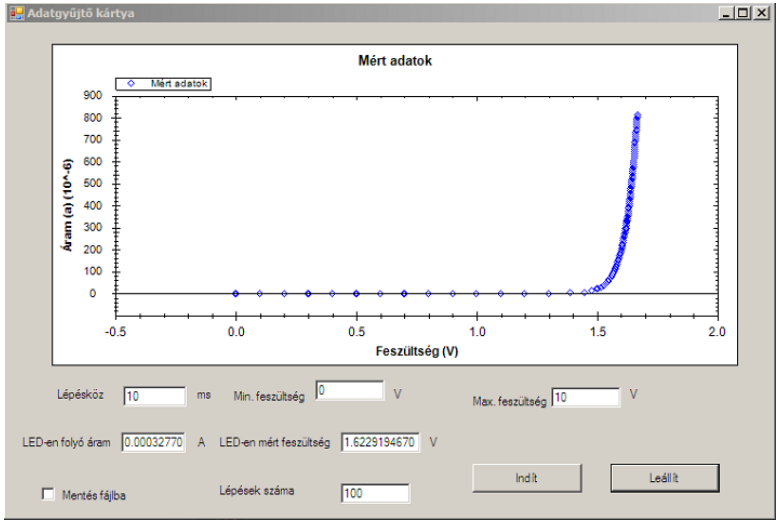
Physics laboratory for MSc students



Instructor:

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BME TTK, Department of Physics

2022/2023 Fall semester

MŰEGYETEM 1782

Outline

Day 1

- Setting the goal
- Basics of C# programming
  - Making a GUI
  - Syntax, flow control, etc.
  - Debugging in Visual Studio
  - File I/O

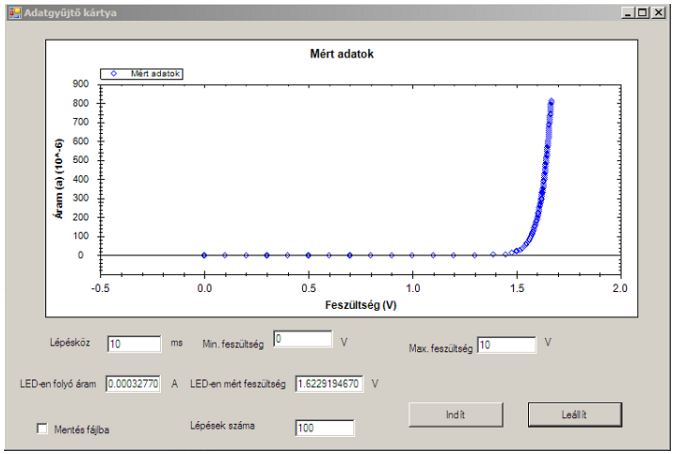
Day 2

- Connecting instruments via serial port
  - Communication with instruments
  - Plot acquired data
- Solving complex measurement control and data analysis tasks
  - NI myDAQ data acquisition device

Computer-controlled measurements

Tasks: Automated measurement, data acquisition, real-time data analysis

Devices: **Instrument**: measures a physical quantity;
Computer: data acquisition, display and analysis



Computer-controlled measurements

Communication protocols:

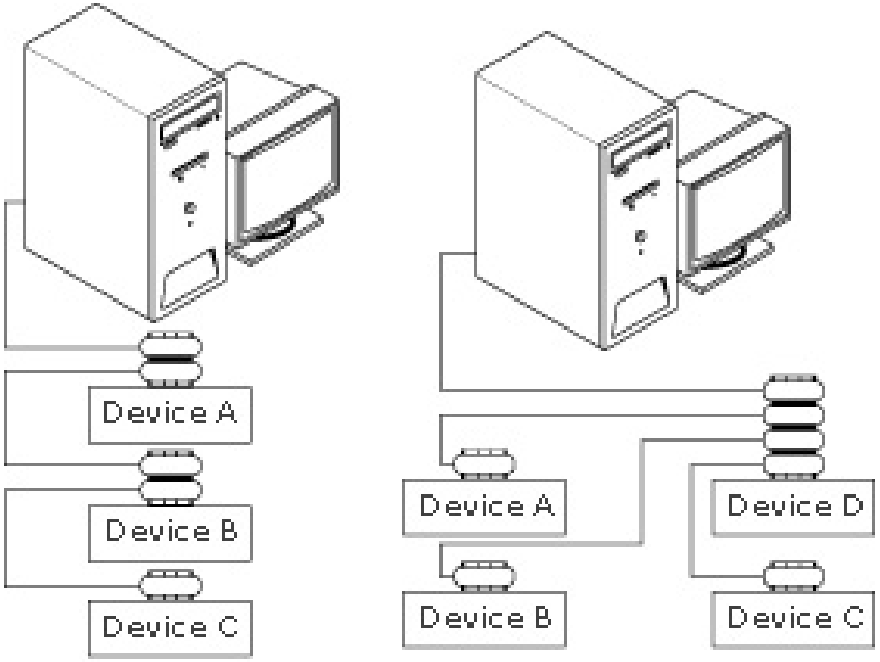
- RS-232

- USB

- LPT

- GPIB

...



