Programming 3 Advanced

Generics, Enumeration, Nullable

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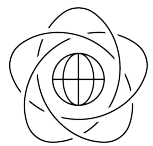
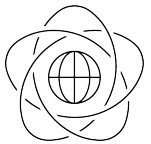


Outline

1. Generics
2. Enumeration
3. Nullable



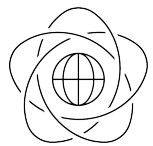
Generics

Generics in .NET

https://learn.microsoft.com/en-us/dotnet/standard/generics/

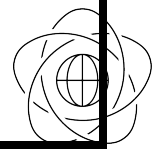
Generics Overview

https://learn.microsoft.com/en-us/dotnet/standard/generics



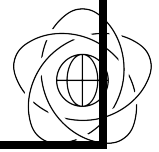
Generics

```
1  public class Stack<T>
2  {
3      private T[] _items = new T[100];
4      public int Count { get; private set; }
5      public void Push(T item) => _items[Count++] = item;
6      public T Pop() => _items[--Count];
7  }
8  Stack<int> intStack = new Stack<int>();
9  for (int i = 0; i < 10; i++)
10 {
11     intStack.Push(i);
12 }
13 while (intStack.Count > 0)
14 {
15     int item = intStack.Pop();
16     Console.Write(item);
17 }
```



Why not use *object*?

```
1  public class Stack
2  {
3      private object[] _items = new T[100];
4      public int Count { get; private set; }
5      public void Push(object item) => _items[Count++] = item;
6      public object Pop() => _items[--Count];
7  }
8  Stack intStack = new Stack();
9  for (int i = 0; i < 10; i++)
10 {
11     intStack.Push(i);
12 }
13 while (intStack.Count > 0)
14 {
15     int item = (int)intStack.Pop();
16     Console.Write(item);
17 }
```

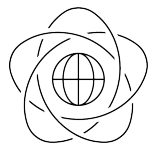


Generic methods

```
1 public static void Swap<T>(ref T a, ref T b)
2 {
3     T temp = a;
4     a = b;
5     b = temp;
6 }
```

Documentation

https://learn.microsoft.com/en-us/dotnet/csharp/programming-guide/generics/generic-methods



Generics constraints

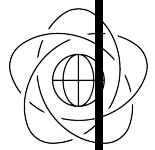
```
1  where T : base-class // Base-class constraint
2  where T : interface  // Interface constraint
3  where T : class      // Reference-type constraint
4  where T : class?     // Nullable reference-type constraint
5  where T : struct     // Reference-type constraint
6  where T : unmanaged  // Unmanaged constraint
7  where T : new()      // Parameterless constructor constraint
8  where U : T          // Naked type constraint
9  where T : notnull    // Non-nullable value type, or (C# 8+)
10                      // a non-nullable reference type
```

Documentation

https://learn.microsoft.com/en-us/dotnet/csharp/programming-guide/generics/constraints-on-type-parameters

Generics constraints

```
1  Console.WriteLine(Max(1, 5, 2, -4, 0, 210, 42));
2  Console.WriteLine(Max("the", "quick", "brown", "fox"));
3  // Compile time error, fruits do not implement IComparable:
4  // Console.WriteLine(Max(new Apple(), new Orange());
5
6  public static T Max<T>(T value, params T[] values)
7  where T : IComparable<T>
8  {
9      var max = value;
10     foreach (var t in values)
11     {   // we know T implements IComparable<T>
12         if (max.CompareTo(t) < 0)
13         {
14             max = t;
15         }
16     }
17     return max;
18 }
```



Generics Variance

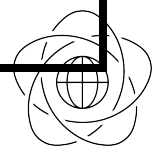
```
1  // Covariant T type parameter
2  // (can be used only as a return value)
3  public interface IPoppable<out T>
4  {
5      T Pop();
6  }
7
8  // Contravariant T type parameter
9  // (can be used only as an input parameter)
10 public interface IPushable<in T>
11 {
12     void Push(T item);
13 }
```

