

Module 6

"Threads and Asynchrony in WPF"



TEKNOLOGISK
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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



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