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Exception Handling

Handling Errors during the Program Execution

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What are Exceptions?

The Paradigm of Exceptions in OOP

What are Exceptions?

- The exceptions in .NET Framework are classic implementation of the OOP exception model
- Deliver powerful mechanism for centralized handling of errors and unusual events
- Substitute procedure-oriented approach, in which each function returns error code
- Simplify code construction and maintenance
- Allow the problematic situations to be processed at multiple levels

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Handling Exceptions

Catching and Processing Errors

Handling Exceptions

- In C# the exceptions can be handled by the `try-catch-finally` construction

```
try
{
    // Do some work that can raise an exception
}
catch (SomeException)
{
    // Handle the caught exception
}
```

- `catch` blocks can be used multiple times to process different exception types

Handling Exceptions – Example

```
static void Main()
{
    string s = Console.ReadLine();
    try
    {
        Int32.Parse(s);
        Console.WriteLine(
            "You entered valid Int32 number {0}.", s);
    }
    catch (FormatException)
    {
        Console.WriteLine("Invalid integer number!");
    }
    catch (OverflowException)
    {
        Console.WriteLine(
            "The number is too big to fit in Int32!");
    }
}
```

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Handling Exceptions

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The System.Exception Class

- Exceptions in .NET are objects
- The `System.Exception` class is base for all exceptions in CLR
  - Contains information for the cause of the error / unusual situation
    - `Message` – text description of the exception
    - `StackTrace` – the snapshot of the stack at the moment of exception throwing
    - `InnerException` – exception caused the current exception (if any)

Exception Properties – Example

```
class ExceptionsExample
{
  public static void CauseFormatException()
  {
    string s = "an invalid number";
    Int32.Parse(s);
  }
  static void Main()
  {
    try
    {
      CauseFormatException();
    }
    catch (FormatException fe)
    {
      Console.Error.WriteLine("Exception: {0}\n{1}",
        fe.Message, fe.StackTrace);
    }
  }
}
```

Exception Properties

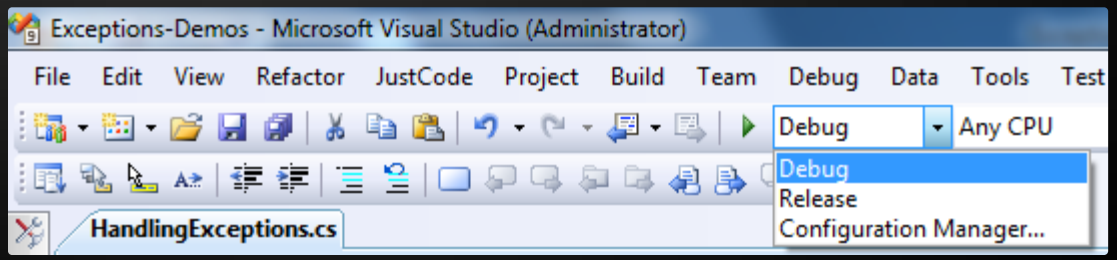
- The `Message` property gives brief description of the problem
- The `StackTrace` property is extremely useful when identifying the reason caused the exception

```
Exception caught: Input string was not in a correct
format.
   at System.Number.ParseInt32(String s, NumberStyles
style, NumberFormatInfo info)
   at System.Int32.Parse(String s)
   at ExceptionsTest.CauseFormatException() in
c:\consoleapplication1\exceptionstest.cs:line 8
   at ExceptionsTest.Main(String[] args) in
c:\consoleapplication1\exceptionstest.cs:line 15
```

Exception Properties (2)

- File names and line numbers are accessible only if the compilation was in Debug mode
- When compiled in Release mode, the information in the property StackTrace is quite different:

```
Exception caught: Input string was not in a correct
format.
   at System.Number.ParseInt32(String s, NumberStyles
style, NumberFormatInfo info)
   at ExceptionsTest.Main(String[] args)
```



