C# Fundamentals

Hans-Wolfgang Loidl
<H.W.Loidl@hw.ac.uk>

School of Mathematical and Computer Sciences,
Heriot-Watt University, Edinburgh

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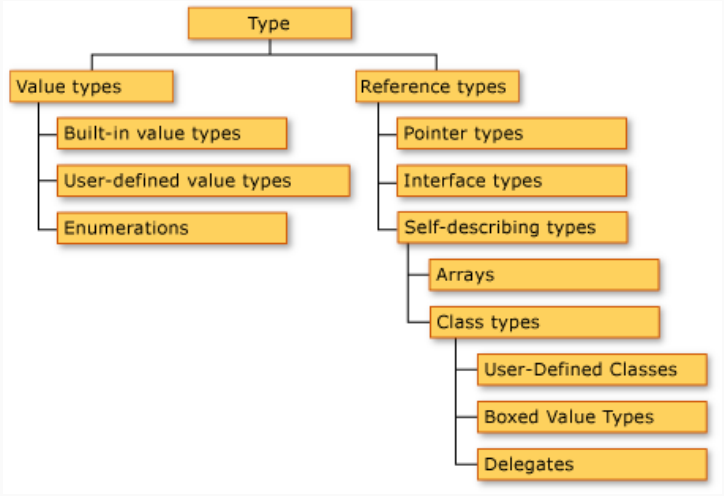
C# Types



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Value Types

- Variables stand for the value of that type (*"has value"*)
- Integers:
  - Signed: `sbyte, int, short, long`
  - Unsigned: `byte, uint, ushort, ulong`
- Floating point:
  - `float`
  - `double`
- Examples:
  - `double average = 10.5`
  - `float total = 34.87f`

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Signed vs Unsigned

- By default int, short, long are *signed* data types as they can hold a negative or a positive value of their ranges.
- Unsigned variables can only hold *positive* values of its range.

Other value types:

- Decimal types: appropriate for storing monetary data. Provides greater precision.
  - `decimal profit = 2211655.76M;`
- Boolean variables: `True` or `False`.
  - `bool student = True;`

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Types and Values

Table 1, The Size and Range of C# Integral Types

Type	Size (in bits)	Range
sbyte	8	-128 to 127
byte	8	0 to 255
short	16	-32768 to 32767
ushort	16	0 to 65535
int	32	-2147483648 to 2147483647
uint	32	0 to 4294967295
long	64	-9223372036854775808 to 9223372036854775807
ulong	64	0 to 18446744073709551615
char	16	0 to 65535

Table 2. The Floating Point and Decimal Types with Size, precision, and Range

Type	Size (in bits)	precision	Range
float	32	7 digits	1.5×10^{-45} to 3.4×10^{38}
double	64	15-16 digits	5.0×10^{-324} to 1.7×10^{308}
decimal	128	28-29 decimal places	1.0×10^{-28} to 7.9×10^{28}

Enumerations

- **Enum Types:**
  - The enum keyword is used to declare an enumeration, a distinct type consisting of a set of named constants called the enumerator list.
  - Every enumeration type has an underlying type, which can be any integral type except char.

Example:

```
enum Days {Sat, Sun, Mon, Tue, Wed, Thu, Fri};
```

- The default underlying type of the enumeration elements is `int`. By default, the first enumerator has the value 0, the next 1, etc.
- In the above example, `Sat` is 0, `Sun` is 1 etc
- Enumerators can have initialisers to override the default values, e.g.

```
enum Days {Sat=1, Sun, Mon, Tue, Wed, Thu, Fri};
```

- In this enumeration, the sequence of elements is forced to start from 1 instead of 0.

Value Types

- A variable of *value type* directly represents its value (*"has value"*).
- Examples of value types are basic types such as `int`, `float`, `bool`
- Enumeration types, as above, are value types.
- Structures, that are collections of mixed types, are also value types.