a. Linear Configuration b. Star Configuration

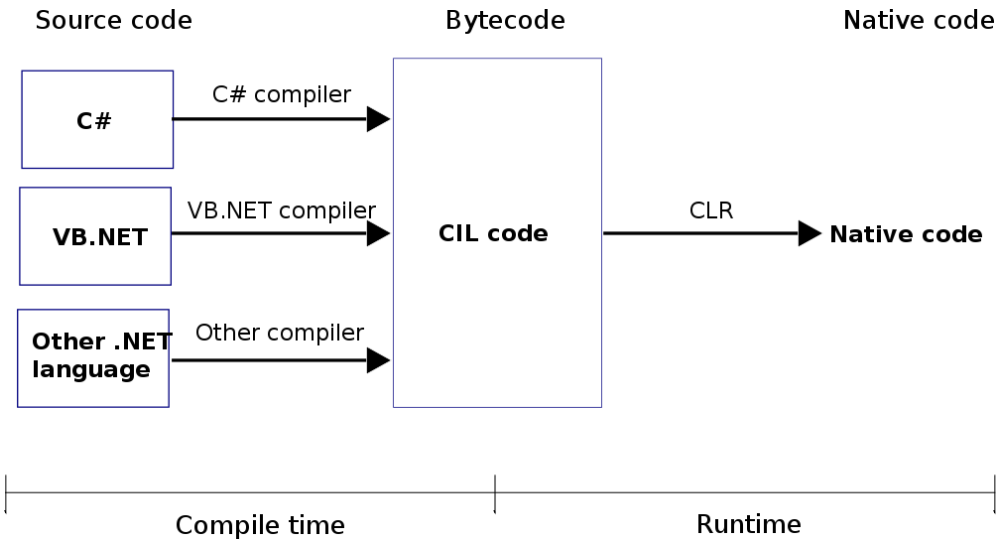
Properties:

- Bandwidth
- Cost
- Connectivity, …

C#

- Object-oriented, general purpose
- High-level
- .NET Framework

- Class Library
- CLR – Common Language Runtime



- MONO (Linux)

Basics of Object-Oriented Programming

Object: abstract unit

Example: **Employee (class)**

Properties:
- First name
- Last name
- Position
- Salary
- Email address

Data

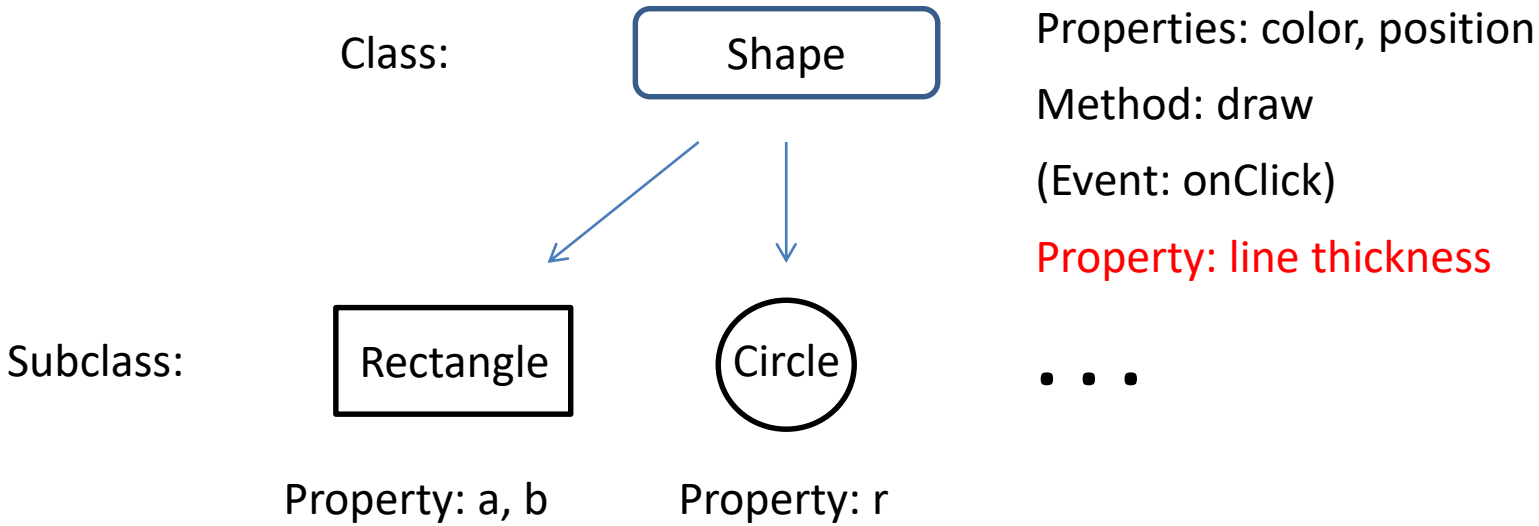
Methods:
- Increase salary
- Fire
- Promote

Logic/procedure/behavior

```
Employee Bill = new Employee("Bill Smith");
Employee John = new Employee("John Doe");
```

Basics of Object-Oriented Programming

Example: drawing program



Summary:

- **Class**: definitions for the data format and available procedures;
- **Object**: instance of a class;
- **Method**: procedure associated with a message and an object;
- **Property**: data stored in the object;
- **Event**: an action or occurrence recognized by software – like user input.

Basics of Object-Oriented Programming

Example: generating random numbers

Class: type of the object

Name of the individual object

Constructor: creating object

Method: returns the next random number.

```
Random rand01;
rand01 = new Random();
Double FloatRandomNumber = rand01.NextDouble();
```

```
Int32 IntRandomNumber = rand01.Next(MaxRandomNumber);
```

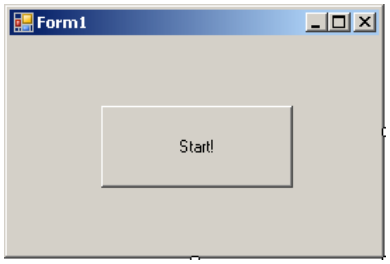
Overloading example:

int Random.Next(int minValue, int maxValue) (+ 2 overloads)
Returns a random integer that is within a specified range.