Documentation

https://learn.microsoft.com/en-us/dotnet/csharp/programming-guide/concepts/covariance-contravariance/variance-in-generic-interfaces

Generics Variance

```
1  // Covariance allows down-casting generic type
2  var apples = new VariantStack<AppleTree>();
3  apples.Push(new AppleTree());
4  apples.Push(new AppleTree());
5  IPoppable<Tree> poppableTrees = apples;
6
7  // Contravariance allows up-casting generic type
8  var trees = new VariantStack<Tree>();
9  trees.Push(new AppleTree());
10 trees.Push(new OrangeTree());
11 IPushable<AppleTree> pushableApples = trees;
12
13 private abstract class Tree;
14 private class AppleTree : Tree;
15 private class OrangeTree : Tree;
```



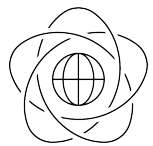
Enumerator

Enumerator

An enumerator is a read-only, forward-only cursor over a sequence of values.

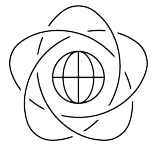
Type is an Enumerator if one of the conditions is fulfilled:

- has public parameterless method `bool MoveNext()` and `Current` property
- implements `System.Collections.Generics.IEnumerable<T>`
- implements `System.Collections.IEnumerable`



IEnumerator interfaces

```
1  public interface IEnumerator
2  {
3      bool MoveNext();
4      object Current { get; }
5      void Reset();
6  }
7
8  public interface IEnumerator<out T> : IDisposable,
9                                        IEnumerator
10 {
11     T Current { get; }
12 }
```



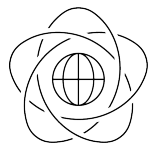
Enumerable

Enumerator

An enumerable object is the logical representation of a sequence. It is not itself a cursor but an object that produces cursors over itself.

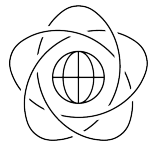
Type is an Enumerable if one of the conditions is fulfilled:

- has a public parameterless method named `GetEnumerator` that returns an enumerator
- implements `System.Collections.Generic.IEnumerable<T>`
- implements `System.Collections.IEnumerable`
- has an extension method named `GetEnumerator` that returns an enumerator



IEnumerable interface

```
1  public interface IEnumerable
2  {
3      IEnumerator GetEnumerator();
4  }
5  public interface IEnumerable<out T> : IEnumerable
6  {
7      IEnumerator<T> GetEnumerator();
8  }
```



foreach

```
1  List<int> collection = [1, 2, 3, 4, 5, 6, 7, 8];
2
3  // Collection needs to be 'Enumerable'
4  foreach(int item in collection)
5  {
6      Console.WriteLine(item.ToString());
7  }
8  // Is translated to (roughly):
9  IEnumerator<int> enumerator = collection.GetEnumerator();
10 while (enumerator.MoveNext())
11 {
12     var item = enumerator.Current;
13     Console.WriteLine(item.ToString());
14 }
```

Documentation

https://learn.microsoft.com/en-us/dotnet/csharp/iterators

Iterator methods

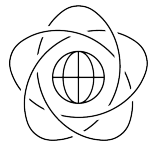
```
1  // return type might be either IEnumerable or IEnumerator
2  private static IEnumerable<int> Fibonacci(int n)
3  {
4      int current = 0, next = 1;
5      for (int i = 0; i < n; i++)
6      {
7          yield return current;
8          (current, next) = (next, current + next);
9      }
10 }
```

Iterators with Yield

https://learn.microsoft.com/en-us/archive/msdn-magazine/2017/june/essential-net-custom-iterators-with-yield

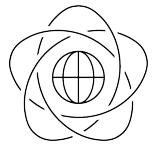
Null-Coalescing Operator

```
1  string s1 = null;
2  string s2 = s1 ?? "non-null";
3  Console.WriteLine($"Value of s2: {s2}");
4  // equivalent:
5  // string s2 = (s1 == null) ? "non-null": s1;
6
7  // Can also throw exception if s1 is null:
8  // s2 = s1 ?? throw new ArgumentNullException();
```



