Module 01:
"Threads"

TEKNOLOGISK
INSTITUT

Agenda

- **Introduction to Threads**
- Threads and Data
- Controlling Threads
- Exception Handling
- Debugging Tips ‘n Tricks

Hello World ☺

```
static void Main()
{
    Thread thread = new Thread(WriteWorld);
    thread.Start();

    for (int i = 0; i < 1000; i++)
    {
        Console.Write("Hello ");
    }
}
```

```
static void WriteWorld()
{
    for (int i = 0; i < 1000; i++)
    {
        Console.Write("World ");
    }
}
```

Managing Threads

- Thread Scheduler manages threads
  - CLR
  - Operating System

- Single processor ~ Time-slicing
- Multiple processors ~ Concurrency + Time-slicing

- Preemption = Thread execution is interrupted

- Threads vs. Processes

Use Cases for Threads

- Responsive UI
- Simultaneous processing of requests or updates
- Parallel Programming
- Efficient use of CPUs
- Speculative Execution

- But… Threads incur complexity issues!

Important Thread Properties

- Always a ”executing” thread
  - `Thread.CurrentThread`

- Each Thread has a number of important properties
  - `ManagedThreadId`
  - `IsAlive`
  - `IsBackground`
  - …

Foreground vs. Background

- Foreground threads
  - Keep the application running
- Background threads
  - Shut down silently when application closes
  - Note: finally and using blocks do not always complete!
- No difference in priority, scheduling, etc…

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Sharing Data Between Threads

- Each thread has a
  - Separate call stack
  - Separate local variables

- Shared between threads
  - Static members
  - Object state

- Well... Unless...

ThreadStatic and ThreadLocal<T>

- Default data sharing between threads can be manually changed

- `ThreadStatic` attribute
  - Enforces per-thread copy of static data
  - Note: This is non-obvious! Don't use this!

- `ThreadLocal<T>` class
  - Lazily created, per-thread local variable
  - Introduced in .NET 4.0

Starting Threads

- **ThreadStart** delegate is implicit (since C# 2.0)

```
public delegate void ThreadStart();
```

```
Thread t1 = new Thread( new ThreadStart (a.Go) );
```

- Can also use lambda expressions etc.

```
Thread t3 = new Thread( () =>
{
    int counter = 0;
    for (int i = 0; i < 100; i++)
    {
        counter++;
    }
});
```

Passing Data to Threads

- **`ParameterizedThreadStart`** delegate is

```
public delegate void ParameterizedThreadStart (object obj);
```

```
Thread t1 = new Thread( new ParameterizedThreadStart (a.Go) );
```

- This value is passed using an overload of **`Start()`**.

```
t1.Start(100);
```

```
void Go(object input)
{
   int max = (int)input; // Needs ugly cast
   ...
}
```

Capturing Data in Threads

- Data can also be *captured* by threads via lambdas
- Beautiful, elegant, powerful, and…

- … a very common source of hard-to-spot errors!

```
string text = "Hello, World";
Thread t1 = new Thread(() => Console.WriteLine(text));

text = "WTF?!?";
Thread t2 = new Thread(() => Console.WriteLine(text));

t1.Start();
t2.Start();
```

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Blocking vs. Spinning

- A thread can be blocked
  - **`Sleep()`** ~ Pause for a time period
  - **`Yield()`** ~ Almost a **`Sleep(0)`**

```
Thread.Sleep( 1000 );
Thread.Yield();
```

  - Usually not for production code

- A thread can spin
  - **`SpinWait()`** ~ Busy-wait for a number of cycles

```
Thread.SpinWait( 100_000_000 );
```

  - Caution! Only for very advanced scenarios

Join

- You can wait for a thread to end using Thread.Join()

```
Thread t = new Thread(Go);
t.Start();
t.Join(); // Wait for t to end
Console.WriteLine("t has completed!");
```

- Note: The calling thread is blocked during Join()

- There is an overload with timeout period specified

```
if( t.Join(5000) )
{
   Console.WriteLine("t has completed within 5 seconds!");
}
```

Interrupt

- A blocked thread can be *interrupted*

```
Thread t = new Thread(Go);
t.Start();
...;
t.Interrupt();
```

- A **`ThreadInterruptedException`** is thrown at blocking location
  - Must be handled by thread method
  - Exception is not re-thrown if unhandled

- Note: You’ll probably never need Thread.Interrupt().

