Module 08:
”Async, Await, and Task Combinators”

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Agenda

- **Async and Await**
- Synchronization Context
- More Task Combinators
- Concluding Remarks

C# 5.0 await Operator

- C# 5.0 introduces **`await`** keyword for methods returning `Task` or `Task<T>`
  - Yields control until awaited task completes
  - Results gets returned

- Allows you to program just like for synchronous programming…!

```
WebClient client = new WebClient();
string result = await client.DownloadStringTaskAsync( ... );

Console.WriteLine( result );
```

- Really complex control flow under the hood is made stunningly simple by compiler

C# 5.0 async Modifier

- C# 5.0 introduces **`async`** keyword
  - Marks method or lambda as asynchronous
  - Note: Methods making use of **`await`** must be marked "**`async`**"

- You can now easily define your own asynchronous methods

```
async static void DoStuff()
{
   // ...

   string result = await client.DownloadStringTaskAsync( ... );

   // ...
}
```

- Can create async methods returning **`void`**, **`Task`**, or **`Task<T>`**

Best Practices for Task Methods

- Microsoft recommends that the name of methods returning Task or Task<T> should be postfixed with …Async
  - Regardless of whether it is marked with async modifier…!

```
async Task<string> DoStuffAsync()
{
   // ...

   string result = await client.DownloadStringTaskAsync( ... );

   return result;
}
```

```
Task<string> GetSimpleAsync()
{
   return Task.CompletedTask; // <-- We will see this later
}
```

C# 7.1 Allows Main to be Async

```
static async Task DoStuffAsync()
{
    ... await ...
    ... await ...
    ... await ...
}
```

```
static void Main(string[] args)
{
    DoStuffAsync().GetAwaiter().GetResult();
}
```

```
static async Task<int> Main( string[] args )
{
   ... await ...
}
int $GeneratedMain( string[] args )
{
    return Main(args).GetAwaiter().GetResult();
}
```

Exceptions Thrown by Tasks and Awaitable Methods

- Observe and catch exceptions "as usual" when awaiting tasks

```
try
{
   string data = await client.DownloadStringTaskAsync( ... );
}
catch ( WebException ex ) { ... }
```

- Note that
  - `Task.WaitXxx()` throws an `AggregateException`
  - `Task.Result` throws an `AggregateException`
  - Awaiting a `Task` throws exceptions "as usual", however!

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What is a SynchronizationContext?

- Context handling synchronization of (a)synchronous operations
  - In general a many-to-many relationship with threads

```
public class SynchronizationContext
{
   public virtual void OperationCompleted() { ... }
   public virtual void OperationStarted() { ... }
   public virtual void Post(SendOrPostCallback d, object state)
   {
      // Perform operation asynchronously
   }
   public virtual void Send(SendOrPostCallback d, object state)
   {
      // Perform operation synchronously
   }
}
```

Built-in SynchronizationContexts

- **`WindowsFormsSynchronizationContext`**
  - Executes on a specific UI thread
  - Executes in the order they were queued.
- **`DispatcherSynchronizationContext`**
  - Queues delegates to a specific UI thread with **`Normal`** priority.
  - Executes in the order they were queued
  - Installed as current context by **`Dispatcher.Run()`**
- Default (Thread Pool) **`SynchronizationContext`**
  - if a thread's current Synchronization Context is null, then it implicitly has this default Synchronization Context.
  - Queues its asynchronous delegates to the Thread Pool but executes its synchronous delegates directly on the calling thread.

Await and SynchronizationContext

- Await captures the current Synchronization Context
  - Essential and very helpful for WPF and WinForms

```
// DispatcherSynchronizationContext here in WPF

string result = await FactorAsync();
lblResult.Content = result;

// Also DispatcherSynchronizationContext here!
```

Not "Thread"!

ConfigureAwait()

- By default execution continues on the current Synchronization Context after **`await`**

- Optionally, this requirement can be manually relaxed by `Task.ConfigureAwait(false)`

```
// DispatcherSynchronizationContext here in WPF

string result = await FactorAsync().ConfigureAwait( false );
lblResult.Content = result;

// Not DispatcherSynchronizationContext here!
```

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Basic Tasks

- You can form constant tasks synchronously

```
Task Method1Async() => Task.CompletedTask;

Task<DateTime> Method2Async() => Task.FromResult(DateTime.Now);

Task<DateTime> Method3Async(
   CancellationToken cancellationToken
) =>
   Task.FromCanceled<DateTime>(cancellationToken);

Task Method4Async() =>
   Task.FromException(new NotImplementedException("Oops"));
```

More Task Combinators

- Combinators also include
  - `Task.WhenAll()` Completes when all tasks have completed
  - `Task.WhenAny()` Completes when any of the tasks completes
  - `Task.Delay()` Completes after a specified time span
  - + more

- You can also write your own

Task.Delay()

- `Task.Delay()` completes after a specified time span

```
await Task.Delay(3000);
```