Returns:
A 32-bit signed integer greater than or equal to minValue and less than maxValue; that is, the range of return values includes minValue but not maxValue. If minValue equals maxValue, minValue is returned.

Basics of Object-Oriented Programming

Example: button



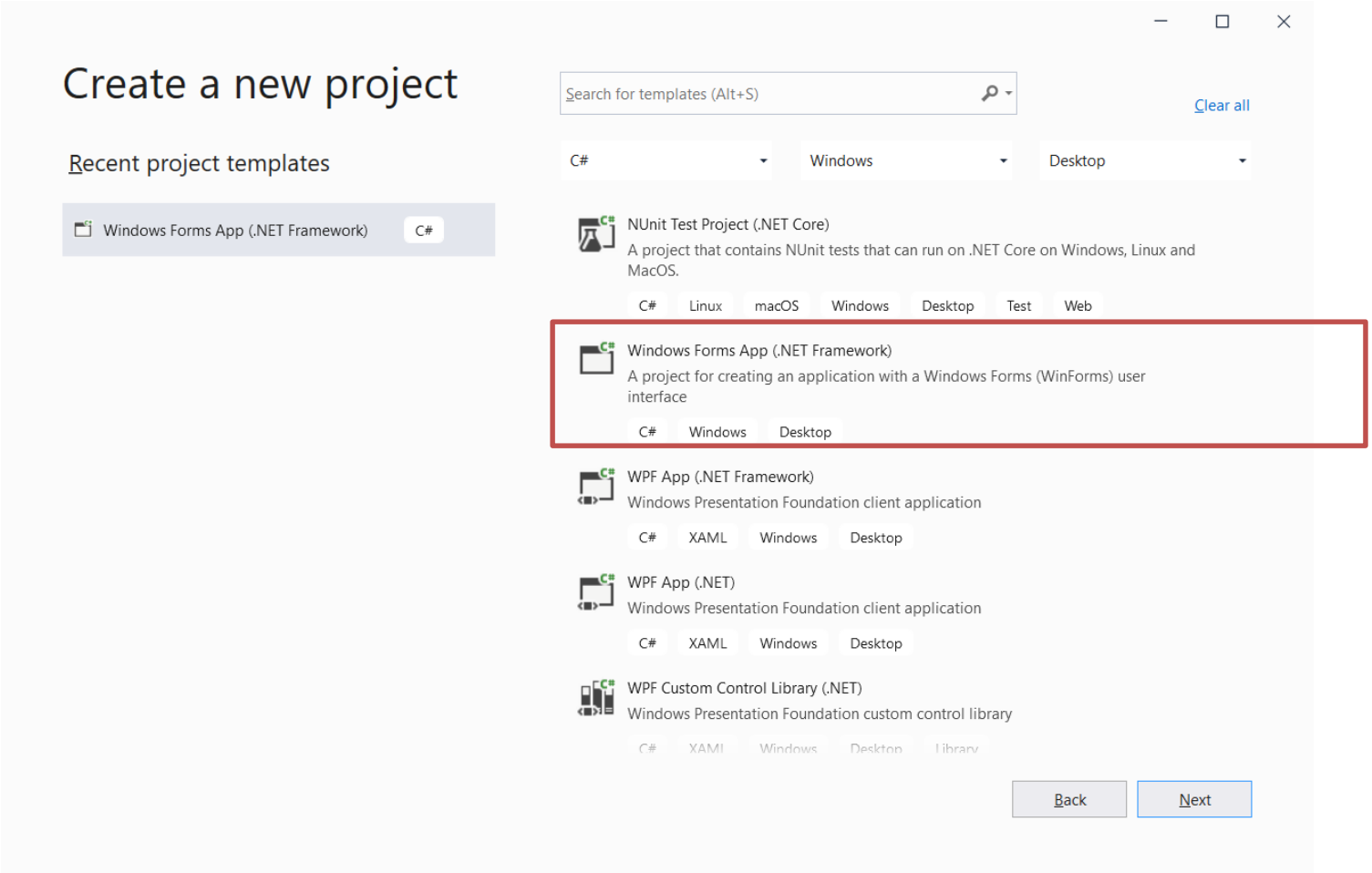
Property: Text displayed on the button.

```
StartButton.Text=”Start!”
private void StartButton_Click(object sender, EventArgs e)
        {

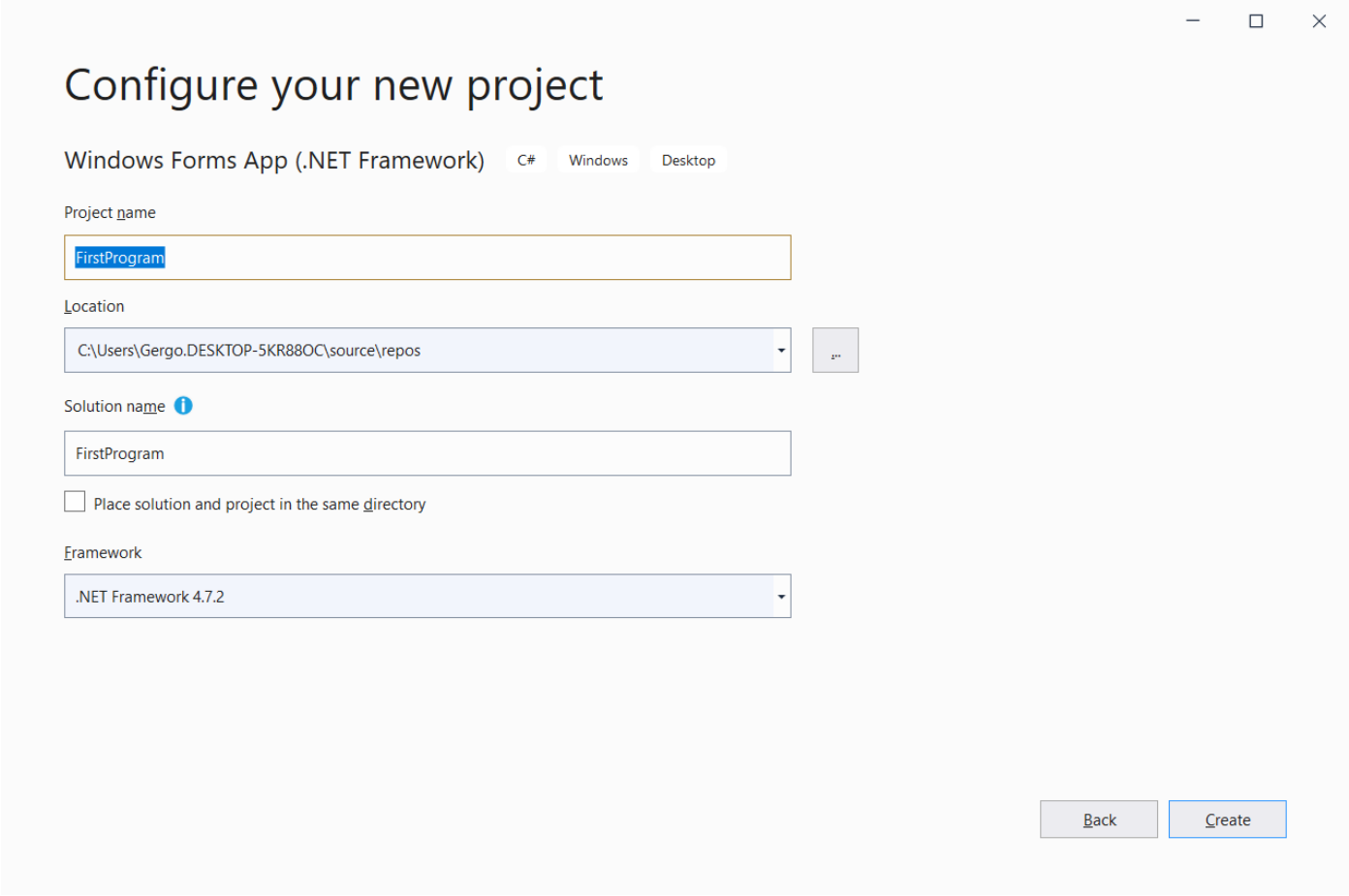
        }
```