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Exception Properties

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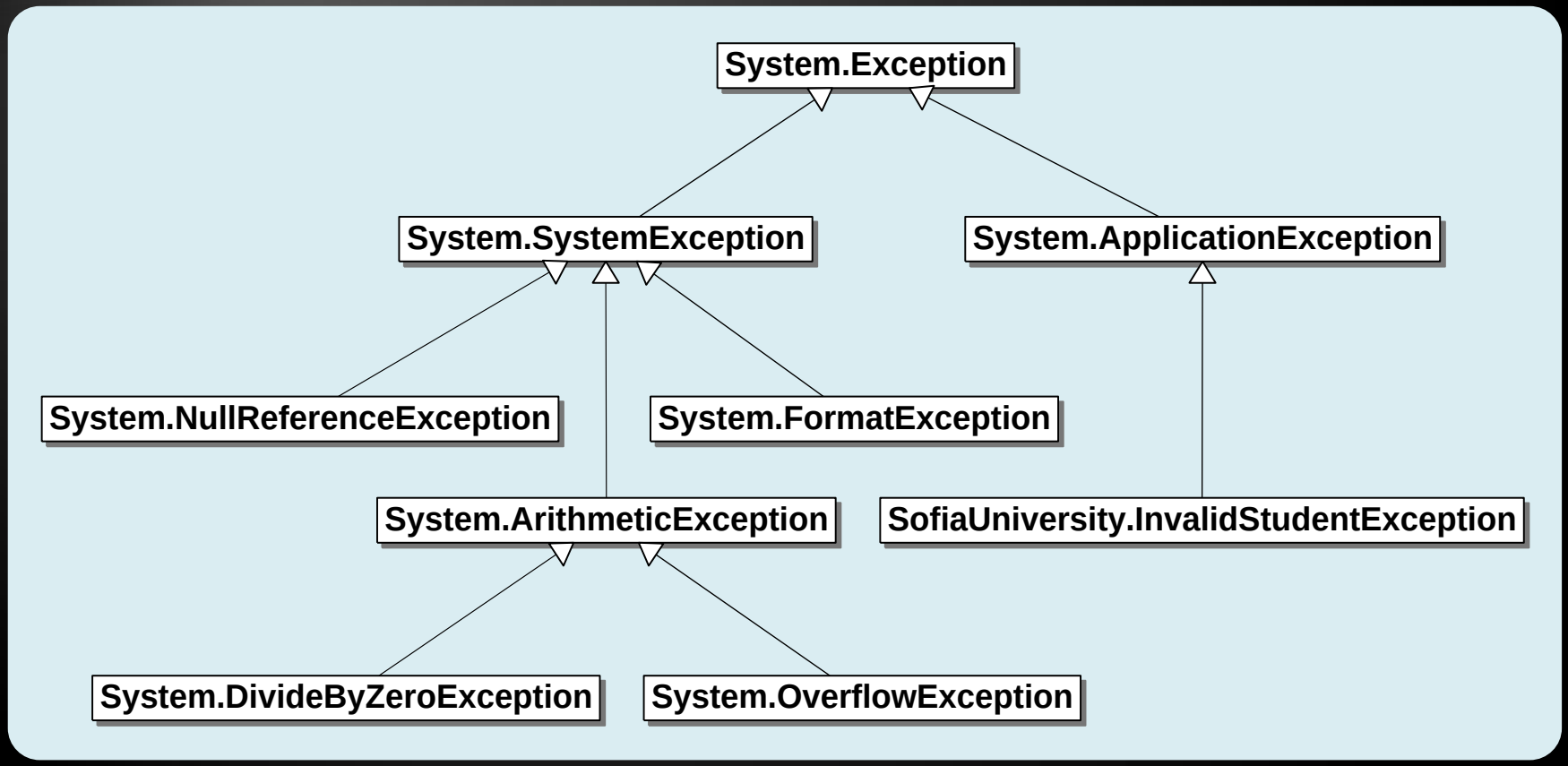
The Hierarchy of Exceptions

Exception Hierarchy

- Exceptions in .NET Framework are organized in a hierarchy

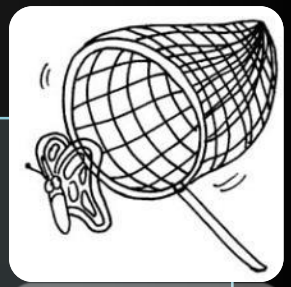


Types of Exceptions

- .NET exceptions inherit from `System.Exception`
- The system exceptions inherit from `System.SystemException`, e.g.
  - `System.ArgumentException`
  - `System.NullReferenceException`
  - `System.OutOfMemoryException`
  - `System.StackOverflowException`
- User-defined exceptions should inherit from `System.ApplicationException`

Handling Exceptions

- When catching an exception of a particular class, all its inheritors (child exceptions) are caught too
- Example:



```
try
{
   // Do some works that can cause an exception
}
catch (System.ArithmeticException)
{
     // Handle the caught arithmetic exception
}
```

Handles `ArithmeticException` and its descendants `DivideByZeroException` and `OverflowException`

Find the Mistake!

```
static void Main()
{
    string s = Console.ReadLine();
    try
    {
        Int32.Parse(s);
    }
    catch (Exception)
    {
        Console.WriteLine("Can not parse the number!");
    }
    catch (FormatException)
    {
        Console.WriteLine("Invalid integer number!");
    }
    catch (OverflowException)
    {
        Console.WriteLine(
         "The number is too big to fit in Int32!");
    }
}
```