- We will encounter better alternatives for signalling later... ☺

Abort

- A blocked thread can be forcibly released by *aborting*

```
Thread t = new Thread(Go);
t.Start();
...;
t.Abort();
```

- A **`ThreadAbortException`** is thrown at immediate location
  - Unpredictable! ”May abort thread”
  - Exception is re-thrown if unhandled

- Note: Don’t use Thread.Abort()
  - Most framework code is not safe to abort

Thread Priority

- Thread priority within the process can be set

```
Thread t = new Thread(Go)
{
   Priority = ThreadPriority.Highest;
}
t.Start();
```

```
enum ThreadPriority
{
   Lowest = 0,
   BelowNormal = 1,
   Normal = 2,
   AboveNormal = 3,
   Highest = 4
 }
```

- Don’t be fooled… by ”everything”!
- Process priority is more important

```
using (Process p = Process.GetCurrentProcess())
{
   p.PriorityClass = ProcessPriorityClass.High;
}
```

- OS is allowed to ignore thread priority

Rule of Thumb

Q: "For large problem sizes, what is the preferred amount of threads to use?

A: Usual rule of thumb is
Two threads per logical core

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Don’t...

- Never handle exceptions at thread creation or start!

```
try
{
    Thread t = new Thread(() =>
    {
        ...
        throw new InvalidOperationException("Argh!");
    });
    t.Start();
}
catch (Exception)
{
    Console.WriteLine("Thread error");
}
```

Do…

- Always handle exceptions in thread method!

```
Thread t = new Thread(Go);
t.Start();
```

```
void Go()
{
    try
    {
        ...
        throw new InvalidOperationException("Argh!");
    }
    catch (Exception)
    {
        Console.WriteLine("Thread error");
    }
}
```

C# 6.0 Exception Filters

- Exception filters facilitates the handling of exceptions matching a specific type and/or predicate

```
var from = Bank.CreateAccount(100);
var to = Bank.CreateAccount(100);

try
{
   Bank.TransferFunds(from, 200, to);
}
catch (InsufficientFundsException e) when (e.Account?.IsVIP == true)
{
   // Handle VIP account
}
```

- Distinct clauses can match same exception type but with different conditions

Unhandled Exceptions

- Remember: Exceptions unhandled in threads will terminate process
- .`AppDomain.CurrentDomain` offers a handler to catch all exceptions
  - But does not prevent shutdown

```
AppDomain.CurrentDomain.UnhandledException += OnException;

Thread t = new Thread(Go);
t.Start();
```

```
void OnException(object sender, UnhandledExceptionEventArgs e)
{
    ...
}
```

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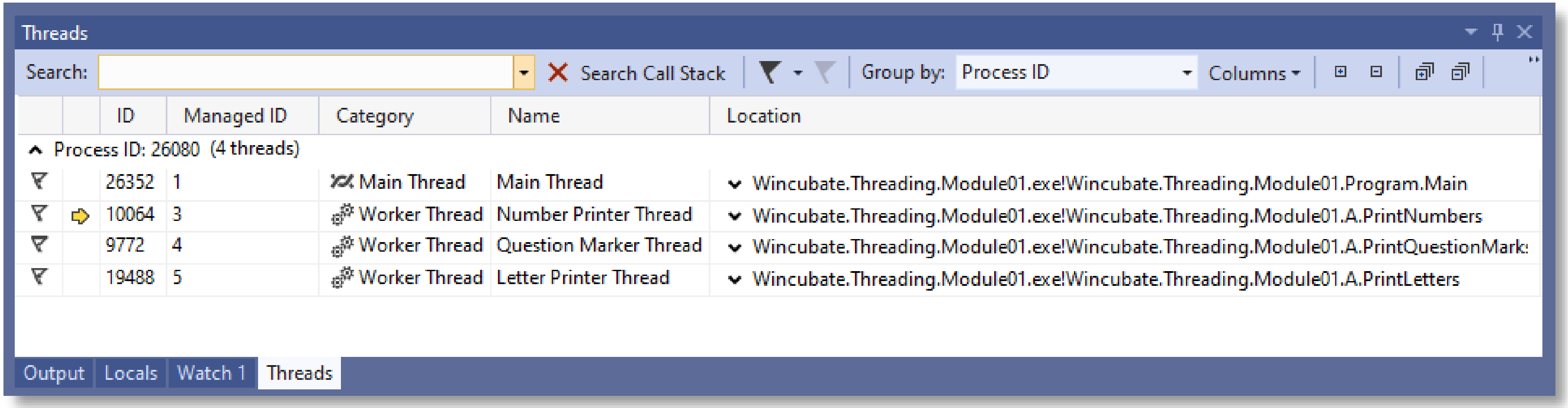
Debugging Threads Tips 'n Tricks

