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Multidimensional Arrays

Processing Matrices and Multidimensional Tables

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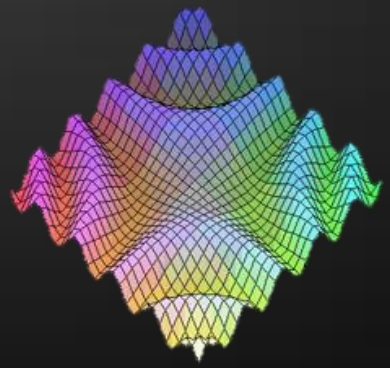

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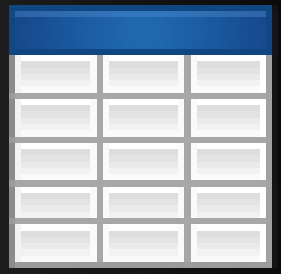

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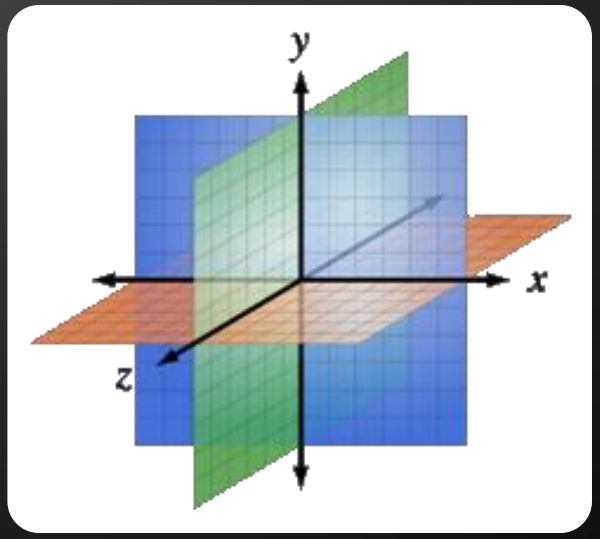
Multidimensional Arrays

Using Array of Arrays, Matrices and Cubes



What is Multidimensional Array?

- Multidimensional arrays have more than one dimension (2, 3, …)
  - The most important multidimensional arrays are the 2-dimensional
    - Known as matrices or tables
- Example of matrix of integers with 2 rows and 4 columns:

	0	1	2	3
0	5	0	-2	4
1	5	6	7	8

Declaring and Creating Multidimensional Arrays

- Declaring multidimensional arrays:

```
int[,] intMatrix;
float[,] floatMatrix;
string[,,] strCube;
```

- Creating a multidimensional array
  - Use new keyword
  - Must specify the size of each dimension

```
int[,] intMatrix = new int[3, 4];
float[,] floatMatrix = new float[8, 2];
string[,,] stringCube = new string[5, 5, 5];
```

Initializing Multidimensional Arrays with Values

- Creating and initializing with values multidimensional array:

```
int[,] matrix =
{
    {1, 2, 3, 4}, // row 0 values
    {5, 6, 7, 8}, // row 1 values
}; // The matrix size is 2 x 4 (2 rows, 4 cols)
```

  - Matrices are represented by a list of rows
    - Rows consist of list of values
  - The first dimension comes first, the second comes next (inside the first)

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Accessing The Elements of Multidimensional Arrays

- Accessing N-dimensional array element:

```
nDimensionalArray[index1, … , indexn]
```

- Getting element value example:

```
int[,] array = {{1, 2}, {3, 4}}
int element11 = array[1, 1]; // element11 = 4
```

- Setting element value example:

```
int[,] array = new int[3, 4];
for (int row=0; row<array.GetLength(0); row++)
  for (int col=0; col<array.GetLength(1); col++)
    array[row, col] = row + col;
```

Number of rows

Number of columns

Reading a Matrix – Example

- Reading a matrix from the console

```
int rows = int.Parse(Console.ReadLine());
int columns = int.Parse(Console.ReadLine());
int[,] matrix = new int[rows, columns];
String inputNumber;
for (int row=0; row<rows; row++)
{
  for (int column=0; column<cols; column++)
  {
    Console.Write("matrix[{0},{1}] = ", row, column);
    inputNumber = Console.ReadLine();
    matrix[row, column] = int.Parse(inputNumber);
  }
}
```