Event: Function, called when the user clicks on the StartButton.

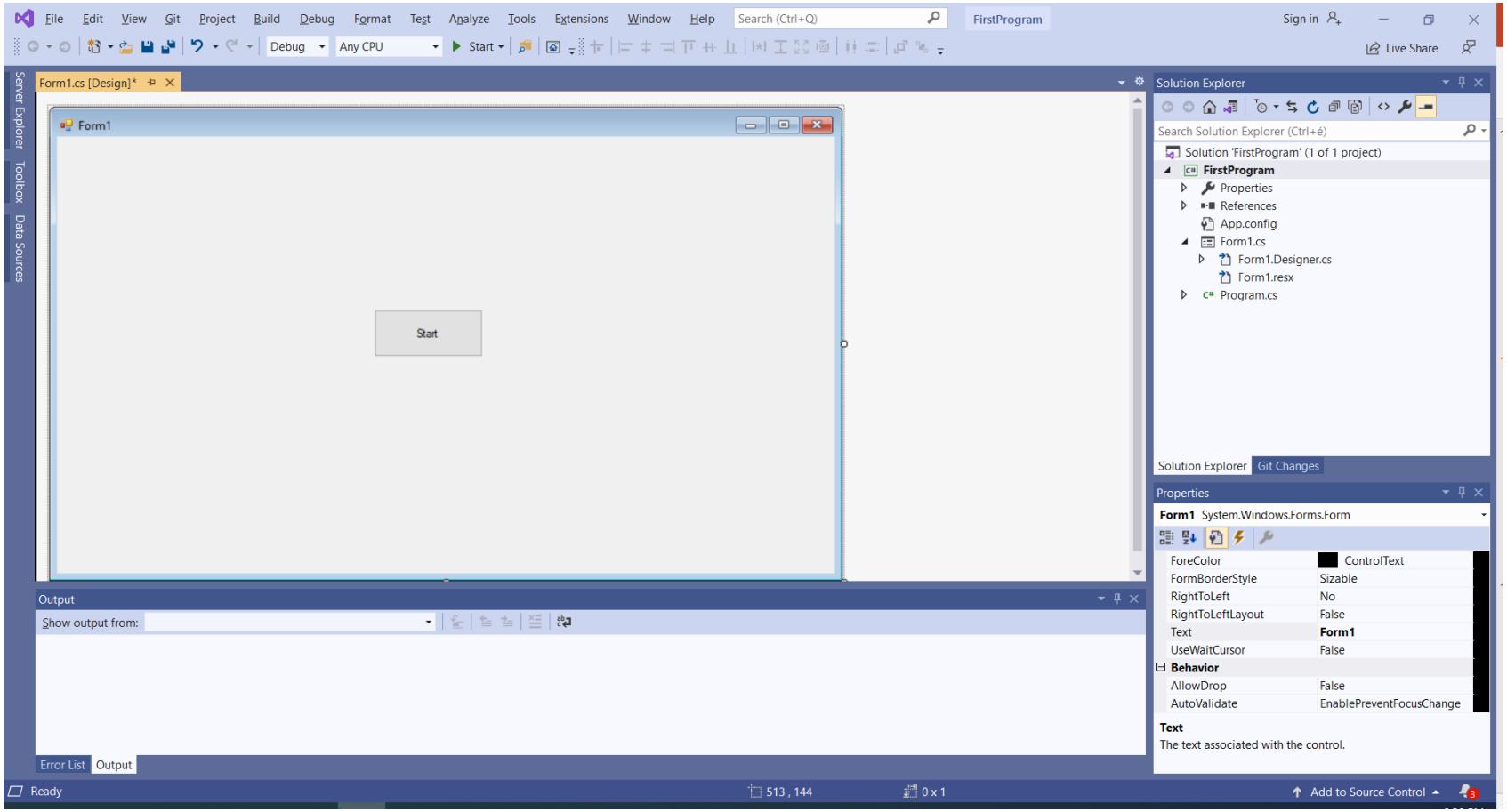
Your first C# program



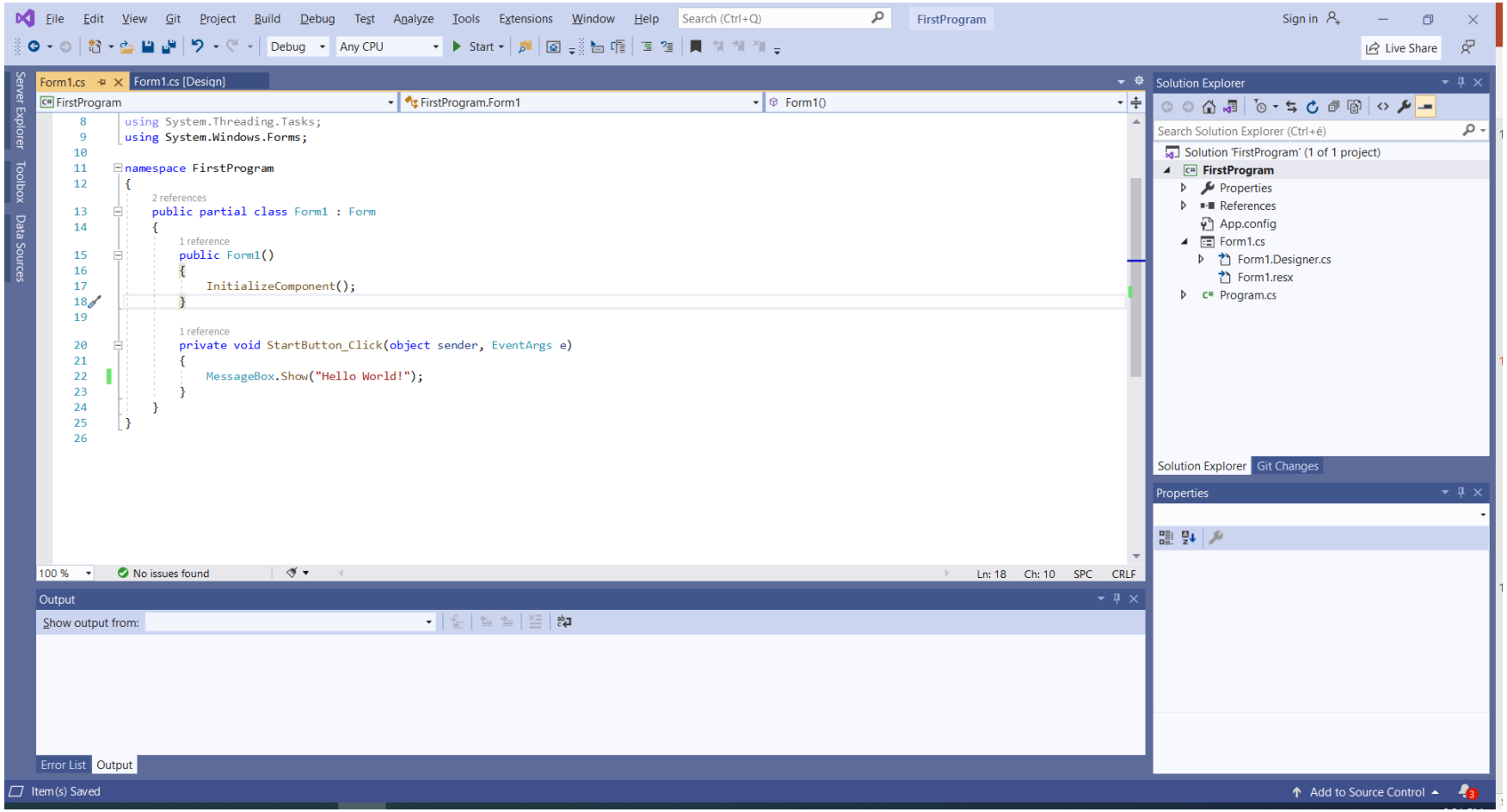
Your first C# program



Your first C# program



Your first C# program



Basics of Object-Oriented Programming

„Hello World!” program:

```
namespace proba
{
    public partial class Form1 : Form
    {
        public Form1()
        {
            InitializeComponent();
        }
        private void Form1_Load(object sender, EventArgs e)
        {
            StartButton.Text = "Start!";
        }

        private void StartButton_Click(object sender, EventArgs e)
        {
            MessageBox.Show("Hello World!");
        }

    }
}
```

Basics of Object-Oriented Programming

„Hello World!" program:

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namespace proba
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    public partial class Form1 : Form
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        {
            MessageBox.Show("Hello World!");
        }

