Module 07:
"Tasks in TPL"

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Agenda

- **Task Parallelism in TPL**
- Introducing Tasks
- Cancelling Tasks and Parallel Operations
- Composing Tasks
- Tasks and Exceptions

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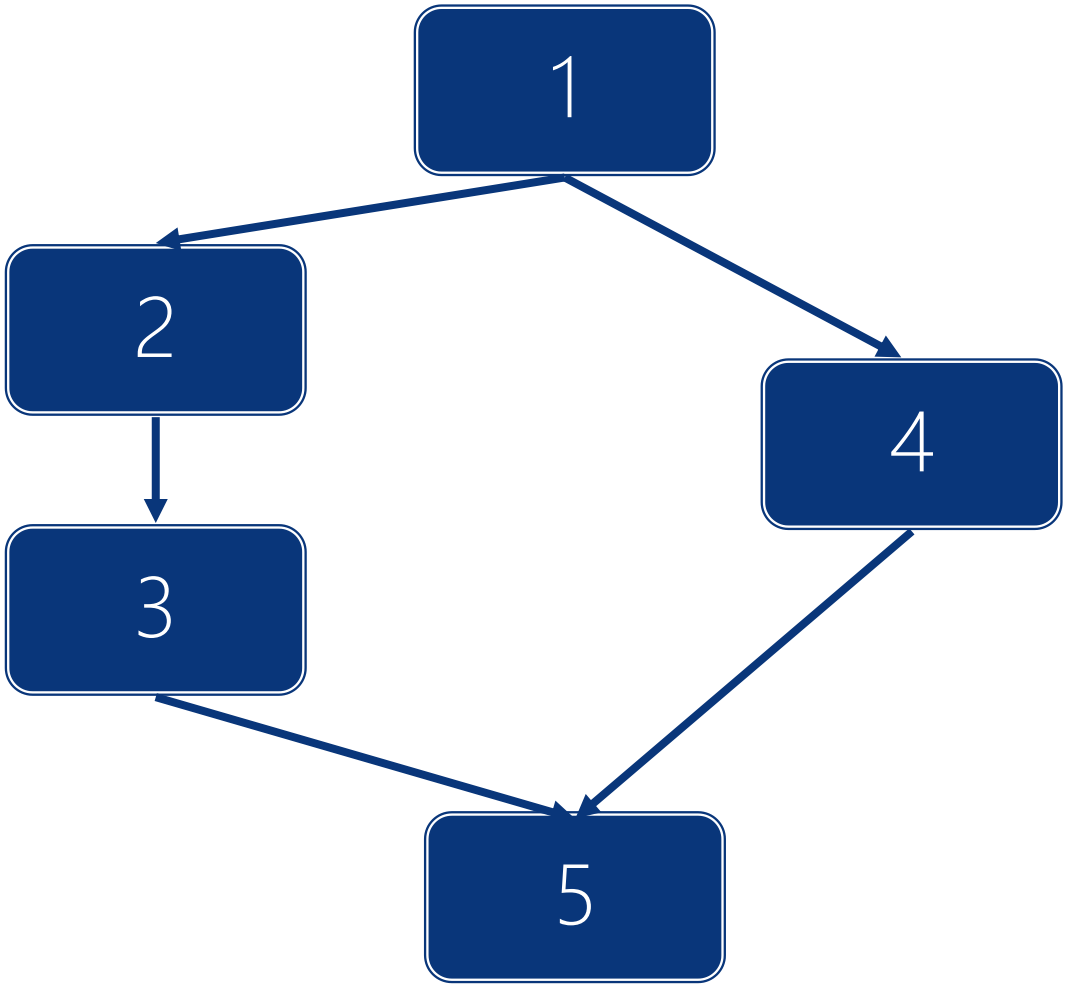
What is Task Parallelism?

Absence of Task Parallelism

Task Parallelism



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Creating Tasks

- The Task class captures a unit of computation
- 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 is blocks when task is not yet completed!

