Task Parallel Library: 1 of n

By Sacha Barber, 17 May 2011

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- Download demo source code - 182 KB
- Download demo code (LINQPad scripts, thanks to reader Rainer Schuster) - 9.06 KB

Introduction

I recall the first time I created a UI in .NET that had to go and get some data from a database, and the amount of data that I fetched was way larger in production that my code assumed it would be in my dumbed down test setup. Guess what happened... my UI froze as soon as it used real data. The reason for this is that the UI thread (i.e., the only thread in my naive UI) was being used to carry out this fetching of data from the backend database. Yikes! Surely there is a better way.

As it turned out, there was. .NET offered (and still does) a wide variety of Threading classes to help with just this sort of situation, such as `Thread`, `BackgroundWorker`, `ThreadPool` etc.

So I got to know and love some of these classes in the `System.Threading` namespace, and they did make a massive difference to the responsiveness of my application, all cool.

Thing is, some of the code one has to write when doing some of this threading stuff using the `System.Threading` namespace (from here on in "classic threading") took a lot of work in some cases, and just was not that intuitive at times. Classic threading is well known as the domain of experts; after messing with its quirks for long enough, one can begin to see why... You are like frack, where did that Exception come from, ahhhh I am using a shared data object with multiple threads, aha! This has by the main stay been a mixture of intuition/luck/skill... and not necessarily in equal parts.

Luckily, help is at hand. With .NET 4.0, there is a new kid in town. It is called a `Task`, which some of you may know is part of the Task Parallel Library (TPL), which is a new collection of very, very useful (and I feel highly intuitive) classes aimed at not only making your parallel programming easier to read, but also offers lighter weight objects when compared to the classic threading alternatives. For example, when a new `Thread` is started in .NET, there is a whole process that goes with that, such as creating queues, thread local storage, managing the `Thread`'s lifecycle etc. This takes time. OK, so you could use the classic threading `ThreadPool`, which does allow you to queue up work item delegates directly to the `ThreadPool`, which means you are not impacted by the overhead of creating a new `Thread` yourself, as the `ThreadPool` will manage all new `Thread` creation etc.

However, even using the classic threading `ThreadPool`, there were problems in that you could not cancel a work item once it has been queued with the `ThreadPool`, or get a return result that easily. It just doesn't read that well either. There is an excellent article here on CodeProject that tackles some of these issues: Smart ThreadPool, which is pretty excellent actually. However, the new TPL infrastructure has got all these problems covered, and many many more useful features in my opinion.

A TPL `Task` actually uses the `ThreadPool` internally, if you use the default scheduler, which you more than likely will most of the time. The scheduler can be swapped out, and that is something I will be showing in a subsequent article. For the time being, if we assume we are using the default scheduler, `Task`s will be allocated threads by the the use of a `ThreadPool`, which handles the creation of `Thread`s to carry out `Task`s, so a lot of the heavy lifting (so to speak) is done behind the scenes for us by TPL.

It is worth mentioning that `Task`s are merely wrappers for passing a delegate of work to be done, also storing state, exceptions, and continuations amongst others. That work may or may not be done by the threadpool, and as already stated, that will depend upon the scheduler used.

Steve Soloman, one of the readers of this article, stated this in the forum, and I could not have said it any better, so included it in this article. Thanks Steve, good bit of extra information there.

The other great thing about TPL is that it is aimed at using each core of your CPU, which may have been otherwise idle. It obviously does this using `Thread`(s) behind the scenes, but you really do not have to get involved with spinning up new `Thread`s at all (OK, in advanced scenarios such as custom Schedulers, maybe, but hey, more on that later; day to day, you really don't have to care about it).

`Task`s also seem to be more inline with how people think about things. For instance, imagine this scenario: "I want to call a Web Service and have it return a `List<int>`". Using a TPL `Task`, I would create a `Task<List<int>>` and get it to call some service in its payload delegate (which will use the `ThreadPool`) that returned me a `List<int>`.

Using classic threading, my code certainly would not be such a simple story. Sure you could do the same thing, but honestly, the sheer readability that TPL brings to the table simply can not be ignored. Add to that the fact that it actually uses the `ThreadPool` and handles `Thread` creation for you. Add to that the fact that Microsoft is investing considerable time in it for C# 5. And I think you will agree that getting to know TPL is a must have skill for most .NET programmers.

In this article (and the subsequent ones), I hope to show you just how easy TPL is to use.

Article Series Roadmap

This is article 1 of a possible 6, which I hope people will like. Shown below is the rough outline of what I would like to cover:

1. Starting Tasks / Trigger Operations / Exception Handling / Cancelling / UI Synchronization (this article)
2. Continuations / Cancelling Chained Tasks
3. Parallel For / Custom Partioner / Aggregate Operations
4. Parallel LINQ
5. Pipelines
6. Advanced Scenarios / v.Next for Tasks

Now I am aware that some folk will simply read this article and state that it is similar to what is currently available on MSDN, and I in part agree with that. However, there are several reasons I have chosen to still take on the task of writing up these articles, which are as follows:

- It will only really be the first couple of articles which show similar ideas to MSDN. After that, I feel the material I will get into will not be on MSDN, and will be the result of some TPL research on my behalf, which I will be outlining in the article(s), so you will benefit from my research which you can just read. Aye, nice.
- There will be screenshots of live output here which is something MSDN does not have that much, which may help some readers to reinforce the article(s) text.
- There may be some readers out here that have never even heard of Task Parallel Library so would not come across it in MSDN. You know the old story, you have to know what you are looking for in the first place.
- I enjoy threading articles, so like doing them, so I did them, will do them, have done them, and continue to do them.

All that said, if people, having read this article, truly think this is too similar to MSDN (which I still hope it won't be), let me know that as well, and I will try and adjust the upcoming articles to make amends.

Table of Contents

What I am going to cover in this article is as follows:

Threads Versus Tasks

Demo code project: ThreadsVersusTasks.

In the introduction, I talked briefly about the differences between `Thread`s and `Task`s, where spinning up a `Thread` compared to spinning up a `Task` should be more costly. To illustrate that, let's consider the following small example, which simply creates 64 `Thread`s and waits (via one of the class threading synchronization primitives: `ManualResetEventSlim`) for these 64 `Thread`s to complete, and then creates and starts 64 `Task`s. Each `Thread`/`Task` will simply write 10 lines to the Console.

