Concurrent Programming in .NET

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Jason Bell


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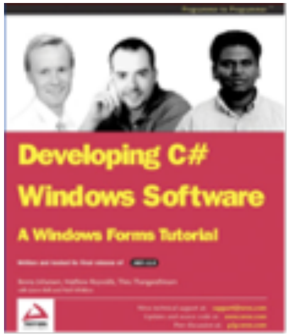
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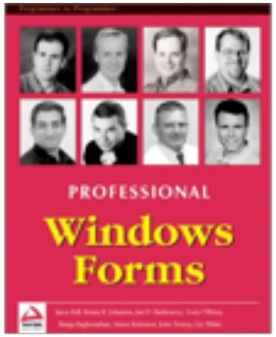
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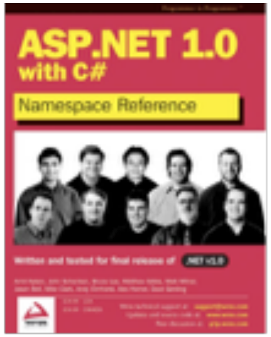
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Namespace Reference


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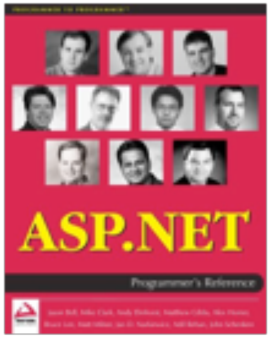
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Agenda

- Concurrency vs. Parallelism
- Threads
- CPU-Bound vs I/O-Bound
- Tasks in .NET
- Async/Await
- Q & A

Concurrency vs. Parallelism

- Operations that are being executed concurrently are **in-progress** at the same time
- Operations that are being executed in parallel are actually **executing** at the same time

Concurrency vs. Parallelism

- Concurrency can keep a GUI application **responsive**
  - GUI thread can still respond to events while other work is performed
- Concurrency is used in Web applications for **scalability**
  - One process per application, one thread per request
- Parallelism can by used to perform a task in less time
  - "Divide and conquer"

Threads

- A **thread** is an operating system construct used to encapsulate a unit of executable work
- Threads are **pre-emptively scheduled** for execution on the available processors
  - Scheduler uses a **priority**-based system to determine how threads are scheduled

Threads

- Threads are **expensive** to create and consume memory
- Too many threads leads to excessive **context switching** and hurts performance
- The **.NET Thread Pool** is a collection of threads that are available to be used in your application
  - Using a thread pool thread avoids the overhead associated with creating a dedicated thread

CPU-Bound vs I/O-Bound

- **CPU-bound** tasks can be completed in less time if more CPU resources are used
  - Complex calculations or in-memory processing
  - Potentially a good candidate for **parallelism** (do the work more efficiently)

CPU-Bound vs I/O-Bound

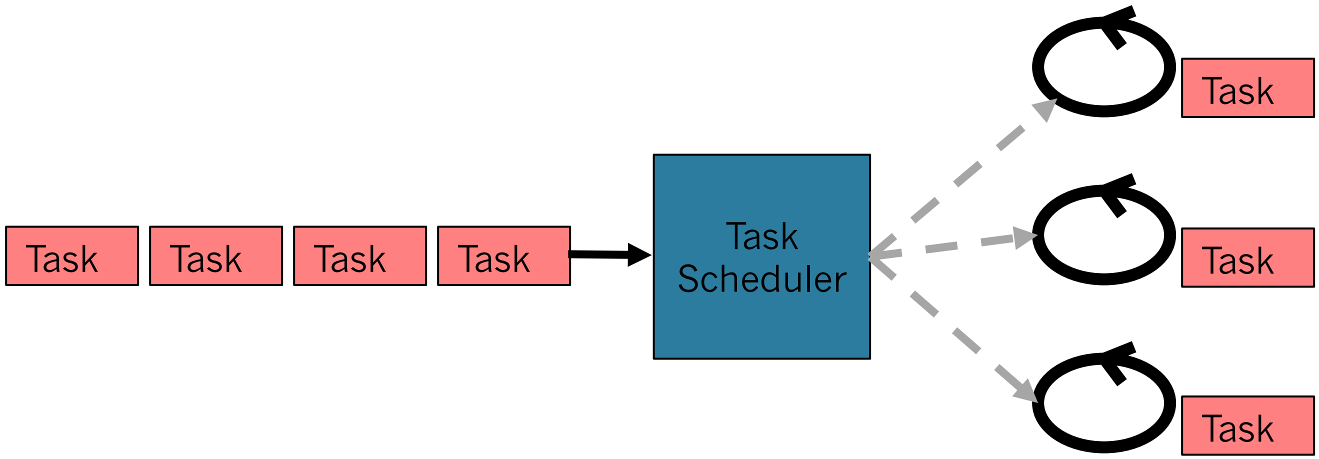
- **I/O-bound** tasks depend on an external resource that involves some latency
  - Disk and network operations
  - A good candidate for concurrency (wait more efficiently)