    }
}
```

namespace

Method (the constructor)

event

property

method

Button

```
using System.Windows.Forms;
```

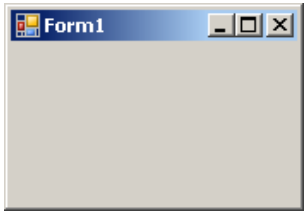
Properties	
Name	Identifier of the object
Text	Text displayed on the button

Methods	
Hide	Hides Button on the user interface
Show	Shows Button on the user interface

Events	
Click	Function, called when user clicks on the button

Form

```
using System.Windows.Forms;
```



Properties	
Name	Identifier of the object
Text	Text displayed in the header of the Form

Methods	
Show	Opens Form
Close	Closes Form (Exits the program)

Events	
Load	Function, called when the program opens
FormClosing	Function, called when the program exits

TextBox


```
using System.Windows.Forms;
```

Properties	
Name	Identifier of the object
Text	Text displayed in the textbox

Methods	
Hide	Hides the TextBox on user interface
Show	Shows the TextBox on the user interface

Events	
~~TextChanged~~	~~Function, called when the input text is changed~~
~~Click~~	~~Function, called when the user clicks on the TextBox~~

Typically, used in combination with a Button.

Label


```
using System.Windows.Forms;
```

Properties	
Name	Identifier of the object
Text	Text displayed on the Label

Methods	
Hide	Hides Label on the user interface
Show	Shows Label on the user interface

Events	
VisibleChanged	Function, called when the label becomes Hidden/Shown
Click	Function, called when the user clicks on the label

File IO

StreamWriter, StreamReader:

```
using System.IO;
```

Constructor (Opening the file)	
StreamWriter FileWriter = new StreamWriter(”File Name”);	
StreamReader FileReader = new StreamReader(”File Name”);	
Methods	
Write(”Text”)	Writes string to the file
WriteLine(”Text”)	Writes string ending with a new line character to the file
~~Read()~~	~~Reads next character from the file~~
ReadLine()	Reads next line from the file
Close()	Closes file
Properties	
EndOfStream	Bool value, signals when the end of the file is reached.

File Dialogs

OpenFileDialog, SaveFileDialog :


```
using System.Windows.Forms;
```

Methods	
ShowDialog()	Opens the FileDialog window
Reset()	Clears the settings of the object

Properties	
FileName	Path and name of the chosen file.
Title	Header of the dialog window
InitialDirectory	Default directory
DefaultExt	Default file extension

Usage: drop them on the GUI first
See example code at the file I/O examples

Examples

Measure time:

```
using System.Diagnostics;
// ...


Stopwatch sw = new Stopwatch();

sw.Start();

// ...

sw.Stop();
double elapsed_time = sw.Elapsed.TotalMilliseconds;
```

Wait (makes the program hang):

```
System.Threading.Thread.Sleep(5000); // time in ms
```

Examples

Generating random numbers:

```
// This code executes once
Random rand01;
rand01 = new Random();

.
.
.

// This code executes whenever a new random number
needs to be generated
Double RandomNumber = rand01.NextDouble();
```

Read from File

Example with StreamReader:

```
using System.IO;

...

StreamReader reader = new StreamReader("filename.txt");
string line;

while ((line = reader.ReadLine()) != null)
{
        TextBox1.AppendText(line);
}
reader.Close();
```

Write to File

StreamWriter, SaveFileDialog example:

```
using System.IO;

...

// The SaveFileDialog object must be added in the designer

...

if(sfDialog.ShowDialog() == DialogResult.OK)
{
        StreamWriter writer = new StreamWriter(sfDialog.FileName);
        writer.WriteLine("your text");
        writer.Close();
}
```

C# basics

Declaration:

```
int i;
```

Initialization:

```
i = 5;
```

Int32 ↔ int, Int64 ↔ long

Declaration + Initialization:

```
double j = 1.5;
```

Array

- Sequence of elements
- Elements must be the same type
- Fixed size
- Refer to them by their index (zero-based)

```
double[] data = new double[16];
data[0] = 1.5;
data[15] = 2.3;

string[] daysOfWeek = { "Monday", "Tuesday", …, "Sunday" };
```

Sorting: `Array.Sort(data) // sorts in-place`

C# basics

Functions:

```
private Int32 Function(arglist)
{
        ...
}
```

private: can only be accessed within the class
public: can be accessed outside of the class

Calling a function:

```
Int32 x = Function(arglist);
```

Type conversion:

```
x = Convert.ToDouble(Object);
string = Convert.ToString(Object);
i = Convert.ToInt(Object);
...
```

String:

```
string Text = "Hello";
int length = Text.Length;
string Part = Text.Substring(start, length);
int index = Text.IndexOf(char);
Text = Object.ToString("Format");
```

C# basics

`string` manipulation

```
string Text = ”  apple  ”;
```

`Length of a string:`

```
int length = Text.Length;
```

`Trim()`: removes white space characters from the beginning and end of the string

`TrimStart(), TrimEnd()`: removes whitespace characters only from the beginning or end of the string

```
newText = Text.Trim(); // ”apple”
newText = Text.TrimStart(); // ”apple  ”
newText = Text.TrimEnd(); // ”  apple”
```

`Substring()`:

```
// Text.Substring(start,length);
newText = Text.Substring(0,4) // ”  ap”
```

`Split()`:

```
string text = “6+3”;
string[] numbers = text.Split('+');
```

// numbers[0] = “6”
// numbers[1] = “3”

C# basics

`string` manipulation

Concatenating strings: “Hello World!” = “Hello” + ” “ + ”World!”

`IndexOf()`: index of the searched character (returns -1 if character is not found).