The full code is as follows. Don't worry, we will get into all the nitty gritty later. For now, I just want to show you a screenshot of the results of running this code:

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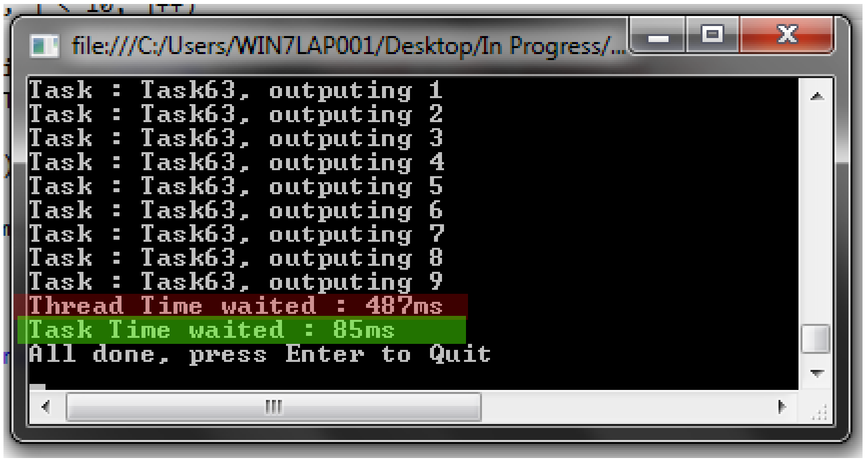
```
static void Main(string[] args)
{
    Stopwatch watch = new Stopwatch();
    //64 is upper limit for WaitHandle.WaitAll() method
    int maxWaitHandleWaitAllAllowed = 64;
    ManualResetEventSlim[] mres =
      new ManualResetEventSlim[maxWaitHandleWaitAllAllowed];

    for (int i = 0; i < mres.Length; i++)
    {
        mres[i] = new ManualResetEventSlim(false);
    }


    long threadTime = 0;
    long taskTime = 0;
    watch.Start();

    //start a new classic Thread and signal the ManualResetEvent when its 
done
    //so that we can snapshot time taken, and

    for (int i = 0; i < mres.Length; i++)
    {
        int idx = i;
        Thread t = new Thread((state) =>
        {
            for (int j = 0; j < 10; j++)
            {
```

```
                Console.WriteLine(string.Format("Thread : {0}, outputing
{1}",
                    state.ToString(), j.ToString()));
            }
            mres[idx].Set();
        });
        t.Start(string.Format("Thread{0}", i.ToString()));
    }

    WaitHandle.WaitAll( (from x in mres select x.WaitHandle).ToArray());

    threadTime = watch.ElapsedMilliseconds;
    watch.Reset();

    for (int i = 0; i < mres.Length; i++)
    {
        mres[i].Reset();
    }

    watch.Start();

    for (int i = 0; i < mres.Length; i++)
    {
        int idx = i;
        Task task = Task.Factory.StartNew((state) =>
            {
                for (int j = 0; j < 10; j++)
                {
                    Console.WriteLine(string.Format("Task : {0}, outputing
{1}",
                        state.ToString(), j.ToString()));
                }
                mres[idx].Set();
            }, string.Format("Task{0}", i.ToString()));
    }

    WaitHandle.WaitAll((from x in mres select x.WaitHandle).ToArray());
    taskTime = watch.ElapsedMilliseconds;
    Console.WriteLine("Thread Time waited : {0}ms", threadTime);
    Console.WriteLine("Task Time waited : {0}ms", taskTime);

    for (int i = 0; i < mres.Length; i++)
    {
        mres[i].Reset();
    }
    Console.WriteLine("All done, press Enter to Quit");

    Console.ReadLine();
}
```

If we observe what the output of this code looks like:



It can be seen that even in this little experiment, the creation time of `Thread`s to do the same job as the `Task`s is far greater. This is undoubtedly down to the work that has to be done to create and manage a classic `Thread`. Like I say, most classic threading developers would use the `ThreadPool` which would give better results, but like I also said in the introduction, the classic `ThreadPool` has its limitations, these limitations are all taken care of with TPL.

The rest of this article will concentrate on how you can create/cancel `Task`s and handle `Exception`s for them.

Creating Tasks

Demo code project: CreatingTasks.

TPL exposes many different ways for a developer to create `Task`s, from new-ing up a new `Task`, to using one of the many overloads of the static `Task.Factory.StartNew()` methods. Shown below are a couple of examples of various `Task`s being created in a variety of methods:

1. Create a `Task` using in-line `Action`
2. Create a `Task` that calls an actual method that returns a string
3. Create and start a `Task` that returns `List<int>` using `Task.Factory`

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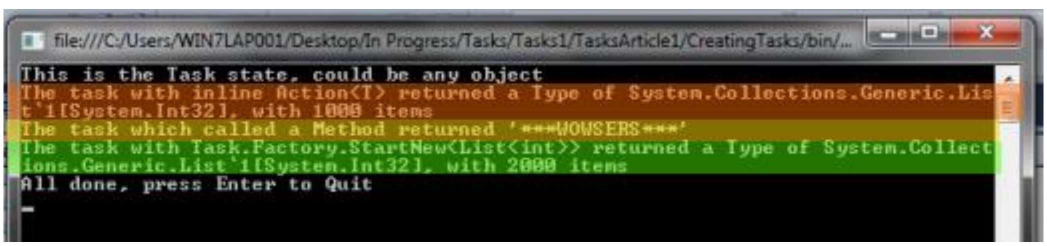
```
class Program
{
    static void Main(string[] args)
    {
        // ****************************************************************
        // OPTION 1 : Create a Task using an inline action
        // ****************************************************************
        Task<List<int>> taskWithInLineAction =
        new Task<List<int>>(() =>
            {
                List<int> ints = new List<int>();
                for (int i = 0; i < 1000; i++)
```

```
        {
            ints.Add(i);
        }
        return ints;

    });


// ***********************************************
// OPTION 2 : Create a Task that calls an actual
//            method that returns a string
// ***********************************************
Task<string> taskWithInActualMethodAndState =
    new Task<string>(new Func<object,
    string>(PrintTaskObjectState),
    "This is the Task state, could be any object");

// ***********************************************
// OPTION 3 : Create and start a Task that returns
//            List<int> using Task.Factory
// ***********************************************
Task<List<int>> taskWithFactoryAndState =
     Task.Factory.StartNew<List<int>>((stateObj) =>
{
    List<int> ints = new List<int>();
    for (int i = 0; i < (int)stateObj; i++)
    {
        ints.Add(i);
    }
    return ints;
}, 2000);



taskWithInLineAction.Start();
taskWithInActualMethodAndState.Start();



//wait for all Tasks to finish
Task.WaitAll(new Task[]
{
    taskWithInLineAction,
    taskWithInActualMethodAndState,
    taskWithFactoryAndState
});

//print results for taskWithInLineAction
var taskWithInLineActionResult = taskWithInLineAction.Result;
Console.WriteLine(string.Format(
    "The task with inline Action<T> " +
    "returned a Type of {0}, with {1} items",
    taskWithInLineActionResult.GetType(),
    taskWithInLineActionResult.Count));
taskWithInLineAction.Dispose();

//print results for taskWithInActualMethodAndState
```

```
        var taskWithInActualMethodResult =
taskWithInActualMethodAndState.Result;
        Console.WriteLine(string.Format(
            "The task which called a Method returned '{0}'",
        taskWithInActualMethodResult.ToString()));
        taskWithInActualMethodAndState.Dispose();

        //print results for taskWithFactoryAndState
        var taskWithFactoryAndStateResult = taskWithFactoryAndState.Result;
        Console.WriteLine(string.Format(
            "The task with Task.Factory.StartNew<List<int>> " +
            "returned a Type of {0}, with {1} items",
            taskWithFactoryAndStateResult.GetType(),
            taskWithFactoryAndStateResult.Count));
        taskWithFactoryAndState.Dispose();

        Console.WriteLine("All done, press Enter to Quit");

        Console.ReadLine();
    }

    private static string PrintTaskObjectState(object state)
    {
        Console.WriteLine(state.ToString());
        return "***WOWSERS***";
    }
}
```