Struct Types

- **Struct types:**
  - are user-defined types
  - can contain data members of different types
  - cannot be extended

Example:

```
struct Person {
  public string fName, lName;
  public Person(String fName, String lName) {
    this.fName = fName;
    this.lName = lName;
  }
}
Person p = new Person("John", "Smith");
```

Structs vs Classes

Classes	Structs
Reference type	*Value type*
Used w/ dynamic instantiation	Used with static instantiation
Ancestors of class Object	Ancestors of class Object
Can be extended by inheritance	*Cannot* be extended by inheritance
Can implement one or more interfaces	Can implement one or more interfaces
Can initialize fields with initializers	*Cannot* initialize fields with initializers
Can have a parameterless constructor	*Cannot* have a parameterless constructor

Reference Types

- A variable of reference type contains a reference to a memory location where data is stored (as pointers in C/C++) (*"contains value"*). Properties:
  - Direct inheritance from Object.
  - Can implement many interfaces.
  - Two predefined reference types in C#:
    - String, e.g.: `string name = "John";`
    - Object, root of all types

Value vs Reference Types

- If x and y are of *value type*, the assignment
  `x = y`
  copies the contents of y into x.
- If x and y are of *reference type*, the assignment
  `x = y`
  causes x to point to the same memory location as y.

Example:

```
1  Person p = new Person("John", "Smith");
2  Person q = p;
3  p.fName = "Will";
4  // what is the value of q.fName?
```

Boxing and Unboxing

- Boxing is the conversion of a value type to a reference type. Unboxing is the opposite process.
- Using boxing, an int value can be converted to an object to be passed to a method (that takes an object as argument).

Example:

```
1 int n = 5;
2 object nObject = n;      //boxing
3 int n2 = (int) nObject; //unboxing
```

Casting

- There are 2 ways of changing the type of a value in the program
  - *Implicit conversion* by assignment e.g.

```
short myShort = 5;
int myInt = myShort;
```

  - *Explicit conversion* using the syntax `(type)expression`

```
double myDouble = 4.7;
int myInt = (int)myDouble;
```

Nullable types

- Variables of reference type can have the value `null`, if they don't refer to anything.
- Variables of value type cannot have the value `null`, because they represent values.
- Sometimes it is useful to have a variable of value type that may have "no value".
- To this end, a *nullable type* can be used:
  `int? i;`
- Here, `i` is of type `int`, but may have the value `null`

Arrays

- C# supports one- and multi-dimensional arrays.
- One-dimensional array
  - are declared like this
    `string[] names = new string[30];`
  - starts at index 0 up to index 29 (in general, bound - 1).
  - are accessed like this:
    `names[2] = "John";`
- Multi-dimensional array:
  `int[,] numbers = new int[5,10];`

Some useful methods on arrays

- `Length` ... Gives the number of elements in an array.
- `Rank` ... Gives the number of dimensions of the array.
- `GetLength(n)` ... Gives the number of elements in the n-th dimension

Jagged Arrays

- A jagged array is a multi-dimensional array, where the "rows" may have different sizes. It is declared like this `int [][] myJaggedArray = new int[4][];`
- The rows are filled in separately `myJaggedArray[0] = new int[5];`
- Access to array elements works like this: `myJaggedArray[0][2];`

Control Structures: Conditional

```
if (expression)
  statement 1
[else
  statement 2]
```

In the above if statement:

- The `expression` must evaluate to a `bool` value.
- If `expression` is true,
  - flow of control is passed to `statement 1`
  - otherwise, control is passed to `statement 2`.
- Can have multiple else clauses (using else if).

Logical Operators

- For comparing values these operators exist: `==, !=, <=, >=, <, >`
- *NB:* `=` is for assignment; `==` is for equality test
- These operators combine boolean values: `&&, ||, !`
- Operators over `int` and `float`: `+, -, *, /` (`%` int only)
- A conditional expression is written like this: `boolean_expr ? expr_true : expr_false`

Control Structures: Switch

```
switch (switch_expression) {
  case constant-expression:
    statement
    jump statement
  ...
  case constant-expressionN:
    statementN
    jump statement
  [default]
}
```

- `switch_expression` must be of type `sbyte, byte, short, ushort, int, uint, long, ulong, char or string`.
- Each case clause must include a *jump-statement* (e.g. break statement) apart from the last case in the switch.
- Case clauses can be combined by writing them directly one after the other.

each of the constant-expressions.

