {0}", point );

Tuple<string, bool, int> person =
   Tuple.Create( "Anders Hejlsberg", true, 220 );
```

- Provides overridden methods
  - `ToString()`
  - `Equals()`
- Implements
  - `IComparable` (explicitly)

The **System.Numerics** Namespace

- .NET 4.0 introduced **System.Numerics** namespace containing
  - BigInteger
  - Complex

```
BigInteger bigFactor = 87;
BigInteger bigInteger =

BigInteger.Parse( "99999999999999999999999999999999999" );
BigInteger bigNumber = bigFactor * bigInteger;
Console.WriteLine( bigNumber );
```

- Used more or less like ordinary types
  - But these are immutable!
- Note: Must manually add reference to **System.Numerics**

TEKNOLOGISK INSTITUT

Agenda

- Common Type System
- Collections and Generics
- Iterators
- Anonymous Types
- Tuples and Other Types
- **Methods**
- Extension Methods
- Lab 1
- Discussion and Review

The Syntax of a Method

- The syntax of methods are

```
ReturnValue MethodName( arguments ) { MethodBody }
```

- All methods must exist inside of a class definition – no “global” methods!

```
class Program
{
    static void DoStuff( )
    {
        Console.WriteLine( 87 );
    }
}
```

```
class Calculator
{
    public int Add(int x, int y)
    {
        return x + y;
    }
}
```

Implicit Typing in Methods

- The **var** keyword cannot be used as parameters or return value in methods

```
public var M( var x, var y )
{
    ...
}
```

- But can be used locally inside the method body

```
int GetSomeInt()
{
    var ret = 87;
    return ret;
}
```

Passing Parameters by Value

- Define *formal* parameters within parentheses in method
  - Supply type and name for each parameter

```
static void Twice( int x )
{
    x = 2 * x;
}
```

- Invoke method by supplying *actual* parameters in parentheses
  - The formal and actual parameter types and count must be compatible

```
int i = 42;
Twice( i );
Console.WriteLine( i );
```

- Parameter values are copied from actual to formal
- Changes made inside method has no effect outside method!

The `ref` Modifier

- Reference parameters are references to memory locations, i.e. aliases for variables
- Use the **`ref`** modifier to pass variables by reference

```
static void Twice( ref int x )
{
   x = 2 * x;
}
```

```
int i = 42;
Twice( ref i );
Console.WriteLine( i );
```

- Also use the **`ref`** keyword when invoking the method

- Parameter values are referred (or aliased)
- Changes made inside method has indeed effect outside method!

- Variable must be assigned before call

The out Modifer

- Passing by reference consists of both “inputting” and “outputting”
- Use the **out** modifier when only outputting value

```
static void FillWithNumber( out int x )
{
    x = 87;
}
```

```
int i;
FillWithNumber( out i );
Console.WriteLine( i );
```

- Also use the **out** keyword when invoking the method

- Parameter values are output
- Changes made inside method has indeed effect outside method!

- Variable does not have to be assigned before call

The `params` Modifier

- Passing parameter lists of varying length by using the **`params`** modifier

```
static int Sum( params int[] values )
{
   int total = 0;
   foreach( int i in values )
   {
      total += i;
   }
   return total;
}
```

```
Console.WriteLine( Sum( 42, 87 ) );
```

- Actual parameters are then passed into the method by value as an array

- Only one **`params`** per method

Optional Parameters

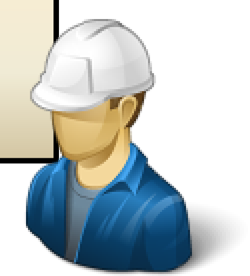
- Methods can have optional parameters by specifying their default values

```
static void M( int x, int y = 87, bool z = false )
{
    ...
}
```

```
M(1, 2, true);
M(1, 2);      // Equivalent to M(1, 2, false)
M(1);         // Equivalent to M(1, 87, false)
M();          // Illegal! x is required!
```

- Optional parameters can be omitted when invoking the method
- Note: Optional parameters <u>must appear last</u> in parameter list
- Default values for optional parameters must be known at compile time!