And here is the result of running this demo



So which is the preferred method of starting `Task`s then? Well, generally, `Task.Factory.StartNew()` is the preferred method, but there are a few edge cases where it is better to new up a `Task` directly.

Stephen Toubs (Microsoft engineer, part of the TPL team) has a blog post which has an interesting discussion on this subject, which is where I took the following text from. Oh, one thing, Stephen's blog talked about continuations which is something we are going to get on to in the next article, so I hope this does not confuse you all too much.

With TPL, there are several ways to create and start a new task. One way is to use the constructor for the task followed by a call to the `Start` method, e.g.:

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```
new Task(...).Start();
```

and the other is by using the `StartNew` method of `TaskFactory`, e.g.:

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```
Task.Factory.StartNew(...);
```

This begs the question... when and why would you use one approach versus the other? In general, I always recommend using `Task.Factory.StartNew` unless the particular situation provides a compelling reason to use the constructor followed by `Start`. There are a few reasons I recommend this. For one, it's generally more efficient. For example, we take a lot of care within TPL to make sure that when accessing tasks from multiple threads concurrently, the "right" thing happens. A task is only ever executed once, and that means we need to ensure that multiple calls to a task's `Start` method from multiple threads concurrently will only result in the task being scheduled once. This requires synchronization, and synchronization has a cost. If you construct a task using the task's constructor, you then pay this synchronization cost when calling the `Start` method, because we need to protect against the chance that another thread is concurrently calling `Start`. However, if you use `TaskFactory.StartNew`, we know that the task will have already been scheduled by the time we hand the task reference back to your code, which means it's no longer possible for threads to race to call `Start`, because every call to `Start` will fail. As such, for `StartNew`, we can avoid that additional synchronization cost and take a faster path for scheduling the task. There are, however, some cases where creating a new task and then starting it is beneficial or even required (if there weren't, we wouldn't have provided the `Start` method). One example is if you derive from `Task`. This is an advanced case and there's typically little need to derive from `Task`, but nevertheless, if you do derive from it, the only way to schedule your custom task is to call the `Start` method, since in .NET 4, `TaskFactory.StartNew` will always return the concrete `Task` or `Task<tresult>` types. Another even more advanced use case is in dealing with certain race conditions. Consider the need for a task's body to have access to its own reference, such as if the task wanted to schedule a continuation off of itself. You might try to accomplish that with code like:

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```
Task t = null;
t = Task.Factory.StartNew(() =>
{
        ...
        t.ContinueWith(...);
});
```

This code, however, is buggy. There is a chance that the `ThreadPool` will pick up the scheduled task and execute it before the `Task` reference returned from `StartNew` is stored into `t`. If that happens, the body of the task will see `Task t` as being `null`. One way to fix this is to separate the creation and scheduling of the task, e.g.:

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```
Task t = null;
t = new Task(() =>
{
        ...
        t.ContinueWith(...);
```

```
});
t.Start();
```

Now, we know that `t` will in fact be properly initialized by the time the task body runs, because we're not scheduling it until after it's been set appropriately. In short, there are certainly cases where taking the "`new Task(...).Start()`" approach is warranted. But unless you find yourself in one of those cases, prefer `TaskFactory.StartNew`.

--http://blogs.msdn.com/b/pfxteam/archive/2010/06/13/10024153.aspx Stephen Toubs (Microsoft TPL team) blog, up on date 31/01/11.

Trigger Methods/Properties

So you have now created some `Task`s and got them to do stuff, but will things always go right? Heck yeah. Er.. no, they won't, quite frankly they seldom do.

So guess what... yes that's right, we have to learn how to handle problems (a.k.a. `Exception`s) that can occur within our TPL `Task`s. I will be showing you various ways in which to handle `Exception`s in your own `Task`s in just a minute, but before I get into that, I just wanted to talk about one thing that may or may not be obvious to you when reading the `System.Threading.Tasks` documentation; me personally, I do not think it is that obvious.

So here goes, there are various points at which things can go wrong within `Task`s, ranging from a normal `Exception` occurring within the `Task` body, to a `CancellationTokenSource.Cancel()` request (more on this later) causing a `OperationCancelledException` to occur, which will be grouped together into a new type of `Exception` that is specific to TPL. This new `Exception` is known as an `AggregateException`, where all the individual `Exception`s are bundled up within the `AggregateException.InnerExceptions` property. The `AggegrateExeption` also offers a way to handle `Exception`s from `Task`s, but I will get into that in just a minute.

For the time being, just know that any `Exception` thrown inside of `Task`s are bundled up into a `AggegrateExeption`, and it **is** your job to handle this. TPL also has a concept of an `AggegrateExeption` being observed, that is to say, that if you have a `AggegrateExeption` raised by something in your `Task`, it will only really be handled (by using one of the techniques I show in a minute) if it is currently being observed.

If you do not get this, please re-read that paragraph, it is a very important point.

The `Task` class itself has several methods/properties that cause a `AggegrateExeption` to be observed; some of these are as follows:

- `Wait()`
- `Result`

When your code makes use of these, you are effectively saying, yes I am interested in observing any `AggregateException` that occurs. Throughout the rest of this article, I will refer to these special methods/properties as trigger methods.

One important thing to note is that if you do not use one of the trigger methods such as `Wait()/Result` etc., TPL will not escalate any `AggegateException` as there is deemed to be nothing observing the `AggregateException`, so an unhandled `Exception` will occur.

This is one small gotcha when working with TPL, but it is a vitally important one.

Anyway, now that we know that, let's have a look at different ways in which to handle `Exception`s.

Handling Exceptions

In this section, I will show you various techniques for handling `Task Exception`s.

Uncaught Exception Demo

Demo code project: UncaughtExceptionInWinFormsDemoApp.

Before I show you how to handle `Task Exception`s, let's just see some code that does not handle an `Exception` and familiarise ourselves with what sort of error dialog we get.

