

# Module 6

## "Threads and Asynchrony in WPF"



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# Agenda

- ▶ **Dispatcher**
- ▶ Data Binding
- ▶ Tasks, Async, and Await



# WPF Class Hierarchy

## ▶ object

- **DispatcherObject**

Access only on creating thread

- DependencyObject

- Freezable

- Visual

- UIElement

- FrameworkElement

- Control

Routed events, layout, focus, ...

Styling, data binding, ...

Foreground, Background, ...

- Visual3D

- UIElement3D

- ContentElement

- FrameworkContentElement



# The Dispatcher

- ▶ Any operation on **DispatcherObject** must happen on the UI thread
  - **InvalidOperationException**
- ▶ Use **DispatcherObject.Dispatcher** property
  - **Invoke()** – Synchronous
  - **BeginInvoke()** – Asynchronous
- ▶ WPF has two built-in “main threads”
  - Main thread
  - Render thread



# DispatcherPriority

- ▶ Priority is captured by **DispatcherPriority** enumeration
  - <http://msdn.microsoft.com/en-us/library/system.windows.threading.dispatcherpriority.aspx>
  - **Send** Highest (= immediately)
  - **Normal**
  - **DataBind**
  - **Render**
  - ...
  - **Background**
  - ...
  - **ApplicationIdle**
  - **SystemIdle** Lowest



# DispatcherTimer

- ▶ Many different timers
  - ~~System.Timers.Timer~~
  - ~~System.Threading.Timer~~
  - System.Windows.Threading.DispatcherTimer
    - Tick event
    - Interval
    - Start()
    - Stop()



# Multiple UI Threads

- ▶ More dispatcher threads can be created
- ▶ Multiple UI threads can be created
  - **Dispatcher.Run()** on separate thread
- ▶ Be careful!
  - **Application.\*** is now misleading and dangerous!
  - Application.Windows
  - Application.Dispatcher



# Agenda

- ▶ Dispatcher
- ▶ **Data Binding**
- ▶ Tasks, Async, and Await





# Notifications and Threads

- ▶ Adding elements to **ObservableCollection** by other threads
  - ▶ Not directly possible
  - ▶ Needed ugly dispatching!
- ▶ WPF 4.5 adds easy-to-use Collection Synchronization
  - ▶ Provide lock for the collection
  - ▶ Enable collection synchronization
  - ▶ Update **IEnumerable** from any thread

```
BindingOperations.EnableCollectionSynchronization(  
    _participants,    // collection  
    _syncObject       // lock object  
);
```



# Asynchronous Data Binding

- ▶ Data binding can be evaluated asynchronously
  - `Binding.IsAsync`
- ▶ Is often combined with `PriorityBinding`

```
<PriorityBinding FallbackValue="N/A">  
    <Binding Path="Slowest" IsAsync="True"/>  
    <Binding Path="Slow" IsAsync="True"/>  
    <Binding Path="Normal" IsAsync="True"/>  
    <Binding Path="Fast" IsAsync="True"/>  
    <Binding Path="Fastest" />  
</PriorityBinding>
```

- ▶ Beware: Asynchronous bindings can be a sign of poor design



# Agenda

- ▶ Dispatcher
- ▶ Data Binding
- ▶ **Tasks, Async, and Await**



# Task Parallel Library

- ▶ Task Parallel Library (TPL)
  - Was introduced in .NET 4.0
  - Enhanced in .NET 4.5
    - Special keywords are included in C# 5.0
  
- ▶ Features
  - **Task Parallelism**
  - Data Parallelism
  - Parallel LINQ
  - Thread-safe collections
  
- ▶ Emerging trends leverage parallelism! Also .NET!



# Creating Tasks

- ▶ The **Task** class captures a unit of asynchronous operation
- ▶ Initialized from constructor using a computation described by
  - Action delegate
  - Anonymous method
  - Lambda expression (usually preferred)

```
Task task = new Task( () =>  
    Console.WriteLine( "Hello World from Task Parallel Library" )  
);
```

- ▶ Note: Does not run automatically when created!



