Quick answers to common problems

Multithreading in C# 5.0 Cookbook

Over 70 recipes to help you learn asynchronous and parallel programming with C# 5.0 quickly and efficiently

Eugene Agafonov

[PACKT] PUBLISHING

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To my dearly beloved wife Helen and son Nikita

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Preface

Not so long ago, a typical personal computer CPU had only one computing core, and the power consumption was enough to cook fried eggs on it. In 2005, Intel introduced its first multiple-core CPU, and since then computers started developing in a different direction. Low power consumption and a number of computing cores became more important than a row computing core performance. This lead to programming paradigm changes as well. Now we need to learn how to use all CPU cores effectively to achieve the best performance, and at the same time, save battery power by running only the programs we need at a particular time. Besides that, we need to program server applications in a way to use multiple CPU cores or even multiple computers as efficiently as possible to support as many users as we can.

To be able to create such applications, you have to learn to use multiple CPU cores in your programs effectively. If you use the Microsoft .NET development platform and C# programming language, this book will be a perfect starting point for programming applications that have good performance and responsiveness.

The purpose of this book is to provide you with a step-by-step guide for multithreading and parallel programming in C#. We will start with the basic concepts, going through more and more advanced topic based on the information from previous chapters, and end with real-world parallel programming patterns and Windows Store application samples.

What this book covers

Chapter 1, *Threading Basics*, introduces basic operations with threads in C#. It explains what a thread is, the pros and cons of using threads, and other important thread aspects.

Chapter 2, *Thread Synchronization*, describes thread interaction details. You will learn why we need to coordinate threads together and the different ways of organizing thread coordination.

Chapter 3, *Using a Thread Pool*, explains a thread pool concept. It shows how to use a thread pool, how to work with asynchronous operations, and good and bad practices of using a thread pool.

Chapter 4, *Using Task Parallel Library*, is a deep dive into a Task Parallel Library framework. This chapter outlines every important aspect of TPL, including tasks combination, exceptions management, and operations cancellation.

Chapter 5, *Using C# 5.0*, explains in detail the new C# 5.0 feature – asynchronous methods. You will find out what async and await keywords mean, how to use them in different scenarios, and how await works under the hood.

Chapter 6, *Using Concurrent Collections*, describes standard data structures for parallel algorithms included in the .NET Framework. It goes through sample programming scenarios for each data structure.

Chapter 7, *Using PLINQ*, is a deep dive into the Parallel LINQ infrastructure. The chapter describes task and data parallelism, parallelizing a LINQ query, tweaking parallelism options, partitioning a query, and aggregating parallel query result.

Chapter 8, *Reactive Extensions*, explains how and when to use the Reactive Extensions framework. You will learn how to compose events and how to perform a LINQ query against an event sequence.

Chapter 9, *Using Asynchronous I/O*, covers in detail the asynchronous I/O process including files, networks, and database scenarios.

Chapter 10, *Parallel Programming Patterns*, outlines the common parallel programming problem solutions.

Chapter 11, *There's More*, covers the aspects of programming asynchronous applications for Windows 8. You will learn how to work with Windows 8 asynchronous APIs, and how to perform background work in Windows Store applications.

What you need for this book

For most of the recipes, you will need Microsoft Visual Studio Express 2012 for Windows Desktop. Recipes in Chapter 11 will require Windows 8 and Microsoft Visual Studio Express 2012 for Windows 8 to compile Windows Store applications.

Who this book is for

Multithreading in C# 5.0 Cookbook is written for existing C# developers with little or no background in multithreading, and asynchronous and parallel programming. The book covers these topics from basic concepts to complicated programming patterns and algorithms using C# and .NET ecosystem.

Conventions

In this book, you will find a number of styles of text that distinguish among different kinds of information. Here are some examples of these styles, and an explanation of their meaning.

Code words in text are shown as follows: " When we construct a thread, an instance of the `ThreadStart` or `ParameterizedThreadStart` delegate is passed to the constructor."

A block of code is set as follows:

```
static void PrintNumbers()
{
  Console.WriteLine("Starting...");
  for (int i = 1; i < 10; i++)
  {
    Console.WriteLine(i);
  }
}
```

New terms and **important words** are shown in bold. Words that you see on the screen, in menus or dialog boxes for example, appear in the text like this: "Start Visual Studio 2012. Create a new C# **Console Application** project."

Warnings or important notes appear in a box like this.

Tips and tricks appear like this.