Here is the some dodgy code:

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```
private void btnStartTask_Click(object sender, EventArgs e)
{
    // create the task
    Task<List<int>> taskWithFactoryAndState =
    Task.Factory.StartNew<List<int>>((stateObj) =>
    {
        List<int> ints = new List<int>();
        for (int i = 0; i < (int)stateObj; i++)
        {
            ints.Add(i);
            if (i > 100)
            {
                InvalidOperationException ex =
            new InvalidOperationException("oh no its > 100");
                ex.Source = "taskWithFactoryAndState";
                throw ex;
            }
        }
        return ints;
    }, 2000);

    //wait on the task, but do not use Wait() method
```

```
    //doing it this way will cause aany unhandled Exception to remain
unhandled
    while (!taskWithFactoryAndState.IsCompleted)
    {
        Thread.Sleep(500);
    }

    if (!taskWithFactoryAndState.IsFaulted)
    {
        lstResults.DataSource = taskWithFactoryAndState.Result;
    }
    else
    {
        StringBuilder sb = new StringBuilder();
        AggregateException taskEx = taskWithFactoryAndState.Exception;
        foreach (Exception ex in taskEx.InnerExceptions)
        {
            sb.AppendLine(string.Format("Caught exception '{0}'",
ex.Message));
        }
        MessageBox.Show(sb.ToString());
    }

    //All done with Task now so Dispose it
    taskWithFactoryAndState.Dispose();
}
```

See above how I am not using any of the trigger methods/properties? So any `AggregateException` remains unobserved, so when we run this code, we get an error dialog shown to us.

This is quite bad. Left unhandled, this sort of thing could cause enough of a problem to potentially bring down your process altogether.

So it is always a good idea to handle any `Exception` with your `Task`s, so make sure to use the trigger methods I talked about to ensure that all `Exception`s are observed.

Using Try Catch

Demo code project: HandlingExceptionsUsingTryCatch.

One of the simplest ways to handle an `AggregateException` is to use one of the trigger methods inside a `try/catch`. The following code shows an example of this. I think this code is pretty self-explanatory.

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```
// create the task
Task<List<int>> taskWithFactoryAndState =
    Task.Factory.StartNew<List<int>>((stateObj) =>
{
    List<int> ints = new List<int>();
    for (int i = 0; i < (int)stateObj; i++)
    {
        ints.Add(i);
        if (i > 100)
```

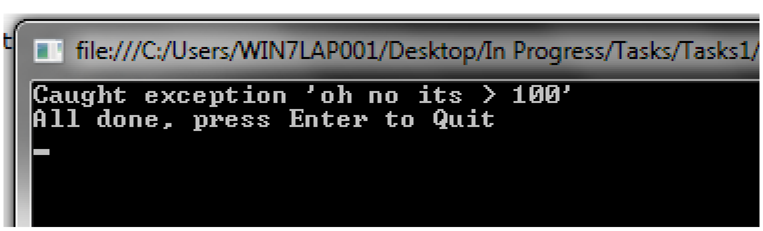
```
        {
            InvalidOperationException ex =
                new InvalidOperationException("oh no its > 100");
            ex.Source = "taskWithFactoryAndState";
            throw ex;
        }
    }
    return ints;
}, 2000);

try
{
    //use one of the trigger methods (ie Wait() to make sure
AggregateException
    //is observed)
    taskWithFactoryAndState.Wait();
    if (!taskWithFactoryAndState.IsFaulted)
    {
        Console.WriteLine(string.Format("managed to get {0} items",
            taskWithFactoryAndState.Result.Count));
    }

}
catch (AggregateException aggEx)
{
    foreach (Exception ex in aggEx.InnerExceptions)
    {
        Console.WriteLine(string.Format("Caught exception '{0}'",
            ex.Message));
    }
}
finally
{
    taskWithFactoryAndState.Dispose();
}

Console.WriteLine("All done, press Enter to Quit");
Console.ReadLine();
```

Here is what we get when we run this example code:



Using AggregateException.Handle()

Demo code project: HandleUsingExHandle.

Another method is to use the `AggregateException.Handle()`. As before, this relies on you using one of the trigger methods, which you **must** use to make sure any `Exception` is observed. The following code shows an example of this. Again, I hope the code is pretty self-explanatory.

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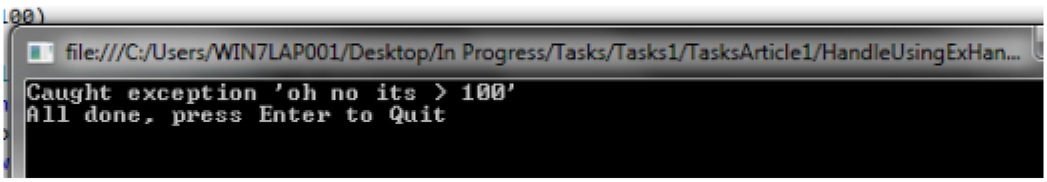
```
static void Main(string[] args)
{
    // create the task
    Task<List<int>> taskWithFactoryAndState =
    Task.Factory.StartNew<List<int>>((stateObj) =>
    {
        List<int> ints = new List<int>();
        for (int i = 0; i < (int)stateObj; i++)
        {
            ints.Add(i);
            if (i > 100)
            {
                InvalidOperationException ex =
                    new InvalidOperationException("oh no its > 100");
                ex.Source = "taskWithFactoryAndState";
                throw ex;
            }
        }
        return ints;
    }, 2000);

    try
    {
        taskWithFactoryAndState.Wait();
        if (!taskWithFactoryAndState.IsFaulted)
        {
            Console.WriteLine(string.Format("managed to get {0} items",
                taskWithFactoryAndState.Result.Count));
        }
    }
    catch (AggregateException aggEx)
    {
        aggEx.Handle(HandleException);
    }
    finally
    {
        taskWithFactoryAndState.Dispose();
    }

    Console.WriteLine("All done, press Enter to Quit");

    Console.ReadLine();
}

private static bool HandleException(Exception ex)
{
    if (ex is InvalidOperationException)
    {
        Console.WriteLine(string.Format("Caught exception '{0}'",
ex.Message));
        return true;
```

```
    }
    else
    {
        return false;
    }
}
```

Here is what we get when we run this example code:



Reading Task Values

Demo code project: HandlingExceptionsUsingTryCatch.

This is probably one of the simplest methods, but probably not that useful (just being honest, sorry) as it is a strange cross mixture of a `try/catch` but you ignore the catch and instead read the `Exception` property from the source `Task`. You **must** still use one of the trigger methods to ensure that the `AggregateException` is observed, and you must pretty much do the same amount of work as when you use the `try/catch` method. Anyway, I just don't see this approach as being that useful, I covered it for the sake of completeness.