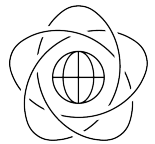
Null-Coalescing Assignment Operator

```
1  string s = null;
2  s ??= "non-null";
3  Console.WriteLine($"Value of s: {s}");
4
5  // equivalent:
6  // string s = (s == null) ? "non-null" : s;
```



Null-Conditional Operator

```
1 System.Text.StringBuilder sb = null;
2 string s = sb?.ToString();
3 // equivalent:
4 // string s = (sb == null ? null : sb.ToString());
```

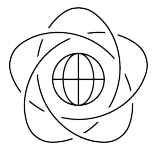


Nullable value types

```
1 // Cannot assign null to a value types:
2 // int integer = null; // Compile-time error
3
4 // Can assign null to a nullable value type (denoted with ?)
5 int? i = null;
6 Console.WriteLine (i == null); // True
```

Documentation

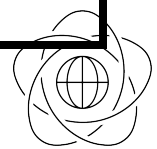
https://learn.microsoft.com/en-us/dotnet/csharp/language-reference/builtin-types/nullable-value-types



Nullable struct

```
1  public struct Nullable<T> where T : struct
2  {
3      public T Value {get;}
4      public bool HasValue {get;}
5      public T GetValueOrDefault();
6      public T GetValueOrDefault(T defaultValue);
7      //...
8  }
```

```
1  int? i = null;
2  Console.WriteLine (i == null);
3  // Equivalent:
4  Nullable<int> i = new Nullable<int>();
5  Console.WriteLine (! i.HasValue);
```

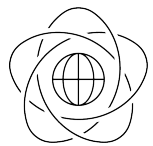


Nullable conversions

```
1  int? i = 5;       // implicit conversion
2  int j = (int)i;   // explicit conversion
3
4  // Equivalent:
5  // int j = i.Value;
```

Explicit conversion

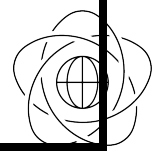
Both explicit conversion and accessing Value property might throw an exception if the value is null.



Nullable

Operator Lifting

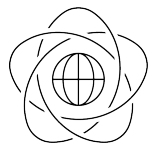
```
1  int? x = 5;
2  int? y = null;
3  // Equality operator examples
4  Console.WriteLine(x == y);    // false
5  Console.WriteLine(x == null); // false
6  Console.WriteLine(x == 5);    // true
7  Console.WriteLine(y == null); // true
8  Console.WriteLine(y == 5);    // false
9  Console.WriteLine(y != 5);    // true
10 // Relational operator examples
11 Console.WriteLine(x < 6);     // true
12 Console.WriteLine(y < 6);     // false
13 Console.WriteLine(y > 6);     // false
14 // All other operator examples
15 Console.WriteLine(x + 5);     // 10
16 Console.WriteLine(x + y);     // null
```



Nullable

bool? logic

```
1  bool? n = null;
2  bool? f = false;
3  bool? t = true;
4  Console.WriteLine (n | n); // null
5  Console.WriteLine (n | f); // null
6  Console.WriteLine (n | t); // true
7  Console.WriteLine (n & n); // null
8  Console.WriteLine (n & f); // false
9  Console.WriteLine (n & t); // null
```



Nullable Reference Types

```
1  #nullable enable
2  #nullable disable
3  #nullable restore
4
5  string s1 = null;  // Generates a compiler warning
6  string? s2 = null;  // OK, s2 is marked as nullable
7
8  class Foo
9  {
10     // Also a warning, since x is not initialized
11     string x;
12 }
```

Documentation

https://learn.microsoft.com/en-us/dotnet/csharp/language-reference/builtin-types/nullable-reference-types

Nullable Reference Types

Null-forgiving operator

```
1  string s1 = null!;          // `!` Silences the warning
2  string? s2 = null;
3  int s2Length = s2!.Length; // `!` Silences the warning
4
5  // Either is better (exception-safe):
6  // int? s2Length2 = s2?.Length;
7  // if (s2 != null) Console.Write(s2.Length);
```