This should be last

Unreachable code

Unreachable code

Handling All Exceptions

- All exceptions thrown by .NET managed code inherit the `System.Exception` exception
- Unmanaged code can throw other exceptions
- For handling all exceptions (even unmanaged) use the construction:

```
try
{
    // Do some works that can raise any exception
}
catch
{
    // Handle the caught exception
}
```

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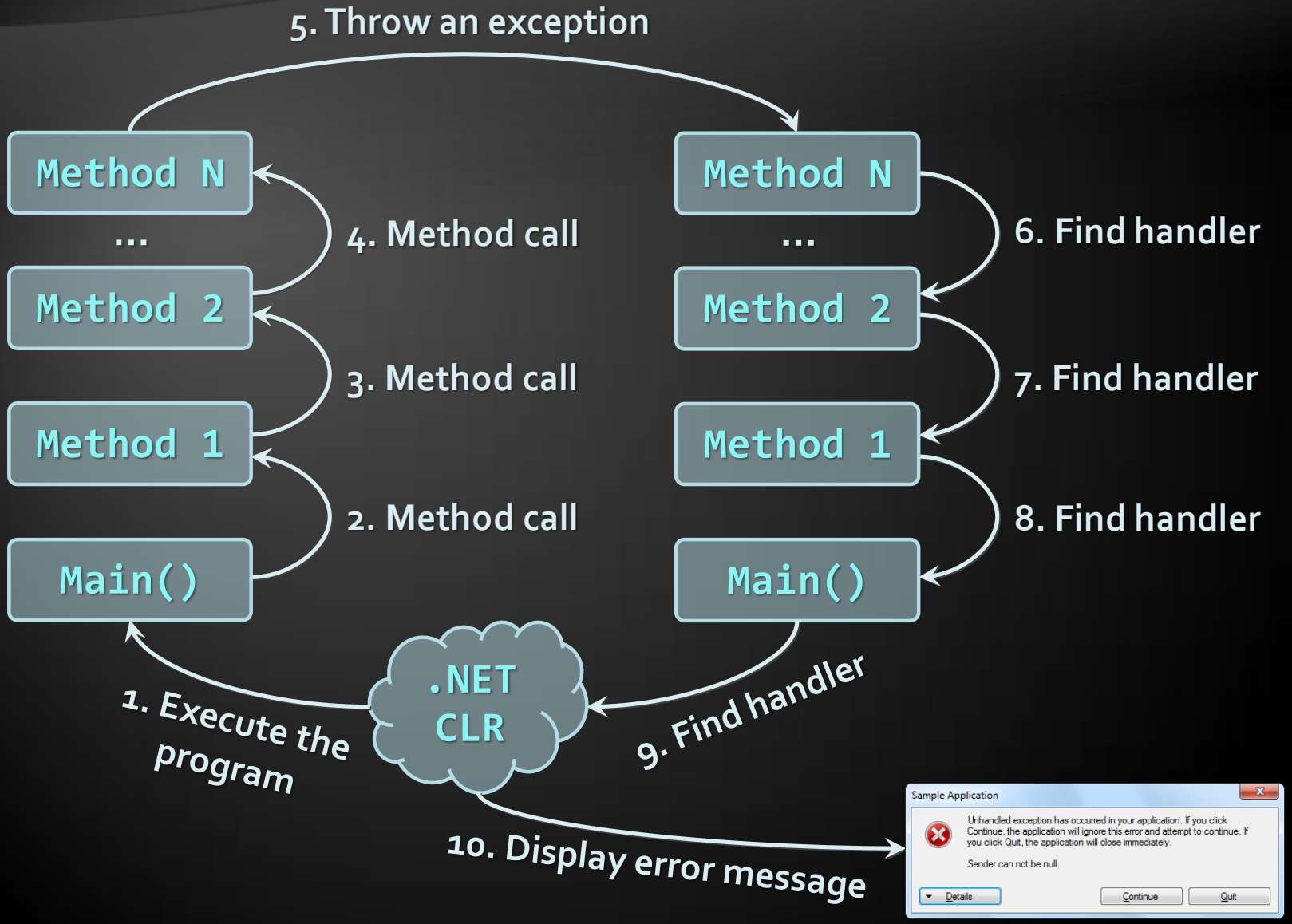
Throwing Exceptions

Throwing Exceptions

- Exceptions are thrown (raised) by `throw` keyword in C#
  - Used to notify the calling code in case of error or unusual situation
- When an exception is thrown:
  - The program execution stops
  - The exception travels over the stack until a suitable `catch` block is reached to handle it
- Unhandled exceptions display error message

How Exceptions Work?