Here is the demo code for this:

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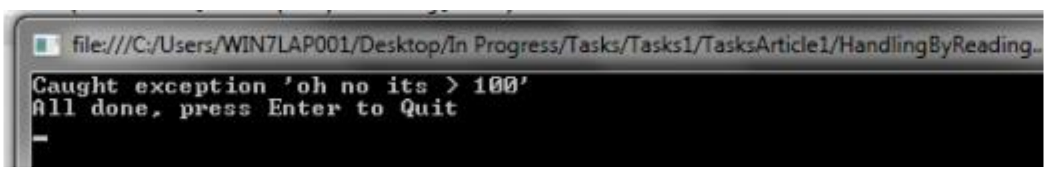
```
// create the task
Task<List<int>> taskWithFactoryAndState =
    Task.Factory.StartNew<List<int>>((stateObj) =>
{
    List<int> ints = new List<int>();
    for (int i = 0; i < (int)stateObj; i++)
    {
        ints.Add(i);
        if (i > 100)
        {
            InvalidOperationException ex =
                new InvalidOperationException("oh no its > 100");
            ex.Source = "taskWithFactoryAndState";
            throw ex;
        }
    }
    return ints;
}, 2000);

try
{
    taskWithFactoryAndState.Wait();
    if (!taskWithFactoryAndState.IsFaulted)
```

```
    {
        Console.WriteLine(string.Format("managed to get {0} items",
            taskWithFactoryAndState.Result.Count));
    }
}
catch (AggregateException aggEx)
{
    //do nothing
}

//so just read the Exception from the Task, if its in Faulted state
if (taskWithFactoryAndState.IsFaulted)
{
    AggregateException taskEx = taskWithFactoryAndState.Exception;
    foreach (Exception ex in taskEx.InnerExceptions)
    {
        Console.WriteLine(string.Format("Caught exception '{0}'",
ex.Message));
    }

}

//All done with Task now so Dispose it
taskWithFactoryAndState.Dispose();

Console.WriteLine("All done, press Enter to Quit");
Console.ReadLine();
```

And here is what this example looks like when run:



Using Continuations

There is one final method, that is to use a `Task` continuation, but I will be showing that in the next article, so until then...

Cancelling Tasks

So far we have concentrated on creating and running `Task`s and handling `Exception`s that may occur, cool, good stuff... but what about if we want to cancel a `Task`? Is that even possible? Well, yes it is, TPL offers us a very easy mechanism for doing this, a `CancellationToken`.

The basic idea is that we need to obtain a `CancellationToken` from a `CancellationTokenSource` and pass the obtained `CancellationToken` as one of the `Task` creation parameters, either via the `Task` constructor, or by using one of the `Task.Factory.StartNew(..)` method overloads.

When we want to cancel a `Task`, we simply call the `Cancel()` method on the `CancellationTokenSource` that provides the `CancellationToken` that we passed to the creation of the `Task`. It is pretty much that simple. The only other thing that should be done is within the `Task` body itself. It is the recommended practice that an `OperationCancelledException` should be thrown if the `Task`'s `CancellationToken` is found to be cancelled. Throwing the `OperationCancelledException` is **very important** as it is a `Task`'s way of acknowledging the cancellation, which will esnure that the `Task` transitions to a status of `Cancelled`, which is quite important as the user code or continuations may rely on this status.

By throwing a new `OperationCancelledException` when the `CancellationToken` is seen to be `Cancelled`, no more work for that `Task` will be scheduled. Of course, the throwing of an `OperationCancelledException` does need to handled, where you can use any of the Exception handling techniques discussed above.

There are several choices to throwing a `OperationCancelledException` depending on your needs.

Option 1: Your Task Does Not Rely On Any Resources That Need Cleaning Up

If your `Task` does **not** use any resources that need cleaning up, you can simply use `token.ThrowIfCancellationRequested()` which will ensure the `Task` transitions to a status of `Cancelled` correctly.

This is what I show in the demo code.

Option 2: Your Task Does Rely On Resources That Need Cleaning Up

If your `Task` does use resources that need cleaning up (such as Streams, `WebClient`, database connections, etc.), you can check the `CancellationToken` for a `IsCancelledRequested` value, and then throw a new `OperationCancelledException`.

The thing with this approach is that there is a penalty to pay by checking for the `IsCancellationRequested` status too often, so you should try and limit how often you check for this. I can not advise you on this matter, that is down to your requirements.

Although the demo code for this article does not show an example of this, here is a trivial (and quite contrived) example showing you how you might clean up a resource that is created inside of a `Task`:

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```
Task<List<string>> someTask =
    Task.Factory.StartNew<List<string>>((website) =>
{
    System.Net.WebClient wc = new System.Net.WebClient();

    if (token1.IsCancellationRequested)
```

```
    {
        //cleanup your resources
        wc.Dispose();
        //and then throw new OperationCanceledException
        //to acknowledge cancellation request
        throw new OperationCanceledException(token1);
    }
    else
    {
        //do something with a resource that should be cleaned up
        //this example is just that, an example, so this may not
        //be best
        string webContent =
            wc.DownloadString((string)website);
        return webContent.Split(
            new string[] { " ", ","},
            Int16.MaxValue,
            StringSplitOptions.None).ToList();
    }
},"www.codeproject.com",token1);
```

OK, so that was the idea. Let's now have a look at some examples.

Cancel Single

Demo code project: CancellingSingleTask.

In this example, I simply create a new `Task` using `Task.Factory.CreateNew(..)` which is passed a `CancellationToken` which is immediately cancelled via the `CancellationTokenSource`. This example also makes use of one of the trigger methods I talked about earlier, `Result`, so we must ensure that we handle any `Exception`s that occur. I opted for using the `try/catch` approach.

Anyway, here is the code:

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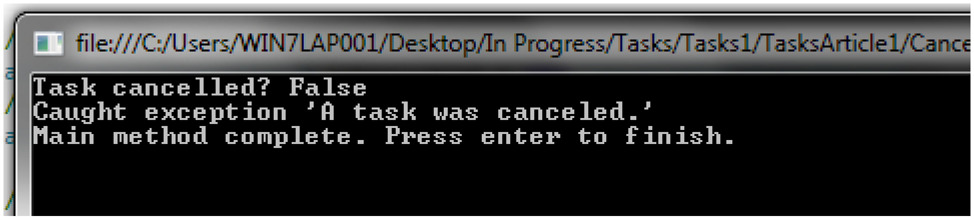
```
static void Main(string[] args)
{
    // create the cancellation token source
    CancellationTokenSource tokenSource = new CancellationTokenSource();
    // create the cancellation token
    CancellationToken token = tokenSource.Token;

    // create the task
    Task<List<int>> taskWithFactoryAndState =
    Task.Factory.StartNew<List<int>>((stateObj) =>
    {
        List<int> ints = new List<int>();
        for (int i = 0; i < (int)stateObj; i++)
        {
            ints.Add(i);
            token.ThrowIfCancellationRequested();
```