Printing Matrix – Example

- Printing a matrix on the console:

```
for (int row=0; row<matrix.GetLength(0); row++)
{
  for (int col=0; col<matrix.GetLength(1); col++)
  {
    Console.Write("{0} ", matrix[row, col]);
  }
  Console.WriteLine();
}
```

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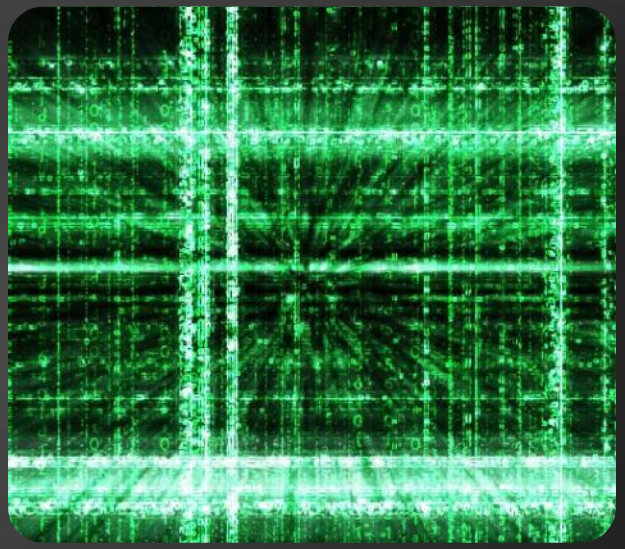

Reading and Printing Matrices

Live Demo

Maximal Platform – Example

- Finding a 2 x 2 platform in a matrix with a maximal sum of its elements

```
int[,] matrix = {
  {7, 1, 3, 3, 2, 1},
  {1, 3, 9, 8, 5, 6},
  {4, 6, 7, 9, 1, 0}
};
int bestSum = int.MinValue;
for (int row=0; row<matrix.GetLength(0)-1; row++)
  for (int col=0; col<matrix.GetLength(1)-1; col++)
  {
    int sum = matrix[row, col] + matrix[row, col+1]
       + matrix[row+1, col] + matrix[row+1, col+1];
    if (sum > bestSum)
      bestSum = sum;
  }
```

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Maximal Platform

Live Demo

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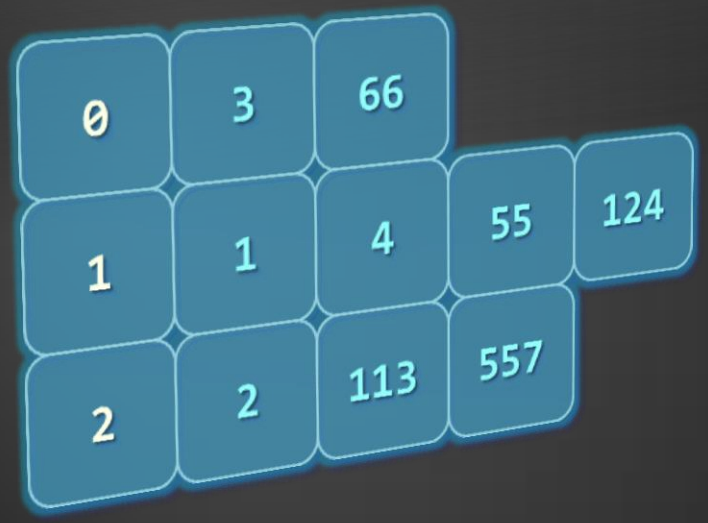
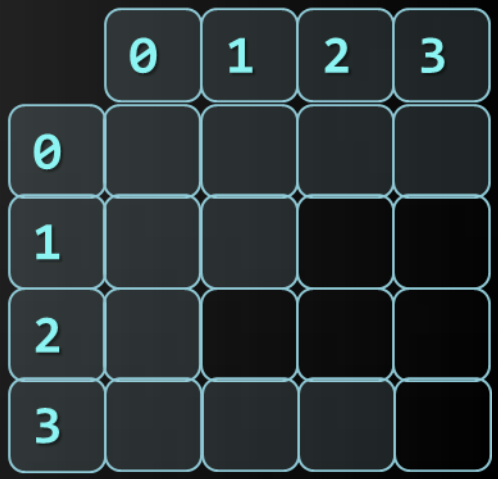


Jagged Arrays

What are Jagged Arrays and How to Use Them?