Control Structures: Iteration

```
while (boolean_expression)
  statement
```

In a while statement, the `boolean_expression` is evaluated before the `statement` is executed, which is iterated while the `boolean_expression` remains true.

```
do
  statement
while (boolean_expression)
```

In a do/while statement the `boolean_expression` is evaluated *after* the `statement` is executed, which is iterated until the `boolean_expression` becomes false.

Control Structures: Iteration (cont'd)

```
for (initialization; boolean_expression; step)
  statement
```

The for statement

- performs `initialization` before the first iteration
- iterates while `boolean_expression` remains true
- performs `step` at the end of each iteration

```
foreach (type identifier in expression)
  statement
```

The foreach statement iterates over arrays and collections. The variable `identifier` is bound to each element in turn.

Functions

- Functions (or static methods) encapsulate common sequences of instructions.
- As an example, this function returns the n-th element of an array, e.g.

```
static int Get (int[] arr, int n) {
  return arr[n];
}
```

- This static method is called directly, e.g.

```
i = Get(myArr, 3);
```

Exercise: check that n is in a valid range

Function Parameters

- All objects, arrays and strings are passed by reference, i.e. changes effect the argument that is passed to the function:

```
static void Set (int[] arr, int n, int x) {
  arr[n] = x;
}
```

- But, value types are copied. The keyword `ref` is needed for passing by reference:

```
static void SetStep (int[] arr, ref int n, int x)
    {
  arr[n] = x;
  n += 1 ;
}
```

Example: nullable types

```
public static int? Min(int[] sequence){
  int theMinimum;
  if (sequence.Length == 0)
    return null;
  else {
   theMinimum = sequence[0];
   foreach (int e in sequence)
     if (e < theMinimum)
       theMinimum = e;
  }
  return theMinimum;
}
```

Discussion

- The type `int?` is a nullable int type.
- The value `null` of this type is used to indicate that there is no minimum in the case of an empty sequence.
- The method `HasValue` can be used to check whether the result is `null`:
  ```
  int?  min = Min(seq);
  if (min.HasValue) ...
  ```
- The combinator `??` can be used to select the first non-null value:
  ```
  min ??  0
  ```
- This returns the value of `min`, if its value is non-null, 0 otherwise.

Example: nullable types (cont'd)

```
public static void ReportMinMax(int[] sequence) {
 if (Min(sequence).HasValue && Max(sequence).HasValue)
   Console.WriteLine("Min: {0}. Max: {1}",
                     Min(sequence), Max(sequence));
 else
   Console.WriteLine("Int sequence is empty");
}

public static void Main(){
 int[] is1 = new int[] { -5, -1, 7, -8, 13};
 int[] is2 = new int[] { };
 ReportMinMax(is1);
 ReportMinMax(is2);
}
```

Exercises

Recommended Exercises:

(a) Define `Weekday` as an enumeration type and implement a `NextDay` method

(b) Implement a `WhatDay` method returning either `WorkDay` or `WeekEnd` (use another enum)

(c) Write a method calculating the sum from 1 to n, for a fixed integer value n

(d) Write a method calculating the sum over an array (one version with foreach, one version with explicit indexing)

Exercises (cont'd)

(e) Use the `SetStep` method to implement a method Set0, which sets all array elements to the value 0.

(f) Implement a method, reading via `ReadLine`, and counting how many unsigned short, unsigned int and unsigned long values have been read.

(g) Define complex numbers using structs, and implement basic arithmetic on them.

Mandatory exercises:

(I) Implement Euclid's greatest common divisor algorithm as a static method over 2 int parameters.

(II) Implement matrix multiplication as a static method taking two 2-dimensional arrays as arguments.

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