Using throw Keyword

- Throwing an exception with an error message:

```
throw new ArgumentException("Invalid amount!");
```

- Exceptions can accept message and cause:

```
try
{
  Int32.Parse(str);
}
catch (FormatException fe)
{
  throw new ArgumentException("Invalid number", fe);
}
```

- Note: if the original exception is not passed the initial cause of the exception is lost

Re-Throwing Exceptions

- Caught exceptions can be re-thrown again:

```
try
{
  Int32.Parse(str);
}
catch (FormatException fe)
{
  Console.WriteLine("Parse failed!");
  throw fe; // Re-throw the caught exception
}
```

```
catch (FormatException)
{
  throw; // Re-throws the last caught exception
}
```

Throwing Exceptions – Example

```
public static double Sqrt(double value)
{
    if (value < 0)
        throw new System.ArgumentOutOfRangeException(
            "Sqrt for negative numbers is undefined!");
    return Math.Sqrt(value);
}

static void Main()
{
    try
    {
        Sqrt(-1);
    }
    catch (ArgumentOutOfRangeException ex)
    {
        Console.Error.WriteLine("Error: " + ex.Message);
        throw;
    }
}
```

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Throwing Exceptions

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Choosing the Exception Type

- When an invalid parameter is passed to a method:
  - `ArgumentException`, `ArgumentNullException`, `ArgumentOutOfRangeException`
- When requested operation is not supported
  - `NotSupportedException`
- When a method is still not implemented
  - `NotImplementedException`
- If no suitable standard exception class is available
  - Create own exception class (inherit `Exception`)

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Using Try-Finally Blocks

The try-finally Statement

- The statement:

```
try
{
    // Do some work that can cause an exception
}
finally
{
    // This block will always execute
}
```

- Ensures execution of given block in all cases
  - When exception is raised or not in the try block
- Used for execution of cleaning-up code, e.g. releasing resources

try-finally – Example

```
static void TestTryFinally()
{
  Console.WriteLine("Code executed before try-finally.");
  try
  {
    string str = Console.ReadLine();
    Int32.Parse(str);
    Console.WriteLine("Parsing was successful.");
    return; // Exit from the current method
  }
  catch (FormatException)
  {
    Console.WriteLine("Parsing failed!");
  }
  finally
  {
    Console.WriteLine(
      "This cleanup code is always executed.");
  }
  Console.WriteLine(
    "This code is after the try-finally block.");
}
```

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Try-Finally

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Exceptions: Best Practices

Exceptions – Best Practices

- `catch` blocks should begin with the exceptions lowest in the hierarchy
  - And continue with the more general exceptions
  - Otherwise a compilation error will occur
- Each `catch` block should handle only these exceptions which it expects
  - If a method is not competent to handle an exception, it should be left unhandled
  - Handling all exceptions disregarding their type is popular bad practice (anti-pattern)!

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Exceptions – Best Practices (2)

- When raising an exception always pass to the constructor good explanation message
- When throwing an exception always pass a good description of the problem
  - Exception message should explain what causes the problem and how to solve it
  - Good: "*Size should be integer in range [1…15]*"
  - Good: "*Invalid state. First call Initialize()*"
  - Bad: "*Unexpected error*"
  - Bad: "*Invalid argument*"

Exceptions – Best Practices (3)

- Exceptions can decrease the application performance
  - Throw exceptions only in situations which are really exceptional and should be handled
  - Do not throw exceptions in the normal program control flow (e.g. for invalid user input)
- CLR could throw exceptions at any time with no way to predict them
  - E.g. `System.OutOfMemoryException`

Summary

- Exceptions provide flexible error handling mechanism in .NET Framework
  - Allow errors to be handled at multiple levels
  - Each exception handler processes only errors of particular type (and its child types)
    - Other types of errors are processed by some other handlers later
  - Unhandled exceptions cause error messages
- Try-finally ensures given code block is always executed (even when an exception is thrown)

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Exercises

1. Write a program that reads an integer number and calculates and prints its square root. If the number is invalid or negative, print "Invalid number". In all cases finally print "Good bye". Use try-catch-finally.
2. Write a method `ReadNumber(int start, int end)` that enters an integer number in given range [start…end]. If an invalid number or non-number text is entered, the method should throw an exception. Using this method write a program that enters 10 numbers:

$$a_1, a_2, \ldots a_{10}, \text{ such that } 1 < a_1 < \ldots < a_{10} < 100$$

Exercises (2)

3. Write a program that enters file name along with its full file path (e.g. `C:\WINDOWS\win.ini`), reads its contents and prints it on the console. Find in MSDN how to use `System.IO.File.ReadAllText(…)`. Be sure to catch all possible exceptions and print user-friendly error messages.
4. Write a program that downloads a file from Internet (e.g. http://www.devbg.org/img/Logo-BASD.jpg) and stores it the current directory. Find in Google how to download files in C#. Be sure to catch all exceptions and to free any used resources in the finally block.

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