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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`**

Cancelling Parallel Operations

- All operations in TPL are cancelled the same way
  - Task
  - The Parallel Class
  - Parallel LINQ

```
CancellationTokenSource cts = new CancellationTokenSource();
...
var even = numbers
   .AsParallel()
   .WithCancellation( cts.Token )
   .Where(Filter)
   ;
```

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Continuation Tasks

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

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

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

- When t1 completes, the *continutation task* executes

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`
  - …

TaskCreationOptions

- `TaskCreationOptions` allows the creation of child tasks
  - Allows distinguishing between nested and child tasks

- `TaskCreationOptions` enumeration supplied in overloads
  - `None`
  - `PreferFairness`
  - `LongRunning`
  - **`AttachedToParent`**
  - `DenyChildAttach`
  - `HideScheduler`
  - `RunContinuationsAsynchronously`

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Task Exceptions

- Task exceptions are thrown when
  - Waiting for task
  - Getting result for task
- **`AggregateException`** instances are thrown everywhere in TPL
  - Consists of a number of inner exceptions
  - **`Flatten()`** is important!

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

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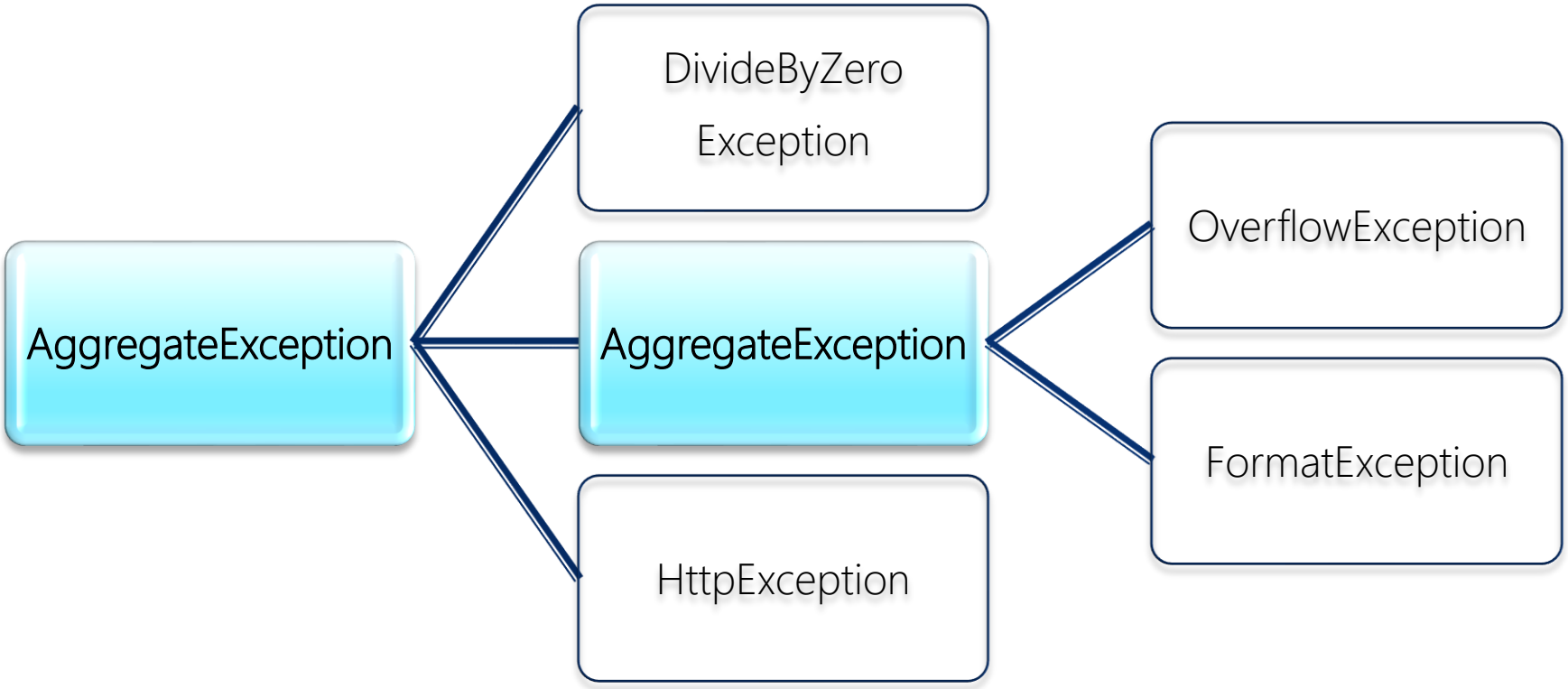
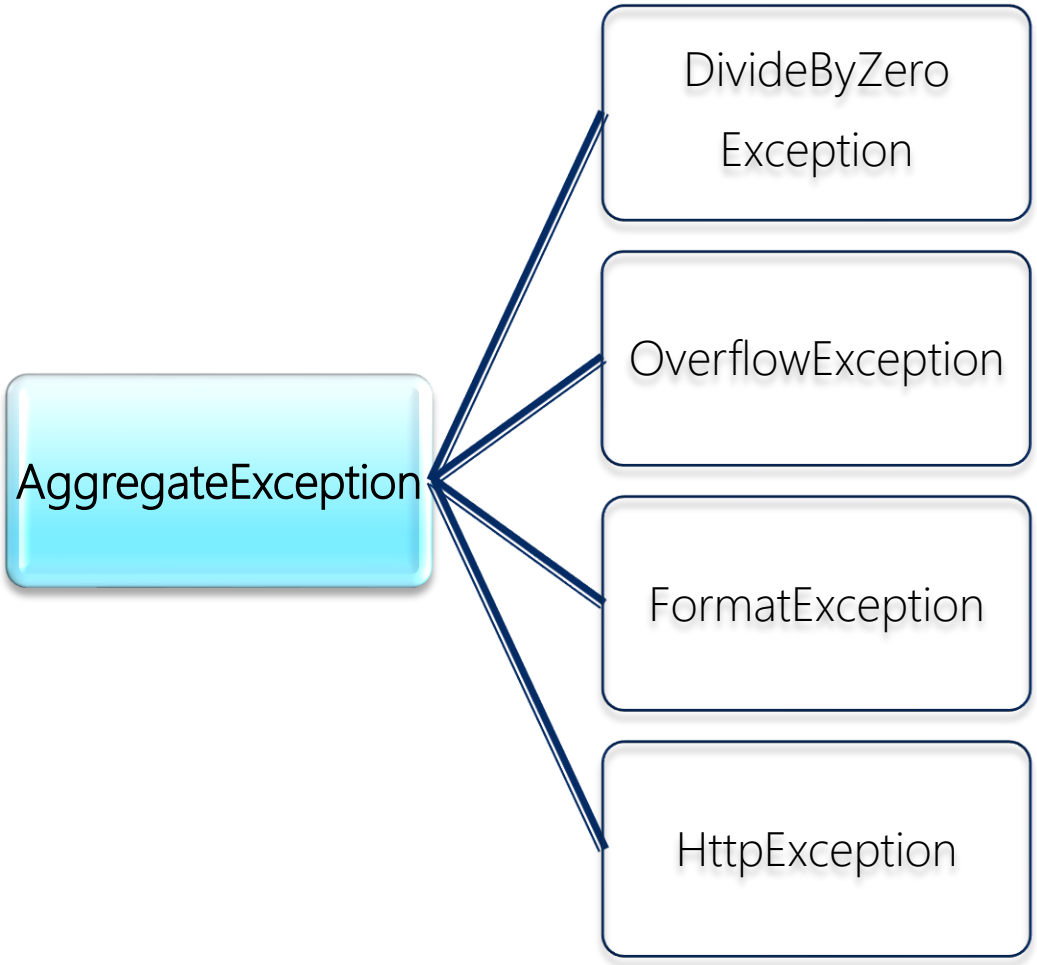
Before Flattening



After Flattening



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