```
int index = Text.IndexOf('p'); // index=4
```

`ToString()`:

```
// Text = Object.ToString(”Format”);
double num = 5.0133;
Text = num.ToString(”0.00”); // fixed 2 decimal places, 5.01
```

C# basics

Character:

```
char c = 'g';
c = (char)103;              //ASCII 'g' character
```

Special characters:

```
char c;
c = '\t';            // tabulator
c = '\n';            // new line
c = '\r';            // carriage return
c = '\\';            // backslash
c = '\'';            // quotation marks
c = '\"';            // double quotation marks
```

C# basics

`if` branching:

```
int seconds = 0;
int minutes = 0;
...
if (seconds == 59)
{
      seconds = 0;
      minutes++;
}
else
      seconds++;
```

Multiple branches:

```
if (day == 0)
      dayName = "Sunday";
else if (day == 1)
      dayName = "Monday";
...
else if (day == 6)
      dayName = "Saturday";
else
      dayName = "unknown";
```

`switch` branching:

```
switch (day)
{
case 0 :
  dayName = "Sunday";
  break;
case 1 :
  dayName = "Monday";
  break;
case 2 :
  dayName = "Tuesday";
  break;
...
default :
  dayName = "Unknown";
  break;
}
```

- Only for internal datatypes (pl. int, string)
- Value has to be compared to a constant

C# basics

`while` loop:

```
int i = 0;
while (i < 10)
{
    MessageBox.Show(i.ToString());
    i++;
}
```

"`Do while`" loop:

```
int i = 0;
do
{
     MessageBox.Show(i.ToString());
     i++;
}
while (i < 10);
```

`for` loop:

```
for (int i = 0; i < 10; i++)
{
    MessageBox.Show(i.ToString());
}
```

Initializing multiple variables:

```
for (int i = 0, j = 10; i <= j; i++, j--)
{
    ...
}
```

C# basics

`Math class`

Mathematical functions:

`Math.Cos(rad)`: cosine function
`Math.Sin(rad)`: sine function
`Math.Min(num1, num2)`: returns the smaller number
`Math.Abs(num)`: absolute value
`Math.Pow(base, exponent)`: Exponential function
`Math.Exp(x)`: e^x
`Math.Round(num, int decimals)`: rounding numbers
`Math.Sqrt(num)`: square root
…

Mathematical constants:

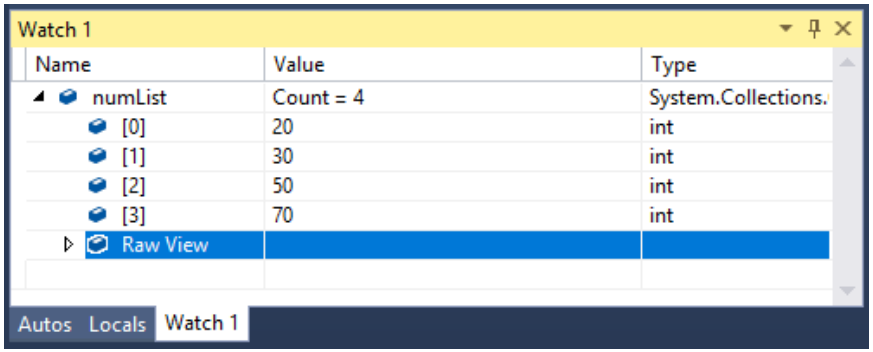
`Math.PI`: π
`Math.E`: e

Lists in C#: <list>

Lists: dynamic arrays in C#

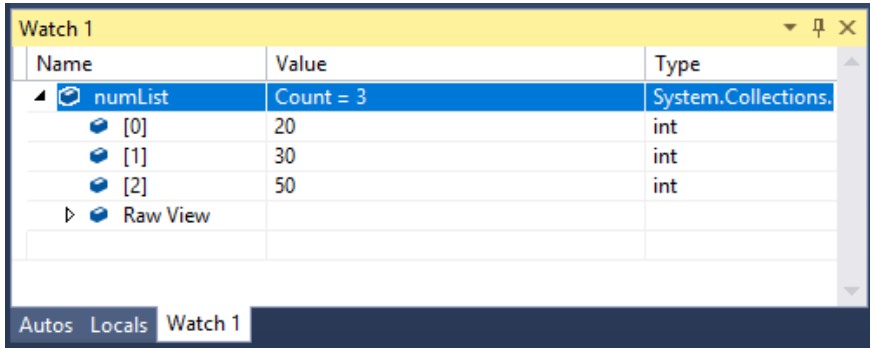
Example: list containing integer numbers

```
List<int> numList = new List<int>();
numList.Add(20);
numList.Add(30);
numList.Add(50);
numList.Add(70);
```




