Programming 3 Advanced

Parallel, Concurrent Collections, Concurrency Workshop

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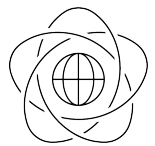
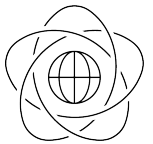


Outline



Parallel Class

Parallel.Invoke Invokes an array of delegates in parallel

Parallel.For Parallel version of for loop

Parallel.ForEach Parallel version of foreach loop

- The work is partitioned efficiently into a few tasks
- All methods block until all work is complete
- In case of exception workers are stopped and exception is rethrown and wrapped in an AggregateException

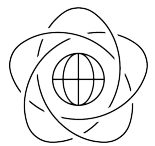
Parallel class

`https://learn.microsoft.com/en-us/dotnet/api/system.threading.tasks.parallel?view=net-9.0`

Parallel.Invoke

```
1 Parallel.Invoke(
2 () => DownloadFile("https://foo.com", "foo.html"),
3 () => DownloadFile("https://bar.net", "bar.html"),
4 () => DownloadFile("https://microsoft.com", "ms.html"));
```

- It will work efficiently even with larger number of delegates, as the delegates are partitioned
- When using Parallel.*, you must ensure thread-safe access to shared variables

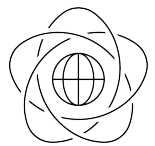


Parallel.For

Simplest signature:

```
1 public static ParallelLoopResult For(
2     int fromInclusive, int toExclusive, Action<int> body)
```

```
1 Parallel.For(from, to, i =>
2 {
3     Console.WriteLine($"Is {i} prime: {IsPrime(i)}");
4 });
```

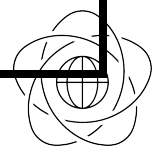


Parallel.ForEach

Simplest signature:

```
public static ParallelLoopResult ForEach<TSource>(
    IEnumerable<TSource> source, Action<TSource> body)
```

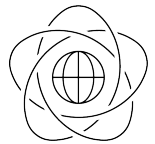
```
List<(string url, string output)> res =
[
    // ...
];

Parallel.ForEach(res, ((string url, string output) tuple) =>
{
    DownloadFile(tuple.url, tuple.output);
});
```



Breaking early

```
1  var res = Parallel.For(10000, 10010, (i, loopState) =>
2  {
3      if (IsPrime(i))
4      {
5          loopState.Break();
6      }
7  }); // result is ParallelLoopResult
8  if (!res.IsCompleted)
9      Console.WriteLine($"Prime: {res.LowestBreakIteration}");
10 else
11     Console.WriteLine("There are no primes in this range");
```

- Both For/ForEach have overloads that expose ParallelLoopState.
- Break: Ensures at least the same iterations as sequential execution.
- Stop: Immediately halts threads after the current iteration.
- Examining ParallelLoopResult object tells whether the loop ran to completion



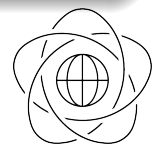
Concurrent Collections

- ConcurrentStack<T>
- ConcurrentQueue<T>
- ConcurrentBag<T>
- ConcurrentDictionary<TKey,TValue>
- BlockingCollection<T>

There is no concurrent version of the List.

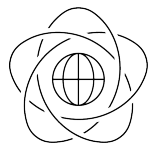
Thread-safe collections

`https://learn.microsoft.com/en-us/dotnet/standard/collections/thread-safe/`



Concurrent Collections Properties

- Conventional collections outperform concurrent collections except in highly concurrent scenarios.
- Enumerating over a concurrent collection during modifications by another thread mixes old and new content, without throwing exceptions.
- Concurrent stack, queue, and bag classes use linked lists internally.

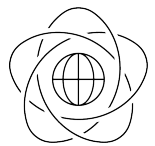


IProducerConsumerCollection

```
1  public interface IProducerConsumerCollection<T> :
2      IEnumerable<T>, ICollection
3  {
4      bool TryAdd(T item);
5      bool TryTake(out T item);
6      T[] ToArray();
7  }
```

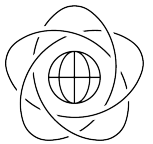
Classes that implement the interface:

- ConcurrentStack<T>
- ConcurrentQueue<T>
- ConcurrentBag<T>



ConcurrentBag

- ConcurrentBag is an unordered collection of objects
- Inside a concurrent bag, each thread gets its own private linked list
- Calling Take on a concurrent bag is very efficient — there are no races as long as each thread doesn't take more elements than it Added



BlockingCollection

- A blocking collection wraps any collection that implements `IProducerConsumerCollection<T>` and lets you Take an element from the wrapped collection — blocking if no element is available.
- A blocking collection also lets you limit the total size of the collection, blocking the producer if that size is exceeded.
- If constructor is called without passing in a collection, the class will automatically use a `ConcurrentQueue<T>`
- Another way to consume elements is to call `GetConsumingEnumerable`. This returns a (potentially) infinite sequence that yields elements as they become available. You can force the sequence to end by calling `CompleteAdding`: this method also prevents further elements from being enqueued.