Jagged Arrays

- Jagged arrays are like multidimensional arrays
  - But each dimension has different size
  - A jagged array is array of arrays
  - Each of the arrays has different length
- How to create jagged array?




```
int[][] jagged = new int[3][];
jagged[0] = new int[3];
jagged[1] = new int[2];
jagged[2] = new int[5];
```

Initialization of Jagged Arrays

- When creating jagged arrays
  - Initially the array is created of `null` arrays
  - Need to initialize each of them

```
int[][] jagged=new int[n][];
for (int i=0; i<n; i++)
{
   jagged[i] = new int[i];
}
```

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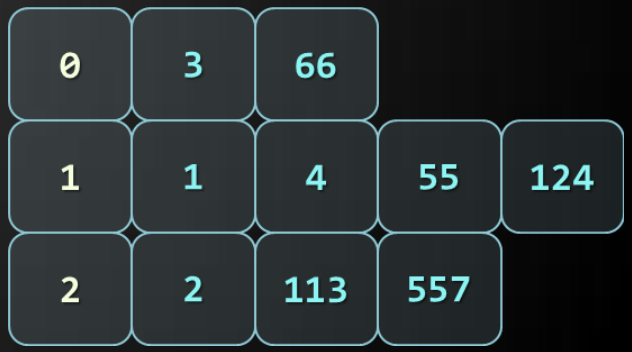
Jagged Arrays

Live Demo

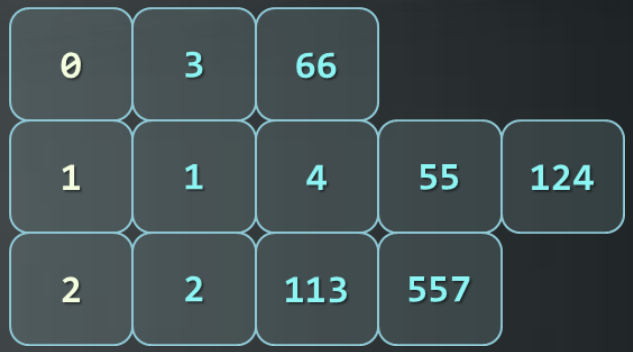
Example of Jagged Arrays

- Check a set of numbers and group them by their remainder when dividing to 3 (0, 1 and 2)
- Example: 0, 1, 4, 113, 55, 3, 1, 2, 66, 557, 124, 2
- First we need to count the numbers
  - Done with a iteration
- Make jagged array with appropriate sizes
- Each number is added into its jagged array



Example of Jagged Arrays

```
int[] numbers = {0,1,4,113,55,3,1,2,66,557,124,2};
int[] sizes = new int[3];
int[] offsets = new int[3];
foreach (var number in numbers)
{
    int remainder = number % 3;
    sizes[remainder]++;
}
int[][] numbersByRemainder = new int[3][] {
  new int[sizes[0]], new int[sizes[1]],
  new int[sizes[2]] };
foreach (var number in numbers)
{
    int remainder = number % 3;
    int index = offsets[remainder];
    numbersByRemainder[remainder][index] = number;
    offsets[remainder]++;
}
```



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Remainders of 3

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Array Class

What Can We Use?