```
int length = numList.Count; // length = 4
int item = numList[2]; // item = 50
```

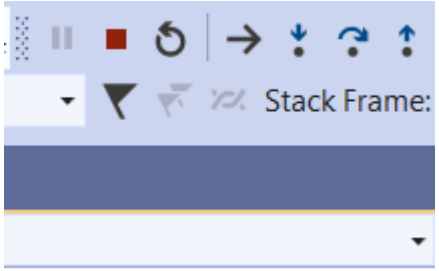
```
numList.RemoveAt(3);
```



Further methods: Clear(), Find(), Sort() …

Debugging

Control the execution



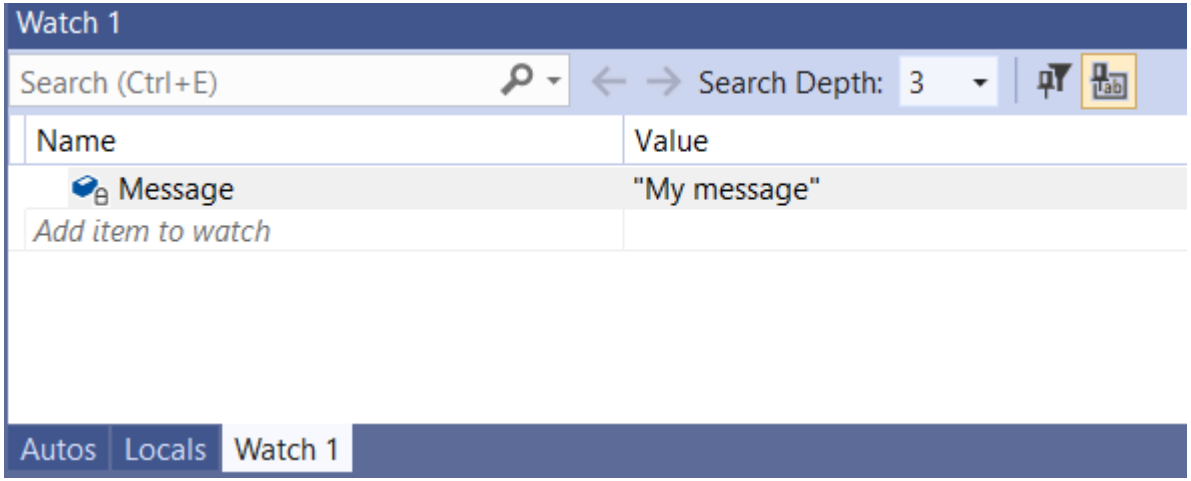

```
22
                1 reference
23              private void StartButton_Click(object sender, EventArgs e)
24              {
25                  MessageBox.Show("Hello World!");
26              }
27          }
28      }
29
```

breakpoint

Watch window:

- Evaluating expressions
- Manipulating objects

Tracking the value of a variable:
In debug mode, right click on the variable → Add watch



See also:

- Conditions
- Actions

Scope of variables

```
namespace helloworld
{
    public partial class Form1 : Form
    {
        string globalText = "Hello World!";

        public Form1()
        {
            InitializeComponent();
        }

        private void Form1_Load(object sender, EventArgs e)
        {
            MessageBox.Show(globalText);
        }

        private void button1_Click(object sender, EventArgs e)
        {
            string text = "Message";
            MessageBox.Show(text);
        }
    }
}
```

Can be accessed by every function in the Class

Can only be accessed from the button1_Click() function

Good practices

"Programs must be written for people to read, and only incidentally for machines to execute." — Harold Abelson

Naming practices, conventions

- Latin letters, English names
- Not too long, not too short
- Descriptive
- Avoid:
  - abbreviations (they are ambiguous, e.g. mon)
    acceptable: i, j, k in loops
  - dropping letters (e.g. lttrs, nmftrls)
  - puns, jokes
  - numeric suffixes (e.g. increase1(), increase2())
- Casing
  - camelCase (e.g. firstName, age, startIndex, lastNegativeNumberIndex)
  - PascalCase (e.g. SendEmail(), CarColor)

https://docs.microsoft.com/en-us/dotnet/csharp/fundamentals/coding-style/coding-conventions

Good practices

Magic numbers

Avoid:

```
int deadline = now + 604800;
```

Instead:

```
const int SecondsPerMinute = 60;
const int SecondsPerHour = 60 * SecondsPerMinute;
const int SecondsPerDay = 24 * SecondsPerHour;
const int SecondsPerWeek = 7  * SecondsPerDay;

int deadline = now + SecondsPerWeek;
```

Make it clear what units you are using

Avoid duplicate code (DRY: Don't Repeat Yourself) → make a function

Pitfalls

1. Dividing integers:

```
double d;
d = 4/5; // d = 0
d = (double) 4/5; // d = 0.8
```

2. `Convert.ToDouble()` depends on the Windows locale settings (decimal separator).

3. `Textbox.TextChanged()` event is generated every time a character is changed.

4. Objects cannot be converted to a number, e.g. `Convert.ToDouble(TextBox1)`. Correctly: `Convert.ToDouble(TextBox1.Text)`

5. Don't copy code from the PDF file. (Special characters get messed up.)

6. When using an example code, make sure that the correct linkage exists (e.g. the function is set as an event function)

Programming exercises

1. When the user pushes a button, change the color of a graphic object on the user interface. Try the debugging features of Visual Studio. (Setting the color: e.g. StartButton.BackColor = Color.Blue;)
2. Measurement of reaction time: the measurement starts when the user pushes a button. After a random time has elapsed (between 2-6 seconds), change the color of a graphical object on the user interface. Then the user has to push a button, and the program measures the elapsed time between the color change and the button press. Use a label to visualize the result on the user interface.
   Remark: you can solve this exercise using a single button on the GUI, or using two buttons. Use the **Stopwatch** to measure the elapsed time.

3. Write the Fibonacci series into a text file. The user defines how many numbers to write to the file using a **TextBox** (e.g. to write the first 100 numbers of the series). Use a **SaveFileDialog** for selecting the file where the data will be written.

Programming exercises

4. Lottery simulator: the user defines the numbers on the lottery ticket by creating a text file containing 5 numbers between 1 and 90, separated by a ';' character. The program opens this file with **OpenFileDialog** and reads the numbers. Then the program starts simulating draws: for each draw, randomly generates 5 **unique** numbers between 1 and 90 and compares them with the numbers on the lottery ticket. The program runs until a hit with 5 numbers is achieved (the 5 randomly generated numbers match those on the lottery ticket). Then the program displays the number of draws that was required. The user should be able to run the experiment repeatedly.

+1 Also count and display how many 2, 3 and 4 number hits were achieved during the draws.

Remarks:

- You may consider sorting your arrays
- What magic numbers can you identify in this exercise?
- What is the expected number of draws for a hit of 5? (From probability theory.)