```
            Console.WriteLine("taskWithFactoryAndState, creating Item: {0}",
i);
        }
        return ints;
    }, 2000, token);



    // write out the cancellation detail of each task
    Console.WriteLine("Task cancelled? {0}",
                      taskWithFactoryAndState.IsCanceled);

    // cancel the second token source
    tokenSource.Cancel();

    if (!taskWithFactoryAndState.IsCanceled &&
        !taskWithFactoryAndState.IsFaulted)
    {
        //since we want to use one of the Trigger method (ie Result),
    //we must catch any AggregateException that occurs
        try
        {
            if (!taskWithFactoryAndState.IsFaulted)
            {
                Console.WriteLine(string.Format("managed to get {0} items",
                    taskWithFactoryAndState.Result.Count));
            }
        }
        catch (AggregateException aggEx)
        {
            foreach (Exception ex in aggEx.InnerExceptions)
            {
                Console.WriteLine(
            string.Format("Caught exception '{0}'", ex.Message));
            }
        }
        finally
        {
            taskWithFactoryAndState.Dispose();
        }
    }
    else
    {
        Console.WriteLine("Task cancelled? {0}",
        taskWithFactoryAndState.IsCanceled);

    }


    // wait for input before exiting
    Console.WriteLine("Main method complete. Press enter to finish.");
    Console.ReadLine();
}
```

And here is what the demo looks like when it runs. See how this small demo app catches the `Exception` that was thrown as a result of us cancelling the `Task` via the use of `CancellationTokenSource.Cancel()`:



Cancel One Of n

Demo code project: CancellingOneOfSeveralTasks.

Now that we have a basic understanding of how to work with a `CancellationTokenSource`, we can look at a slightly (but only slightly) more exotic example, as I don't want to confuse anyone, just yet at least. So this demo starts two almost identical `Task`s (again using `Task.Factory.StartNew()`), where we simply cancel one of them. Here is the code:

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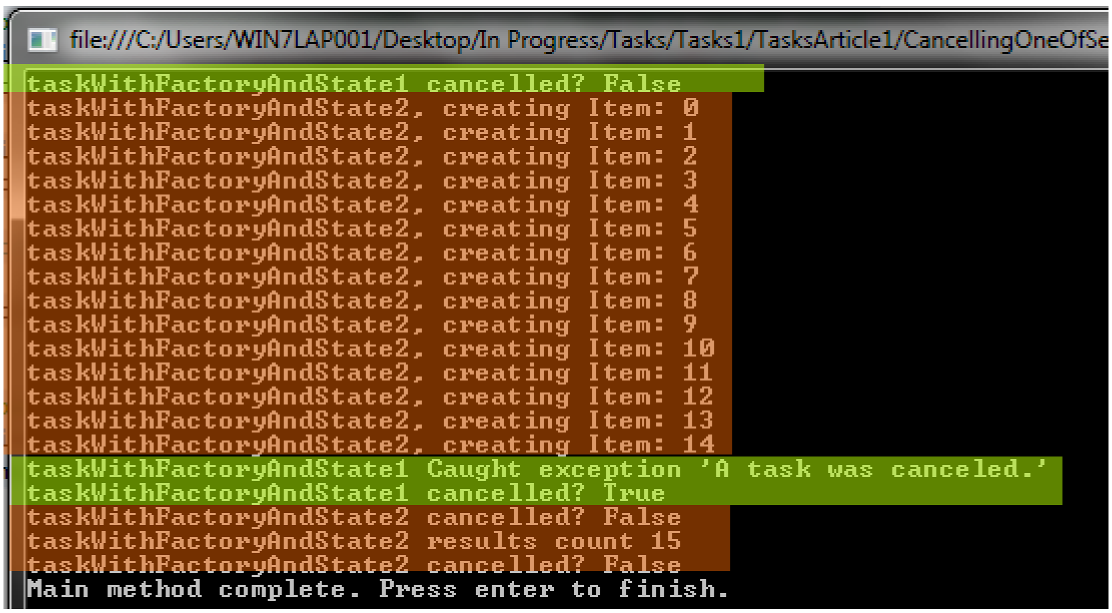
```
static void Main(string[] args)
{
    CancellationTokenSource tokenSource1 = new CancellationTokenSource();
    CancellationToken token1 = tokenSource1.Token;

    Task<List<int>> taskWithFactoryAndState1 =
        Task.Factory.StartNew<List<int>>((stateObj) =>
    {

        List<int> ints = new List<int>();
        for (int i = 0; i < (int)stateObj; i++)
        {
            ints.Add(i);
            token1.ThrowIfCancellationRequested();
            Console.WriteLine("taskWithFactoryAndState1, creating Item: {0}",
i);
        }
        return ints;
    }, 2000, token1);


    CancellationTokenSource tokenSource2 = new CancellationTokenSource();
    CancellationToken token2 = tokenSource2.Token;

    Task<List<int>> taskWithFactoryAndState2 =
        Task.Factory.StartNew<List<int>>((stateObj) =>
    {
        List<int> ints = new List<int>();
        for (int i = 0; i < (int)stateObj; i++)
        {
            ints.Add(i);
```

```
            token2.ThrowIfCancellationRequested();
            Console.WriteLine("taskWithFactoryAndState2, creating Item: {0}",
i);
        }
        return ints;
    }, 15, token2);


    // cancel the 1st token source
    tokenSource1.Cancel();

    //examine taskWithFactoryAndState1
    try
    {
        Console.WriteLine("taskWithFactoryAndState1 cancelled? {0}",
            taskWithFactoryAndState1.IsCanceled);

        //we did not cancel taskWithFactoryAndState1, so print it's result
count
        Console.WriteLine("taskWithFactoryAndState1 results count {0}",
            taskWithFactoryAndState1.Result.Count);

        Console.WriteLine("taskWithFactoryAndState1 cancelled? {0}",
            taskWithFactoryAndState1.IsCanceled);
    }
    catch (AggregateException aggEx1)
    {
        PrintException(taskWithFactoryAndState1, aggEx1,
                       "taskWithFactoryAndState1");
    }


    //examine taskWithFactoryAndState2
    try
    {
        Console.WriteLine("taskWithFactoryAndState2 cancelled? {0}",
            taskWithFactoryAndState2.IsCanceled);

        //we did not cancel taskWithFactoryAndState2, so print it's result
count
        Console.WriteLine("taskWithFactoryAndState2 results count {0}",
            taskWithFactoryAndState2.Result.Count);

        Console.WriteLine("taskWithFactoryAndState2 cancelled? {0}",
            taskWithFactoryAndState2.IsCanceled);
    }
    catch (AggregateException aggEx2)
    {
        PrintException(taskWithFactoryAndState2, aggEx2,
                       "taskWithFactoryAndState2");
    }