The Array Class

- The `System.Array` class
  - Parent of all arrays
  - All arrays inherit from it
  - All arrays have the same:
    - Basic functionality
    - Basic properties
    - E.g. `Length` property

Methods of Array

- Important methods and properties of `System.Array`
  - `Rank` – number of dimensions
  - `Length` – number of all elements through all dimensions
  - `GetLength(index)` – returns the number of elements in the specified dimension
    - Dimensions are numbered from `0`

Methods of Array (2)

- `GetEnumerator()` – returns `IEnumerator` for the array elements
- `BinarySearch(…)` – searches for a given element into a sorted array (uses binary search)
- `IndexOf(…)` – searches for a given element and returns the index of the first occurrence (if any)
- `LastIndexOf(…)` – searches for a given element and returns the last occurrence index
- `Copy(src, dest, len)` – copies array elements; has many overloads

Methods of Array (3)

- `Reverse(…)` – inverts the arrays elements upside down
- `Clear(…)` – assigns value `0` (null) for each elements
- `CreateInstance(…)` – creates an array
  - Accepts as parameters the number of dimensions, start index and number of elements
- Implements `ICloneable`, `IList`, `ICollection` and `IEnumerable` interfaces

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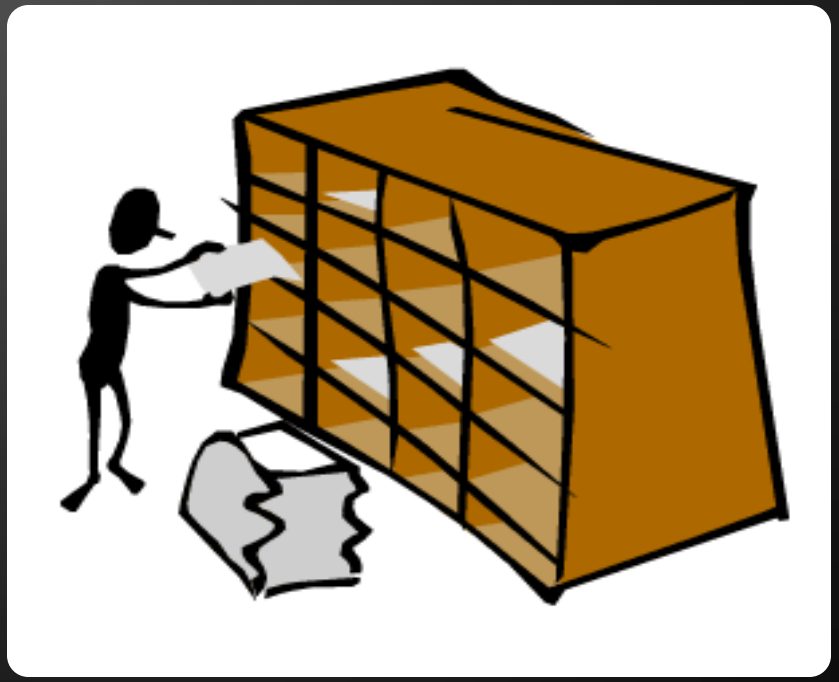
Sorting Arrays



Sorting Arrays

- Sorting in .NET is usually done with `System.Array.Sort()`
  - `Sort(Array)` – sorts array elements
    - Elements should implement `IComparable`
  - `Sort(Array, IComparer)` – sorts array elements by given external `IComparer`
  - `Sort(Array, Comparison<T>)` – sorts array elements by given comparison operation
    - Can be used with lambda expression

Sorting Arrays – Example

```
static void Main()
{
    String[] beers = {"Zagorka", "Ariana",
      "Shumensko","Astika", "Kamenitza", "Bolqrka",
      "Amstel"};
    Console.WriteLine("Unsorted: {0}",
        String.Join(", ", beers));
    // Elements of beers array are of String type,
    // which implement IComparable
    Array.Sort(beers);
    Console.WriteLine("Sorted: {0}",
        String.Join(", ", beers));
    // Result: Sorted: Amstel, Ariana, Astika,
    // Bolyarka, Kamenitza, Shumensko, Zagorka

}
```

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Sorting with IComparer<T> and Lambda Expressions – Example

```
class Student
{
    …
}
public class StudentAgeComparer : IComparer<Student>
{
    public int Compare(Student firstStudent, Student
    secondStudent)
    {
        return firstStudent.Age.CompareTo(secondStudent.Age);
    }
}

…
Array.Sort(students, new StudentAgeComparer());
…
Array.Sort(students, (x, y) => x.Name.CompareTo(y.Name));
```

