# Lecture 3. Collections and generics

## Programming II

School of Business Informatics
Spring 2018

*(: If debugging is the process of removing software bugs, then programming must be the process of putting them in :)*

# Collections

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Why so many?

# Common features

- Collections are reference types (items are stored on the heap)
- Standard collections (except strings) are mutable (can be changed in-place after initialization)
- All modern collection classes are strongly typed. Loosely typed classes, e.g. ArrayList, HashTable, are included for backward compatibility

# Difference between collections

- Internal organization
- Efficiency of different operations
- Allocated memory
- Presence of notifiers (important for automatic updates of the UI)
- Thread-safety (will be covered later in the course)

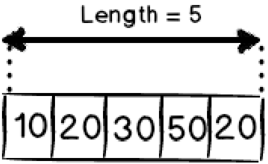
# Main operations on containers

- Get an element by index / key
- Add element to the back / to the front / at arbitrary index
- Remove element from the back / from the front / from an arbitrary index
- Iterate through all elements

# Array

- ✓ Single block of memory allocated for all elements
- ✓ Elements are equal in size
- ✓ Efficient element access by index
- ✗ Dynamic resizing

```
int[] array = new int[] {10, 20, 30, 50, 20};
```



# string vs char[]

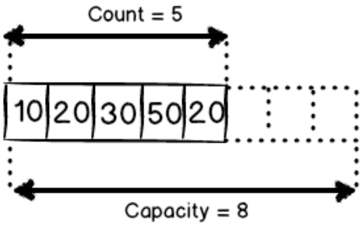
- A string is **immutable**, i.e. after initialization its contents cannot be changed in place. All operations on strings - Concat, ToLower, ToUpper, Remove, Replace, Trim and others - create a new string in memory preserving the old one
- A char[] or List<char> is **mutable**: individual characters can be changed after initialization

```
class String
{
   // char[] -> string
   public String(char[] value);
   // string -> char[]
   public char[] ToCharArray();
}
```

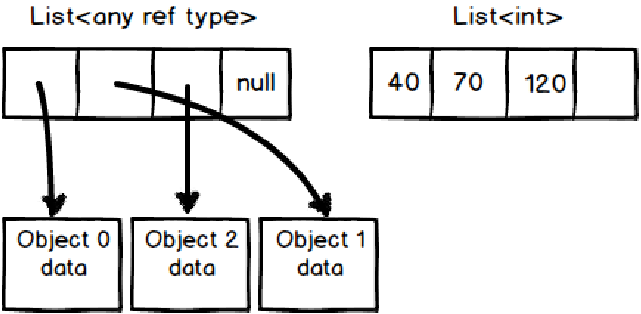
# List

- ✓ Most commonly used container
- ✓ Internally organized as an array
- ✓ Additional logic added to dynamically resize the internal array when no free space is left
- ✗ Efficient insertion to the front /removal from the front

```
List<int> list = new List<int> {10, 20, 30, 50, 20};
```



# Storing values and references



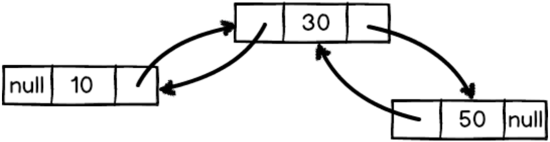
# Linked list

✓ Elements are stored in non-sequential blocks of memory

✓ Efficient insertion to the front / removal from the front

✗ Access to elements by index

```
LinkedList<int> linkedList = new LinkedList<int>();
linkedList.AddLast(30);
linkedList.AddLast(50);
linkedList.AddFirst(10);
```



# Associative container

- An associative container (AC) is formed by key-value pairs (for each key an AC stores the value associated with it) and enables quick retrieval of a value by its key
- Several .NET classes implement an associative container, the most common is:

```
class Dictionary<TKey,TValue>
```

- A Dictionary is also very efficient at inserting and deleting key-value pairs

# Dictionary examples

- A user enters a month name and the program outputs the number of days in the corresponding month.
- Association between a file extension and a default program to open such files.
- Important events that happened on a particular day in history.