# Task Execution

- ▶ Three approaches to starting tasks
  - Create **Task** object and invoke **Task.Start()**
  - Use **Task.Factory.StartNew()** static
  - Use **Task.Run()** static

```
Task task = Task.Factory.StartNew( () =>
{
    for ( int i = 1 ; i < 100 ; i += 2 )
    {
        Console.WriteLine( "\t" + i );
    }
});
```

- ▶ Usually one of the last two options is employed



# Waiting for Task Completion

► Tasks can be awaited

- `Task.Wait()`
- `Task.WaitAny()` static
- `Task.WaitAll()` static

```
Task task1 = ...;  
Task task2 = ...;  
Task task3 = ...;  
  
task1.Wait();  
  
Task.WaitAny( task1, task2, task3 );  
  
Task.WaitAll( task1, task2, task3 );
```



# Tasks with Results

- ▶ **Task<T>**
  - captures a task returning a result of type T
- ▶ **Task.Run<T>()** and **Task.StartNew<T>()** also exist

```
Task<DateTime> t = Task.Run<DateTime>( () => DateTime.Now );  
Console.WriteLine( t.Result );
```

- ▶ Result can be explicitly retrieved via **Task.Result**
  - Note: This property blocks when task is not yet completed!





# Cancelling Tasks

- ▶ Running tasks can be requested cancelled
  - Signal token created by **CancellationTokenSource** class
  - Other code signal token supplied to task
- ▶ Task method then
  - Checks if cancellation is requested
  - Throws **OperationCanceledException** to accept cancellation

```
task = Task.Factory.StartNew( () =>
{
    ...
    if( token.IsCancellationRequested )
    {
        throw new OperationCanceledException( token );
    }
}
```

▶ Check task running status via **Task.Status**



# Combining Tasks

- ▶ Tasks can be combined using **Task.ContinueWith()**

```
Task<DateTime> t1 = new Task<DateTime>( () =>
    DateTime.Now );
Task<string> t2 = t1.ContinueWith( previous =>
    string.Format("The time is {0}!", previous.Result ) );

t1.Start();
Console.WriteLine( t2.Result );
```

- ▶ Combinators 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
- ▶ **TaskCreationOptions** allows the creation of child tasks



# TaskContinuationOptions

- ▶ The behavior of `Task.ContinueWith()` and `Task<T>.ContinueWith()` can be refined
- ▶ `TaskContinuationOptions` enumeration supplied in overloads
  - `None`
  - `OnlyOnCanceled`
  - `OnlyOnFaulted`
  - `OnlyOnRanToCompletion`
  - `NotOnCanceled`
  - `NotOnFaulted`
  - `NotOnRanToCompletion`
  - ...



# Task Exceptions

- ▶ Task exceptions are thrown when
  - Waiting for task
  - Getting result for task
- ▶ **AggregateException** instances are thrown
  - Consists of a number of inner exceptions
  - **Flatten()**

```
try
{
    t.Wait();
}
catch ( AggregateException ae )
{
    foreach( Exception e in ae.Flatten().InnerExceptions )
    {
        Console.WriteLine( e.Message );
    }
}
```



# 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>**



# 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 ) { ... }
```

- ▶ Subscribe to unobserved exceptions through the `TaskScheduler.UnobservedTaskException` event

```
TaskScheduler.UnobservedTaskException +=
( object s, UnobservedTaskExceptionEventArgs ute ) => {
    foreach( Exception e in ute.Exception.InnerExceptions )
    {
        ...
    };
};
```



# Dispatcher vs. Task

- ▶ The **async** and **await** keywords in C# mix perfectly with WPF
- ▶ WPF 4.5 also adds many new **Dispatcher** methods
  - `Dispatcher.Invoke<T>()`
  - `Dispatcher.InvokeAsync()`
  - `Dispatcher.InvokeAsync<T>()`
- ▶ These are basically just rehashings of `Dispatcher.BeginInvoke()`
  - Can return values as well

```
await Dispatcher.InvokeAsync(  
    () => txtResult.Text = DateTime.Now.ToString()  
);  
...  
string old = await Dispatcher.InvokeAsync<string>(   
    () => txtResult.Text  
);
```





# Summary

- ▶ Dispatcher
- ▶ Data Binding
- ▶ Tasks, Async, and Await





WINCUBATE

***Jesper Gulmann Henriksen***

PhD, MCT, MCSD, MCPD

Phone : +45 22 12 36 31

Email : [jgh@wincubate.net](mailto:jgh@wincubate.net)

WWW : <http://www.wincubate.net>

Hasselvangel 243

8355 Solbjerg

Denmark