CPU-Bound vs I/O-Bound

- The operating system provides mechanisms that can be used to efficiently wait for an I/O-bound operation to complete
  - Signals, I/O completion ports, Kqueue
- Goal is to avoid monopolizing a thread simply to wait for an I/O-bound operation to finish (spinning)

Tasks in .NET

- A Task is a schedulable unit of work
  - Wraps a delegate that is the actual work
- Task in queued for execution by a TaskScheduler



Tasks in .NET

- Tasks are created by passing a **delegate** to the constructor
  - Call **Start** to queue the task to the scheduler
  - Can also use **Factory** property

```
Action a = delegate
{
  Console.WriteLine("Hello from task");
};
Task tsk = new Task(a);
tsk.Start();
```

```
Action a = delegate
{
  Console.WriteLine("Hello from task");
};
Task tsk = Task.Factory.StartNew(a);
```

Tasks in .NET

- **Scheduler** maps work on to threads
- Multiple scheduler implementations
- Can control the scheduler to use when starting a task
  - Use **thread pool** threads or **dedicated** threads
  - Use the GUI thread for updating the UI

Tasks in .NET

- Data can be passed to a task using **Action<object>**
- Data can also be passed **implicitly** using anonymous delegate rules

```
Guid jobId = Guid.NewGuid();

Action<object> a = delegate(object state)
{
  Console.WriteLine("{0}: Hello {1}", jobId, state);
};

Task tsk = new Task(a, "World");
tsk.Start();
```

Tasks in .NET

- Generic version of Task available
  - **T** is return type
  - Accessed from the task **Result**

```
Func<object, int> f = delegate(object state)
{
  Console.WriteLine("Hello {0}", state);
  return 42;
};
Task<int> tsk = new Task<int>(f, "World");
tsk.Start();
//...
Console.WriteLine("Task return is: {0}", tsk.Result);
```

Tasks in .NET

- Can wait for one or more tasks to end using **Wait**, **WaitAll** or **WaitAny**
- Can pass **timeout** for wait

```
Task t = new Task( DoWork );
t.Start();
t.Wait();
```

```
Task t1 = new Task( DoWork );
t1.Start();
Task t2 = new Task( DoOtherWork );
t2.Start();

if (!Task.WaitAll(new Task[]{t1, t2}, 2000))
{
  Console.WriteLine( "wait timed out" );
}
```

Tasks in .NET

- Tasks can end in one of three states
  - RanToCompletion: everything completed normally
  - Canceled: task was cancelled
  - Faulted: an unhandled exception occurred on the task
- Unhandled Exceptions get thrown when waiting on a task

```
Task t = new
Task(DoWork);
t.Start();

if (!t.Wait(1000))
{
}
```

```
private static void DoWork()
{
  throw new Exception();
}
```

Tasks in .NET

- Tasks support cancellation
  - Modelled by **CancellationToken**
- Token can be passed into many APIs

```
CancellationTokenSource source = new CancellationTokenSource();

Task t1 = new Task( DoWork, source.Token );
t1.Start();

t1.Wait(source.Token);
```

Tasks in .NET

- CancellationTokenSource has **Cancel** method to trigger the cancellation of tasks and blocking APIs

```
CancellationTokenSource source = new CancellationTokenSource();

Task t1 = new Task( DoWork, source.Token );
t1.Start();

source.Cancel();
```

Tasks in .NET

- Cancellation has different effects depending on state of task
  - Unscheduled tasks are never run
  - Scheduled tasks must **cooperate** to end

```
private static void DoWork(object o)
{
  CancellationToken tok = (CancellationToken)o;

  while (true)
  {
    Console.WriteLine("Working ...");
    Thread.Sleep(1000);
    tok.ThrowIfCancellationRequested();
  }
}
```

Tasks in .NET

- Tasks can be chained together by using **ContinueWith**
- New task will be scheduled when previous one finishes

```
Task t = new Task(DoWork);

t.ContinueWith(tPrev => Console.WriteLine(tPrev.Status));
t.Start();
```

Tasks in .NET

- Tasks can be chained depending on the outcome of the previous task
  - RunToCompletion, Canceled, Faulted
- **TaskContinuationOptions** flag passed to ContinueWith

```
Task<int> t = new Task<int>(GetData);

t.ContinueWith(ProcessData,
                   TaskContinuationOptions.OnlyOnRanToCompletion);

t.Start();
```

Async I/O

- Some .NET APIs model async I/O
  - No thread is consumed while I/O-bound operation takes place
  - Uses IO Completion ports
- APIs that end with "Async" return a Task

Async/Await

- C# now has the **async** and **await** keywords
- Enables continuations whilst maintaining the readability of sequential code
- Built around Task and Task<T>

```
private async void Button_Click(object sender, RoutedEventArgs e) {
   calcButton.IsEnabled = false;
   Task<double> piResult = CalcPiAsync(1000000000);

    // If piResult not ready , return from method, allowing UI to continue
    double pi = await piResult;
   // piResult now available continues to run on UI thread

    calcButton.IsEnabled = true;
    this.pi.Text = pi.ToString();
 }
```

Conclusion

- Evaluation
- Recording of this webinar

Q & A