- The Task-equivalent of `Thread.Sleep()`

Task.WhenAll()

- `Task.WhenAll()` completes when all tasks have completed

```
Task<string[]> all = Task.WhenAll(
   FactorAsync(87),
   FactorAsync(112),
   FactorAsync(176)
);
string[] results = await all;
```

```
Task<string> FactorAsync(int number) { ... }
```

- There is also an overload for plain Tasks

Task.WhenAny()

- `Task.WhenAny()` completes when any of the tasks completes
- Returns the task which is completed

```
List<Task<string>> remaining = new List<Task<string>>
{ ... };

while( remainingTasks.Any() )
{
   Task<string> completedTask = await Task.WhenAny(remaining);
   Console.WriteLine(completedTask.Result);

   remainingTasks.Remove(completedTask);
}
```

TaskCompletionSource<T>

- Any occurrence or computation can be transformed into a `Task<T>` using `TaskCompletionSource<T>`

```
public partial class Form1 : Form
{
    private readonly TaskCompletionSource<DateTime> _tcs =
       new TaskCompletionSource<DateTime>();
    ...
    async private void OnClick(object sender, EventArgs e)
    {
        DateTime dt = await _tcs.Task;
        ...
    }
    private void OnMouseEnter(object sender, EventArgs e)
    {
        _tcs.TrySetResult(DateTime.Now);
    }
}
```

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Three Approaches to Asynchrony

- Synchronous calls
  - `Xxx()` methods
- .NET Asynchronous Programming Model (APM) consisting of
  - `BeginXxx()` methods
  - `EndXxx()` methods
- Event-based Asynchronous Pattern (EAP) consisting of
  - `XxxAsync()` methods
  - `XxxCancelAsync()` methods
  - `XxxCompleted` events
- Task-based Asynchronous Pattern
  - `XxxAsync()` or `XxxTaskAsync()` methods

Tasks and Asynchronous Programming Model

- The ”traditional” .NET Asynchronous Programming Model consists of
  - `BeginXxx()` methods
  - `EndXxx()` methods

- Tasks encapsulate this model using `TaskFactory.FromAsync()`

```
HttpWebResponse response =
   await Task<WebResponse>.Factory.FromAsync(
      request.BeginGetResponse,
      request.EndGetResponse,
      request )
   as HttpWebResponse;
```

When to Use What?

- Thread
  - Avoid if possible!
  - Only for ”eternal” processing
- ThreadPool
  - Use for very quick, small, unordered computations
  - Usually callbacks
- Task
  - Use for ”task parallelism”: computational independence or I/O-bound work
- Parallel
  - Use for ”data parallelism”: processing sets of independent data

Summary

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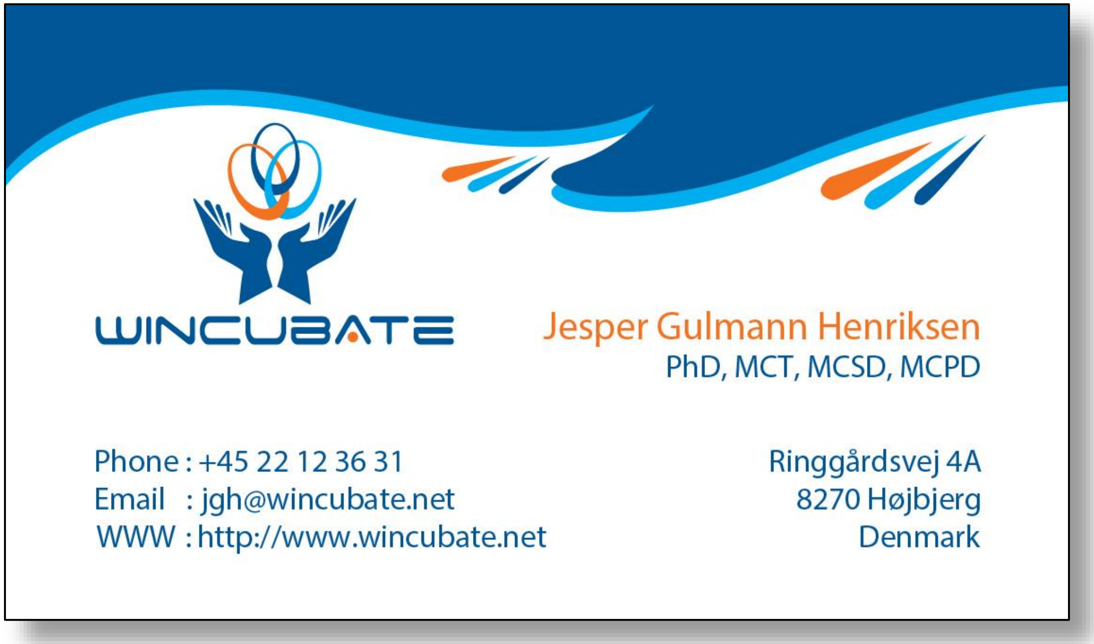
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