```
static void N( bool b, DateTime dt = DateTime.Now )
{
    ...
}
```



Named Parameters

- Can pass parameter values using their *names* (as opposed to their *position*)

```
M(1, z: true);    // z is passed by name
M(x: 1, z: true); // x and z are both passed by name
M(z: true, x: 1); // z and x are both passed by name (equivalent!)

M(z: true, 1 )
```

- Note: Positional parameters must always appear before any named parameters when invoking methods!

- Named and optional parameters mix perfectly
- Syntax look horrible, but what is the alternative…? ☺

Recursive Methods

- Methods can call itself either directly or indirectly.
- Such methods are said to be *recursive*

```
static int Factorial( int n )
{
   if( n <= 1 )
   {
      return 1;
   }

   return n * Factorial( n - 1 );
}
```

```
Console.WriteLine( Factorial( 10 ) );
```

- Perfect for solving inductively defined problems
- Must have terminating base clause
- Use with care!

TEKNOLOGISK INSTITUT

Generic Methods

- You can define methods operating on generic types

```
void Swap<T>( ref T a, ref T b )
{
    T temp = a;
    a = b;
    b = temp;
}
```

```
int i = 42;
int j = 87;
Swap<int>( ref i, ref j );

string s = "Hello";
string t = "World";
Swap<string>( ref s, ref t );
```

- Such methods cannot be defined inside generic classes or structs!
- T is “free” to match any type
  - Use **`typeof(`**T**`)`** to retrieve instantiated type
- The C# compiler will try to infer the generic types when omitted

Caller Info Attributes

- C# 5.0 introduced three types of caller info attributes
  - `[CallerMemberName]`
  - `[CallerFilePath]`
  - `[CallerLineNumber]`

```
static void Log(
        [CallerMemberName] string callerName = null,
        [CallerFilePath] string callerFilePath = null,
        [CallerLineNumber] int callerLine = -1 )
{
   ...
}
```

- Applicable to default parameters
  - Compiler replaces values at compilation time
- In `System.Runtime.CompilerServices`

Agenda

- Common Type System
- Collections and Generics
- Iterators
- Anonymous Types
- Tuples and Other Types
- Methods
- **Extension Methods**
- Lab 1
- Discussion and Review

Defining Extension Methods

- *Extension methods* let you extend types with your own methods
  - Even if you don't have the source or the types are not yours

```
static class MyExtensions
{
   public static string ToMyTimestamp( this DateTime dt )
   {
      return dt.ToString( "yyyy-MM-dd HH:mm:ss.fff" );
   }
}
```

- Must be **static** and defined in a **static** class
- The first parameter contains **`this`** and determines the type being extended

- Extension methods can have any number of parameters

Invoking Extension Methods

- Extension methods can be invoked at the instance level

```
DateTime dt = DateTime.Now;
Console.WriteLine( dt.ToMyTimestamp() );
```

- Alternatively, the method can be invoked statically

```
DateTime dt = DateTime.Now;
Console.WriteLine( MyExtensions.ToMyTimestamp( dt ) );
```

- Visual Studio has special IntelliSense for extension methods

Using Extension Methods

- The static class containing the extension methods must be in scope for the extension methods to be used

- Extension methods are indeed extending – not inheriting!
  - No access to private or protected members
  - All access is through the supplied parameter

```
public static string ToMyTimestamp( this DateTime dt )
{
   return dt.ToString( "yyyy-MM-dd HH:mm:ss.fff" );
}
```

- Can extend interfaces as well, but implementation must be provided

Lab 1: Creating Advanced Types and Methods

- Labs 1.1 – 1.8

Discussion and Review

- Common Type System
- Collections and Generics
- Iterators
- Anonymous Types
- Tuples and Other Types
- Methods
- Extension Methods


WINCUBATE
Jesper Gulmann Henriksen
PhD, MCT, MCSD, MCPD
Phone : +45 22 12 36 31
Email : jgh@wincubate.net
WWW : http://www.wincubate.net
Hasselvangen 243
8355 Solbjerg
Denmark