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1
Threading Basics

In this chapter, we will cover the basic tasks for working with threads in C#.
You will learn about:

- Creating a thread in C#
- Pausing a thread
- Making a thread wait
- Aborting a thread
- Determining thread state
- Thread priority
- Foreground and background threads
- Passing parameters to a thread
- Locking with a C# lock keyword
- Locking with a Monitor construct
- Handling exceptions

Introduction

At some point of time in the past, the common computer had only one computing unit and could not execute several computing tasks simultaneously. However, operating systems could already work with multiple programs simultaneously, implementing the concept of multitasking. To prevent the possibility of one program taking control of the CPU, forever causing other applications and the operating system itself to hang, the operating systems had to split a physical computing unit across a few virtualized processors in some way and give a certain amount of computing power to each executing program. Moreover, an operating system must always have priority access to the CPU and should be able to prioritize CPU access to different programs. A thread is an implementation of this concept. It could be considered a virtual processor given to the one specific program that runs it independently.

Remember that a thread consumes a significant amount of operating system resources. Trying to share one physical processor across many threads will lead to a situation where an operating system is busy just managing threads instead of running programs.

Therefore, while it was possible to enhance computer processors, making them execute more and more commands per second, working with threads was usually an operating system task. There was no sense in trying to compute some tasks in parallel on a single-core CPU because it would take more time than running those computations sequentially. However, when processors started to have more computing cores, older programs could not take advantage of this because they just used one processor core.

To use a modern processor's computing power effectively, it is very important to be able to compose a program in a way that it can use more than one computing core, which leads to organizing it as several threads communicating and synchronizing with each other.

The recipes in this chapter will focus on performing some very basic operations with threads in the C# language. We will cover a thread's lifecycle, which includes creating, suspending, making a thread wait, and aborting a thread, and then we will go through basic synchronization techniques.

Creating a thread in C#

Throughout the following recipes, we will use Visual Studio 2012 as the main tool to write multithreaded programs in C#. This recipe will show you how to create a new C# program and use threads in it.

There are free Visual Studio 2012 Express editions, which can be downloaded from the Microsoft website. We will need Visual Studio 2012 Express for Windows Desktop for most of the examples and Visual Studio 2012 Express for Windows 8 for Windows 8-specific recipes.

Getting ready

To work through this recipe, you will need Visual Studio 2012. There are no other prerequisites. The source code for this recipe can be found at `BookSamples\Chapter1\Recipe1`.