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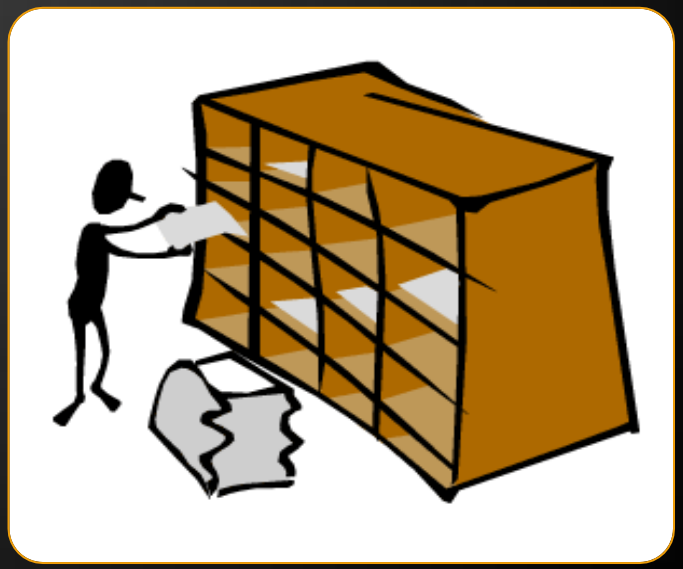
Sorting with IComparer<T> and Lambda Expressions

Live Demo



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Binary Search

Binary Search

- Binary search is a fast method for searching for an element in a sorted array
  - Has guaranteed running time of `O(log(n))` for searching among arrays of with `n` elements
- Implemented in the `Array.BinarySearch(Array, object)` method
  - Returns the index of the found object or a negative number when not found

Binary Search (2)

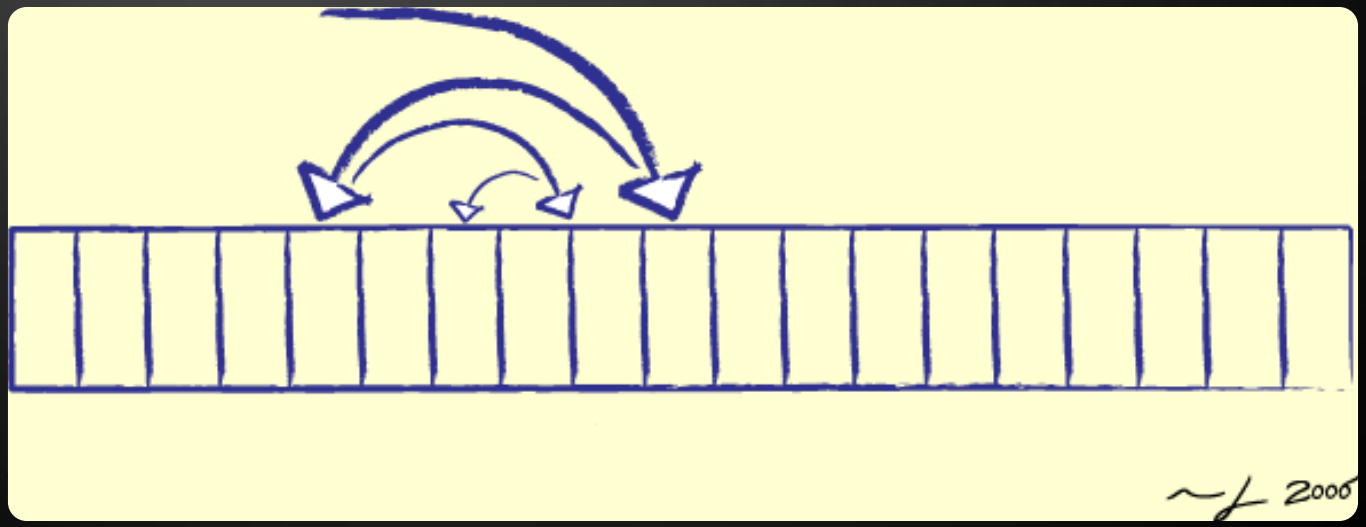
- All requirements of the `Sort()` method are applicable for `BinarySearch()`
  - Either all elements should implement `IComparable<T>` or instance of `IComparer<T>` should be passed