- Visual Studio Threads Window
  - Debug > Windows > Threads (Ctrl+D, T)



Process ID: 26080 (4 threads)

		ID	Managed ID	Category	Name	Location
		26352	1	Main Thread	Main Thread	Wincubate.Threading.Module01.exe!Wincubate.Threading.Module01.Program.Main
	➩	10064	3	Worker Thread	Number Printer Thread	Wincubate.Threading.Module01.exe!Wincubate.Threading.Module01.A.PrintNumbers
		9772	4	Worker Thread	Question Marker Thread	Wincubate.Threading.Module01.exe!Wincubate.Threading.Module01.A.PrintQuestionMark
		19488	5	Worker Thread	Letter Printer Thread	Wincubate.Threading.Module01.exe!Wincubate.Threading.Module01.A.PrintLetters

- `Thread.Name` property helps debugging

Summary

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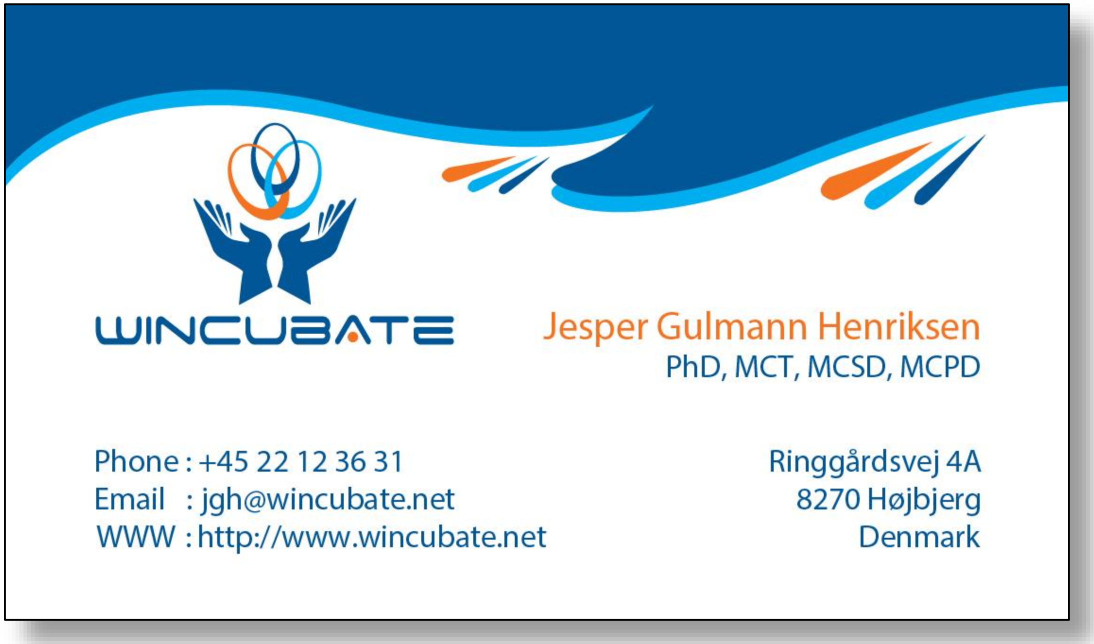

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