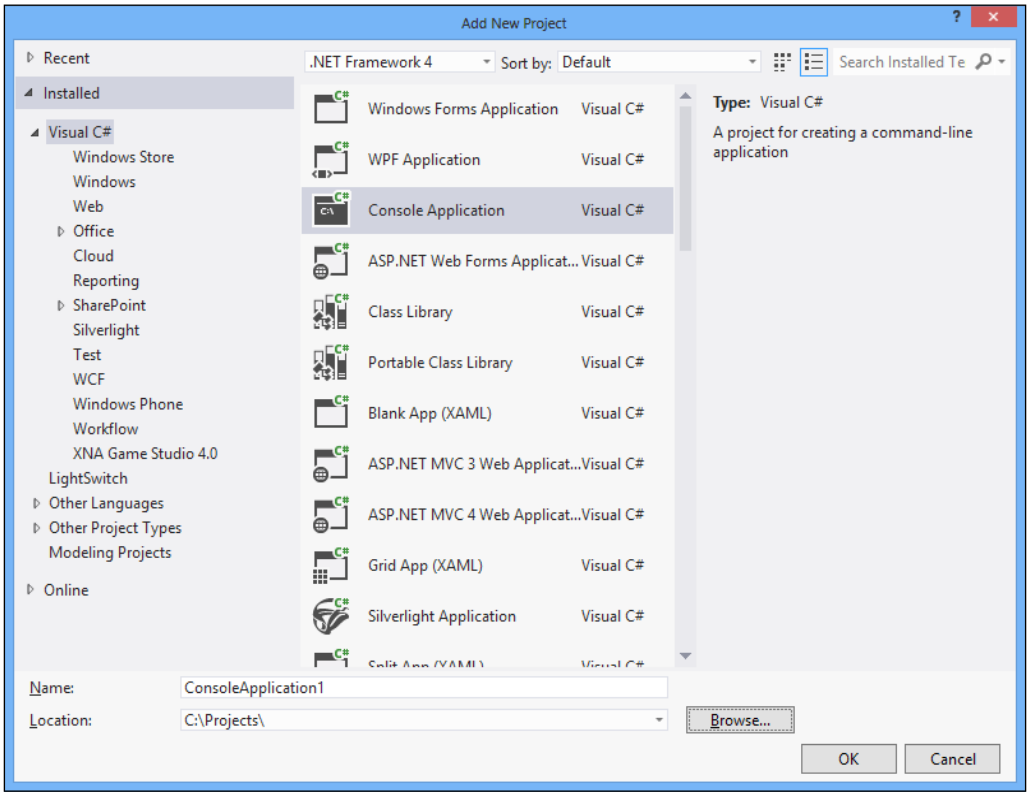
Downloading the example code

You can download the example code files for all Packt books you have purchased through your account at `http://www.packtpub.com`. If you purchased this book elsewhere, you can visit `http://www.packtpub.com/support` and register to have the files e-mailed directly to you.

How to do it...

To understand how to create a new C# program and use threads in it, perform the following steps:

1. Start Visual Studio 2012. Create a new C# **Console Application** project.
2. Make sure that the project uses .NET Framework 4.0 or higher version.



3. In the `Program.cs` file add the following `using` directives:

```
using System;
using System.Threading;
```

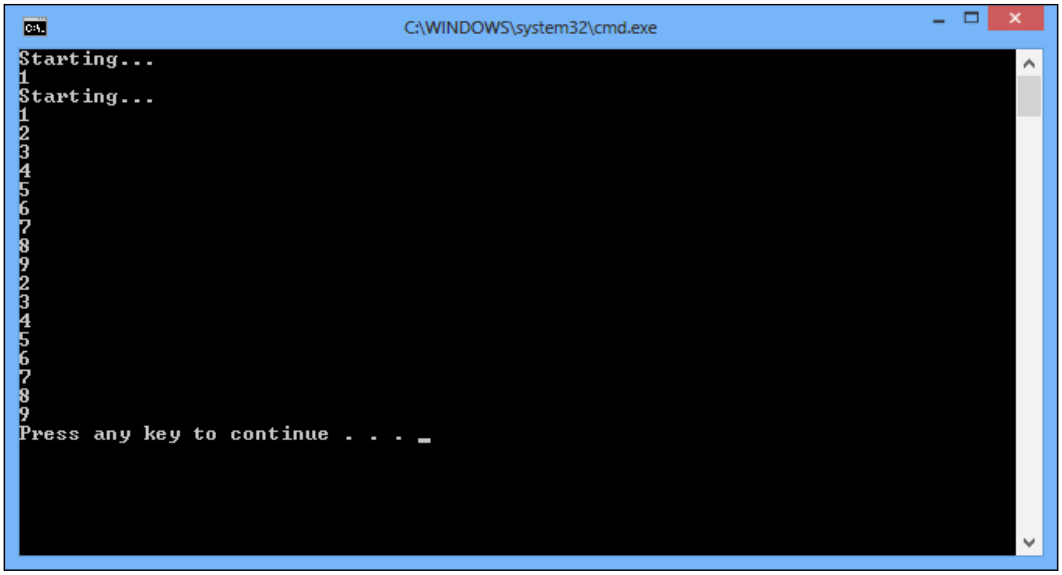
4. Add the following code snippet below the `Main` method:

```
static void PrintNumbers()
{
  Console.WriteLine("Starting...");
  for (int i = 1; i < 10; i++)
  {
    Console.WriteLine(i);
  }
}
```

5. Add the following code snippet inside the `Main` method:

```
Thread t = new Thread(PrintNumbers);
t.Start();
PrintNumbers();
```

6. Run the program. The output will be something like:



How it works...

In steps 1 and 2 we created a simple console application in C# using .Net Framework version 4.0. Then in step 3 we included the namespace `System.Threading`, which contains all the types needed for the program.

An instance of a program is being executed can be referred to as a process. A process consists of one or more threads. This means that when we run a program, we always have one main thread that executes the program code.

In step 4 we defined the method `PrintNumbers`, which will be used in both the main and newly created threads. Then in step 5, we created a thread that runs `PrintNumbers`. When we construct a thread, an instance of the `ThreadStart` or `ParameterizedThreadStart` delegate is passed to the constructor. The C# compiler is creating this object behind the scenes when we just type the name of the method we want to run in a different thread. Then we start a thread and run `PrintNumbers` in the usual manner on the main thread.