Binary Search – Example

```
static void Main()
{
    String[] beers = {"Zagorka", "Ariana",
     "Shumensko","Astika", "Kamenitza", "Bolqrka",
     "Amstel"};
    Array.Sort(beers);
    string target = "Astika";
    int index = Array.BinarySearch(beers, target);
    Console.WriteLine("{0} is found at index {1}.",
        target, index);
    // Result: Astika is found at index 2.
    target = "Heineken";
    index = Array.BinarySearch(beers, target);
    Console.WriteLine("{0} is not found (index={1}).",
        target, index);
    // Result: Mastika is not found (index=-5).
}
```

Binary Search

Live Demo



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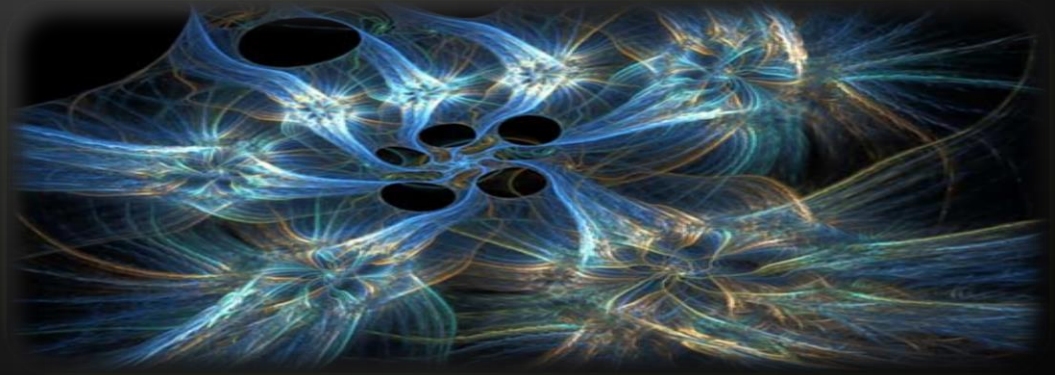
Working with Arrays

Best Practices



Advices for Working with Arrays

- When given method returns an array and should return an empty array, return an array with `0` elements, instead of `null`
- Arrays are passed by reference
  - To be sure that given method will not change the passed array, pass a copy of it
- `Clone()` returns shallow copy of the array
  - You should implement your own deep clone when working with reference types

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Arrays

Questions?

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Exercises

1. Write a program that fills and prints a matrix of size (n, n) as shown below: (examples for n = 4)

a)

1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16

b)

1	8	9	16
2	7	10	15
3	6	11	14
4	5	12	13

c)

7	11	14	16
4	8	12	15
2	5	9	13
1	3	6	10

d) *

1	12	11	10
2	13	16	9
3	14	15	8
4	5	6	7

Exercises (2)

2. Write a program that reads a rectangular matrix of size N x M and finds in it the square 3 x 3 that has maximal sum of its elements.
3. We are given a matrix of strings of size N x M. Sequences in the matrix we define as sets of several neighbor elements located on the same line, column or diagonal. Write a program that finds the longest sequence of equal strings in the matrix. Example:

ha	fifi	ho	hi
fo	ha	hi	xx
xxx	ho	ha	xx

⟶ ha, ha, ha

s	qq	s
pp	pp	s
pp	qq	s

⟶ s, s, s

Exercises (6)

4. Write a program, that reads from the console an array of N integers and an integer K, sorts the array and using the method `Array.BinSearch()` finds the largest number in the array which is ≤ K.
5. You are given an array of strings. Write a method that sorts the array by the length of its elements (the number of characters composing them).
6. * Write a class `Matrix`, to holds a matrix of integers. Overload the operators for adding, subtracting and multiplying of matrices, indexer for accessing the matrix content and `ToString()`.

Exercises (5)

7. * Write a program that finds the largest area of equal neighbor elements in a rectangular matrix and prints its size. Example:

1	3	2	2	2	4
3	3	3	2	4	4
4	3	1	2	3	3
4	3	1	3	3	1
4	3	3	3	1	1

→ 13

Hint: you can use the algorithm "Depth-first search" or "Breadth-first search" (find them in Wikipedia).

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