    // wait for input before exiting
    Console.WriteLine("Main method complete. Press enter to finish.");
    Console.ReadLine();

}
```

```
private static void PrintException(Task task, AggregateException agg, string
taskName)
{
    foreach (Exception ex in agg.InnerExceptions)
    {
        Console.WriteLine(string.Format("{0} Caught exception '{1}'",
taskName, ex.Message));
    }
    Console.WriteLine("{0} cancelled? {1}",taskName, task.IsCanceled);
}
```

And here is the result of running this small demo:



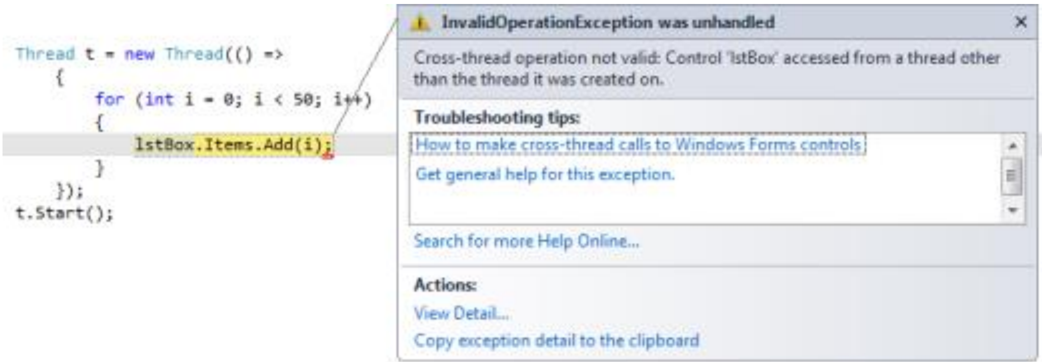
It can be seen that the `Task` with the object state of `taskWithFactoryAndState1` does not even begin to run as it was cancelled immediately, whilst the other non-cancelled `Task` with the object state of `taskWithFactoryAndState2` runs to completion.

Cancelling Chained Tasks

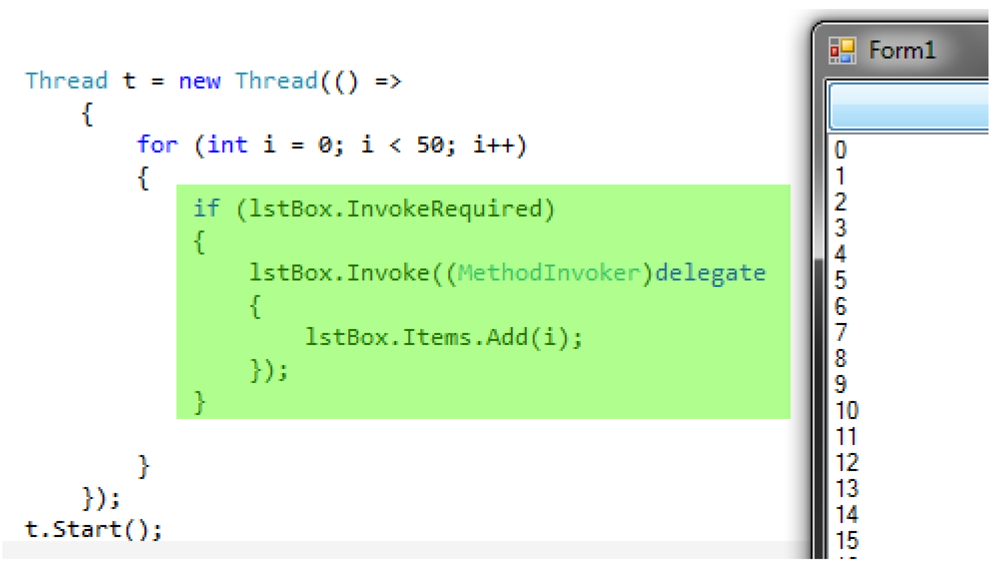
This is something I will be covering in the second article, when we talk about Continuations.

SynchronizationContext

Now, I don't know about many of you, but I come from a WinForms background, and grew quite familiar with the following error dialog:



The reason for this in Windows Forms (and WPF/Silverlight for that matter) is that UI controls have thread affinity, that is they can only be modified by the thread that owns/created them, which is usually the main thread. To get around this issue, we have to litter our code (OK, WPF has a slightly different syntax using `Dispatcher.CheckAccess()`, but it does the same job) with checks to see if the control was created on a different thread by using the `xxx.InvokeRequired` and then invoke a delegate on the correct thread if we needed to. An example of how this code would typically look like is shown below (P.S.: this is WinForms code):



This is not only a pain but a costly exercise. There are other ways of doing this using built-in features of both WinForms and WPF, these are called `SychronizationContext`s. These have been around for a long time, and offer ways to Post/Send delegates on the correct thread such that a developer does not need to litter their code base with loads of invoking checks; just use the `SychronizationContext`s to do the job, all the time.

Thing is, these `SychronizationContext`s did not clear up the code base that much; at least that is what I think, others may disagree.

Luckily, TPL tackles this issue quite nicely. Using the TPL Scheduler, we are able to do away with any invoking checks. The following two sections will show you how to marshal the results from a TPL `Task` to the correct thread. It does this by using a `SychronizationContext` which, as I say, is not a new thing, but TPL just does it for you, so you do not have to worry about issuing Post/Send delegates on the `SychronizationContext` manually, TPL takes care of it, which is nice I think.

In order to demonstrate how TPL can be used with `SychronizationContext`, I am going to have to introduce Continuations in the small examples. I will not be explaining this until the next article, but I think it is all pretty self-explanatory.

I should just say that one reader, a Neo Blanque, pointed out that my examples were a bit confusing on this topic, so thanks Neo for pointing that out, you were right to do that.