As a result, there will be two ranges of numbers from 1 to 10 randomly crossing each other. This illustrates that the `PrintNumbers` method runs simultaneously on the main thread and on the other thread.

Pausing a thread

This recipe will show you how to make a thread wait for some time without wasting operating system resources.

Getting ready

To work through this recipe, you will need Visual Studio 2012. There are no other prerequisites. The source code for this recipe can be found at `BookSamples\Chapter1\Recipe2`.

How to do it...

To understand how to make a thread wait without wasting operating system resource, perform the following steps:

1. Start Visual Studio 2012. Create a new C# **Console Application** project.
2. In the `Program.cs` file add the following `using` directives:

```
using System;
using System.Threading;
```

3. Add the following code snippet below the `Main` method:

```
static void PrintNumbers()
{
  Console.WriteLine("Starting...");
  for (int i = 1; i < 10; i++)
  {
    Console.WriteLine(i);
  }
}
static void PrintNumbersWithDelay()
{
  Console.WriteLine("Starting...");
  for (int i = 1; i < 10; i++)
  {
    Thread.Sleep(TimeSpan.FromSeconds(2));
    Console.WriteLine(i);
  }
}
```

4. Add the following code snippet inside the `Main` method:

```
Thread t = new Thread(PrintNumbersWithDelay);
t.Start();
PrintNumbers();
```

5. Run the program.

How it works...

When the program is run, it creates a thread that will execute a code in the `PrintNumbersWithDelay` method. Immediately after that, it runs the `PrintNumbers` method. The key feature here is adding the `Thread.Sleep` method call to a `PrintNumbersWithDelay` method. It causes a thread executing this code to wait a specified amount of time (two seconds in our case) before printing each number. While a thread is sleeping, it uses as little CPU time as possible. As a result, we will see that the code in the `PrintNumbers` method that usually runs later will be executed before the code in the `PrintNumbersWithDelay` method in a separate thread.

Making a thread wait

This recipe will show you how a program can wait for some computation in another thread to complete to use its result later in the code. It is not enough to use `Thread.Sleep` because we don't know the exact time the computation will take.

Getting ready

To work through this recipe, you will need Visual Studio 2012. There are no other prerequisites. The source code for this recipe can be found at `BookSamples\Chapter1\Recipe3`.

How to do it...

To understand how a program can wait for some computation in another thread to complete to use its result later, perform the following steps:

1. Start Visual Studio 2012. Create a new C# **Console Application** project.
2. In the `Program.cs` file, add the following `using` directives:

```
using System;
using System.Threading;
```

3. Add the following code snippet below the `Main` method:

```
static void PrintNumbersWithDelay()
{
  Console.WriteLine("Starting...");
  for (int i = 1; i < 10; i++)
  {
    Thread.Sleep(TimeSpan.FromSeconds(2));
    Console.WriteLine(i);
  }
}
```

4. Add the following code snippet inside the `Main` method:

```
Console.WriteLine("Starting...");
Thread t = new Thread(PrintNumbersWithDelay);
t.Start();
t.Join();
Console.WriteLine("Thread completed");
```

5. Run the program.

How it works...

When the program is run, it runs a long-running thread that prints out numbers and waits two seconds before printing each number. But in the main program, we called the `t.Join` method, which allows us to wait for thread `t` to complete. When it is complete, the main program continues to run. With the help of this technique, it is possible to synchronize execution steps between two threads. The first one waits until another one is complete and then continues to work. While the first thread is waiting, it is in a blocked state (as it is in the previous recipe when you call `Thread.Sleep`).

Aborting a thread

In this recipe, we will describe how to abort another thread's execution.

Getting ready

To work through this recipe, you will need Visual Studio 2012. There are no other prerequisites. The source code for this recipe can be found at `BookSamples\Chapter1\Recipe4`.

How to do it...

To understand how to abort another thread's execution, perform the following steps:

1. Start Visual Studio 2012. Create a new C# **Console Application** project.
2. In the `Program.cs` file, add the following `using` directives:

```
using System;
using System.Threading;
```

3. Add the following code snippet below the `Main` method:

```
static void PrintNumbersWithDelay()
{
  Console.WriteLine("Starting...");
  for (int i = 1; i < 10; i++)
  {
    Thread.Sleep(TimeSpan.FromSeconds(2));
    Console.WriteLine(i);
  }
}
```