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- Association between a file extension and a default program to open such files. Extension - Program name/path
- Important events that happened on a particular day in history. Date - List of events

Key - Value

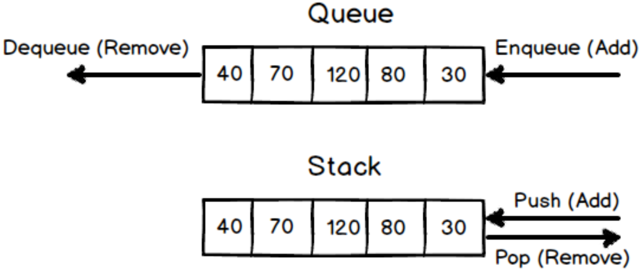
# Dictionary rules

- Each key appears only once in a dictionary. Values can be repeated.
- The dictionary **key** has to be of an **immutable** type (int, double, char, string, DateTime and others)
- The order, in which key-value pairs are stored and then retrieved from a Dictionary (e.g. in a foreach loop) cannot be easily predicted and can be considered as random
- SortedDictionary and SortedList are two examples of associative containers, which allow to retrieve keys in a sorted order.

An article on internal dictionary structure

# Queue and Stack

Array or linked list based collections with a special add-remove logic:



# Queue and Stack usage scenarios

- Intermediate buffer between components (both hardware and software) operating at different speeds
- Search algorithms
- Backtracking
- Expression parsing

# Algorithmic complexity

The theory of algorithmic complexity aims at answering two main questions:

1. How fast is a particular algorithm?
2. How much memory does it consume?

Key problem - how to measure these characteristics?

# Straightforward approach

Take a sample dataset and measure the absolute value of time / memory required for the algorithm to execute

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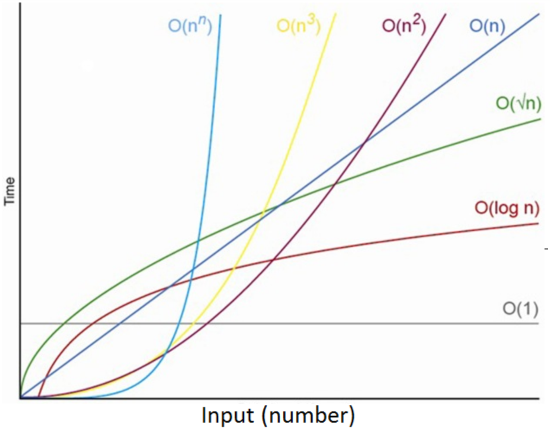
Drawback - results will depend on too many factors (computer performance, size of data, etc.)

# Key idea

Instead of the measuring absolute values of time / memory we estimate how quickly it grows as we increase input size.



# Big Oh notation

## Formal definition

For any functions f(n) and g(n), where n is a natural number, we write:
$f(n) = O(g(n))$ if $\exists k, n_0 : k > 0, n_0 > 0, f(n) \leq k \cdot g(n), \forall n \geq n_0$

Example:
If $f(n) = n^2 + 10n + 30$ then $f(n) = O(n^2)$
because $f(n) \leq 2n^2, \forall n > 13$

# Common complexity types

- Constant time: $O(1)$
- Logarithmic time: $O(logn)$
- Linear time: $O(n)$
- Quadratic time: $O(n^2)$
- Exponential time: $O(2^n)$

# Problem of similar methods

Consider the following method that exchanges values of two integer variables:

```
static void Swap(ref int num1, ref int num2)
{
    int temp = num1;
    num1 = num2;
    num2 = temp;
}
```

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```

What if we need to exchange two “double” values?

# Generic version of Swap

```
static void Swap<T>(ref T num1, ref T num2)
{
    T temp = num1;
    num1 = num2;
    num2 = temp;
}
```

Swap can now be used to interchange variables of any type.

# Generic class example

Generic principles can also be applied to classes.

```
class GenericItem<T>
{
    T Value { get; set; }
    string Comment { get; set; }
}
```

In the example above T can be used for any member of the class.

# Generics in .NET

Generic classes are widely used in .NET Framework (first appeared in .NET v2.0)

- Collections
- Anonymous delegates and lambda expressions
- LINQ
- Entity framework
- and many other standard features

# Why use generics?

Generics offer a number of advantages:

- Type safety is ensured at compile time
- Boxing does not occur in case T is a value type

**Universal programming principle: Compile time errors are preferable to runtime errors.**

# Restrictions of generic classes

```
static T Sum<T>(T[] array)
{
    T sum = 0;
    foreach (var item in array)
        sum += item;
    return sum;
}
```

In the example above:

- Cannot assign a variable to 0
- Cannot add values

Partial solution to the problem: constraints on generic classes

# Constraints on generic classes

```
public class GenericClass<T> where <constraints>
{
}
```

- where T : class
- where T : struct
- where T : new()
- where T : <Name of Base class>
- where T : <Name of Interface>

# Self-study

For the next lecture read about null-coalescing and null-conditional operators, one of the quiz questions will be on this topic