WinForms Synchronization

Demo code project: WinformsSynchonizationContext.

So here is the most relevant part of the code. Note the use of `TaskScheduler.FromCurrentSynchronizationContext()`. That is the magic bit that ensures that the `Task` result is marshaled to the correct (main usually) thread.

In the next article, we will be looking at Continuations, so please just relax until then.

In this example, we simply create a `List<int>` that is set as a `DataSource` for a `ListBox`. You can see that there is no check access code at all, TPL does it for us.

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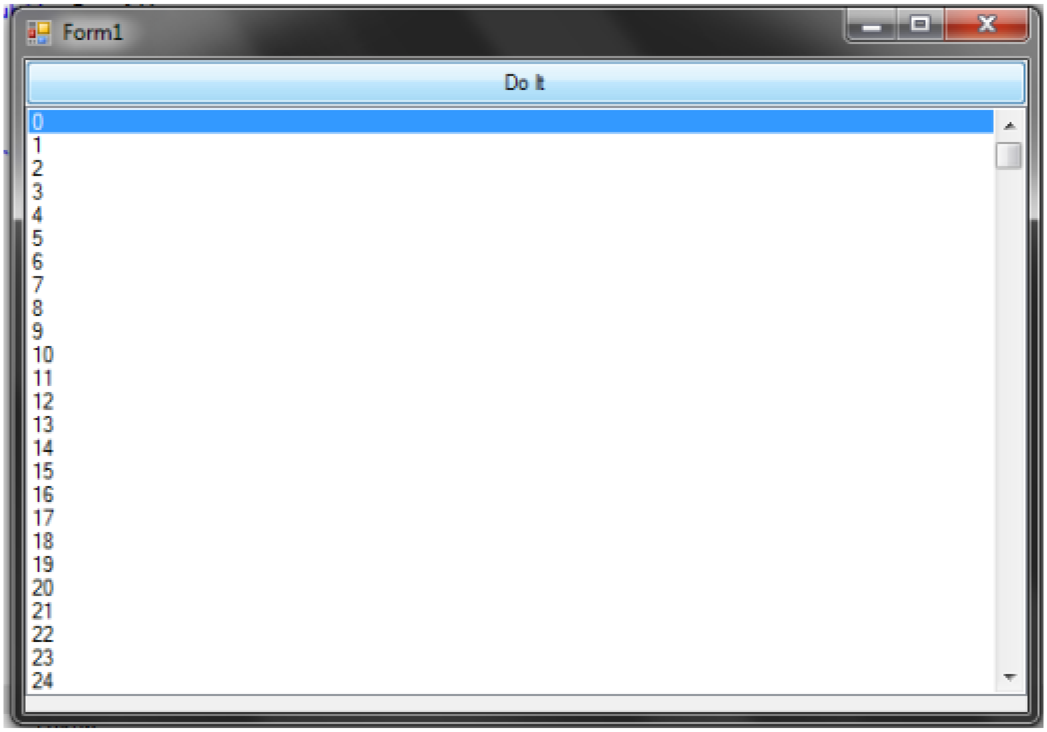
```
private void btnDoIt_Click(object sender, EventArgs e)
{
    Task taskWithFactoryAndState1 =
         Task.Factory.StartNew<List<int>>((stateObj) =>
    {
        // This is not run on the UI thread.
        List<int> ints = new List<int>();
        for (int i = 0; i < (int)stateObj; i++)
        {
            ints.Add(i);
        }
        return ints;
    }, 10000).ContinueWith(ant =>
    {
        //updates UI no problem as we are using correct
SynchronizationContext
        lstBox.DataSource = ant.Result;
    }, TaskScheduler.FromCurrentSynchronizationContext());
}
```

And here is screenshot of the demo running, just to prove to you all that it works. No smoke and mirrors here, oh no... not here... In the words of Don Logan in Sexy Beast (excellent film, watch it at any cost), "No No No No No...No, not this time".



WPF Synchronization

Demo code project: WPFDispatcherSynchonizationContext.

The story in WPF land is much the same, except under the hood, the TPL `Scheduler` will use the WPF specific `DispatcherSynchronizationContext`. Here is the most relevant parts of the WPF code example. Note: this code is almost identical to the previous WinForms example, the only difference being how we set the listbox items.

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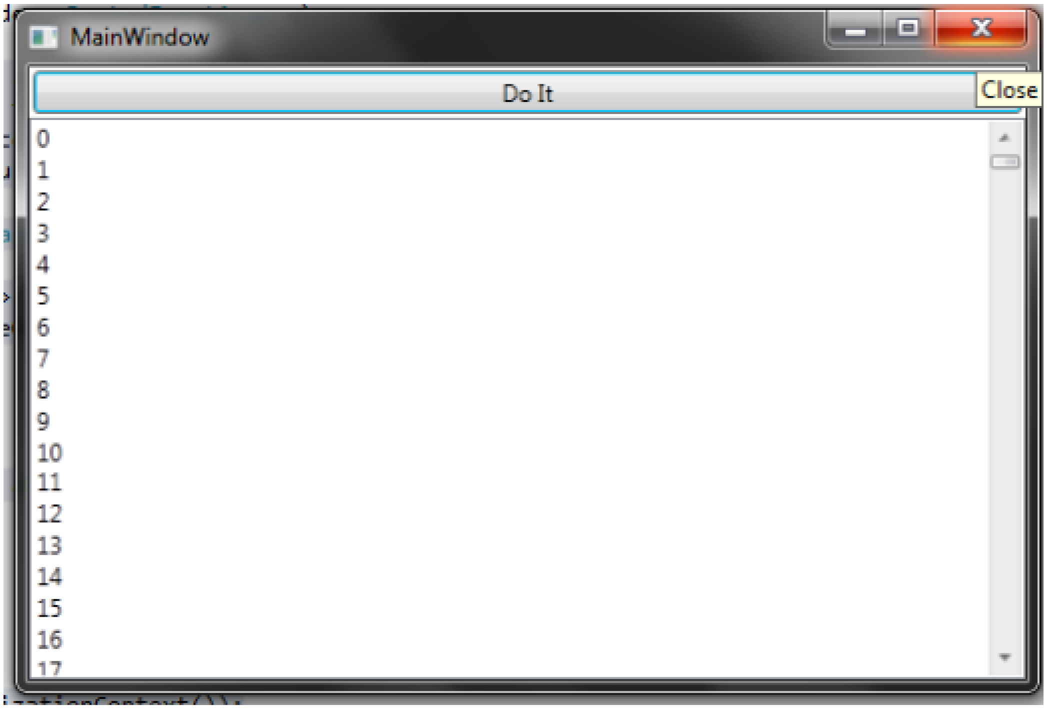
```
private void btnDoIt_Click(object sender, RoutedEventArgs e)
{
    Task taskWithFactoryAndState1 =
         Task.Factory.StartNew<List<int>>((stateObj) =>
    {
        // This is not run on the UI thread.
        List<int> ints = new List<int>();
        for (int i = 0; i < (int)stateObj; i++)
        {
            ints.Add(i);
        }
        return ints;
    }, 10000).ContinueWith(ant =>
    {
        //updates UI no problem as we are using correct
SynchronizationContext
        lstBox.ItemsSource = ant.Result;
    }, TaskScheduler.FromCurrentSynchronizationContext());
}
```

And here is screenshot of the demo running:



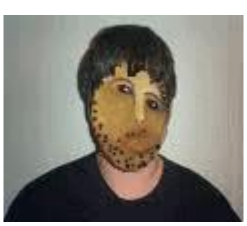
That's It For Now

That is all I wanted to say in this article. I hope you liked it and want more. If you did like this article, and would like more, could you spare some time to leave a comment and a vote? Many thanks.

Hopefully, see you at the next one, and the one after that, and the one after that, yes 6 in total, I better get busy.

License

About the Author



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I currently hold the following qualifications (amongst others, I also studied Music Technology and Electronics, for my sins)

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