Vietnam National University of HCMC
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Data Structures and Algorithms
★ Arrays ★

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SCAN ME

Week by week topics (*)

1. OOP and Java
2. **Arrays**
3. Sorting
4. Queue, Stack
5. List
6. Recursion

Mid-Term

7. Advanced Sorting
8. Binary Tree
9. Hash Table
10. Graphs
11. Graphs Adv.

Final-Exam

8 LABS

Objective

- +Basics of Array in Java
- +Linear search – Binary search
- +Storing objects
- +Big O notation

Introduction

+How do we store list of integer entered by user?

```
int num1;
int num2;
int num3;
```

+If there are 100 of them !?

Introduction

- Array is the most commonly used data structure
- Built into most of the programming languages

123	412	19	20	

Definition

- An ARRAY is a collection of variables all of the same TYPE
  - Element
  - Index / positions
- In Java

	123	412	19	20	
index	*0*	*1*	*2*	*3*	*4*

Initialization

- By default, an array of integers is automatically initialized to 0 when it’s created

```
autoData[] carArray = new autoData[4000];
```

- Initialize an array of a primitive type

```
int[] intArray = { 0, 3, 6, 9, 12, 15, 18, 21, 24, 27 };
```

Accessing array elements

+ Element is access by index number via subscript
+ In Java,

`ArrayName[index]`

+ **`A[3], A[0]`**
+ **`A[6]`**

A	123	412	19	20	
index	*0*	*1*	*2*	*3*	*4*

Example in Java

```
int A[];
int A1[] = new int[100];
int A2[] = new int { 1, 7, 9, 20};

for (int i=0; i< 100; i++)
     A1[i] = i*2;

for (int j=0; j< A2.length; j++)
     A2[j] = j*2;
```

Operations on array

+Insertion

+Searching

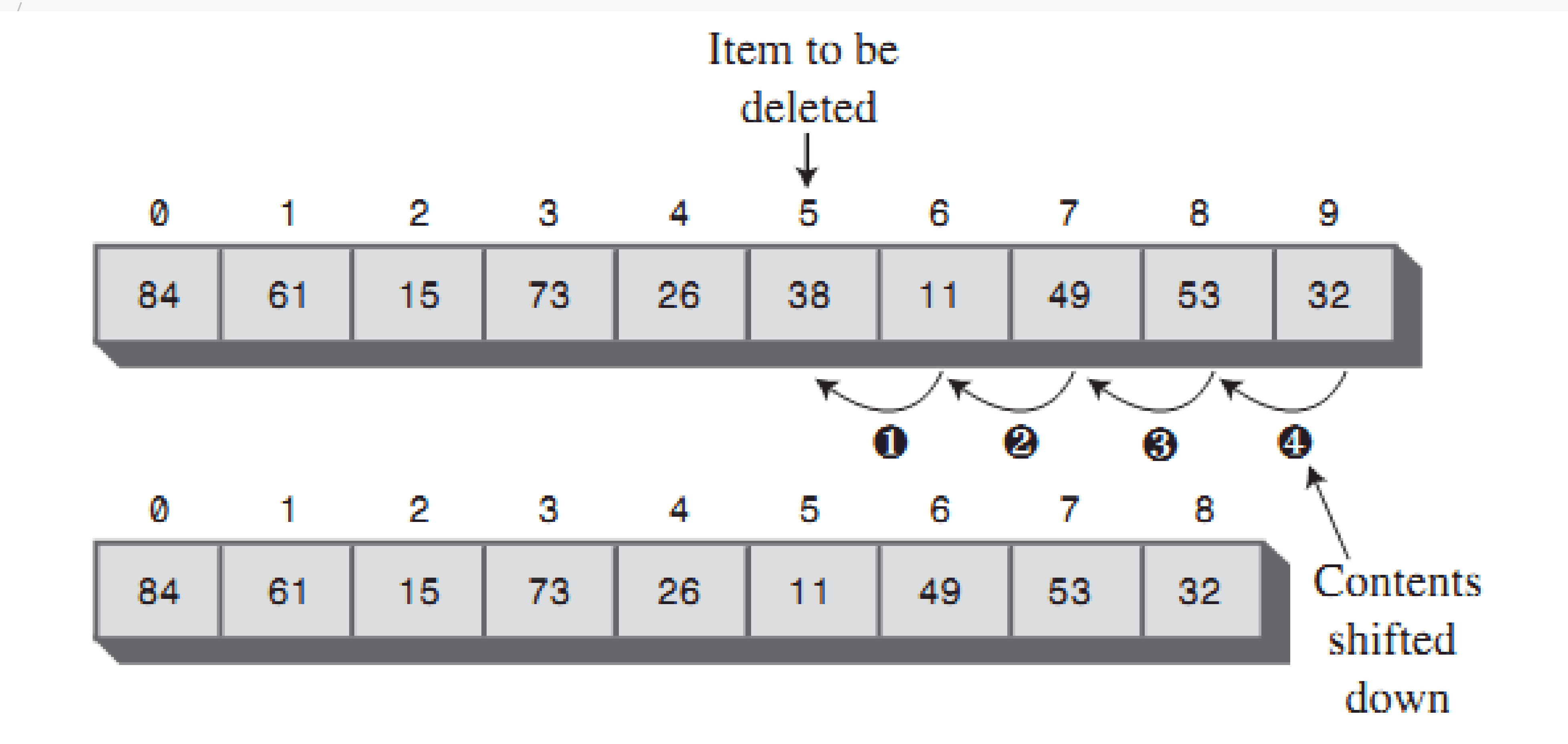
+Deletion

+Duplication issue

→How does it work ?

→Java code in p.41-42

Delete an item



Multi-dimension array

+ A matrix

1	0	3	4
5	1	32	12
6	7	1	10
19	5	4	1

Two-dimension array

+ Declaration

```
int [][] matrix = new int [ROWS][COLUMNS];
int [][] matrix2 =
{
    {1, 2, 3},
    {6, 1, 4},
    {9, 5, 1}
};
```

+ Accessing
    + **matrix[0][10];**

Linear searching technique

+Look for ‘20’ (the SearchKey)

A	123	412	19	20	25
index	*0*	*1*	*2*	*3*	*4*

+Step through the array

+Comparing the SearchKey with each element.

+Reach the end but don’t find any matched element
→ Can’t find

Ordered arrays

+ Data items are arranged in order of key value.

A	412	123	25	20	19
index	*0*	*1*	*2*	*3*	*4*

A2	19	20	25	123	412
Index	*0*	*1*	*2*	*3*	*4*

Linear searching in ordered array

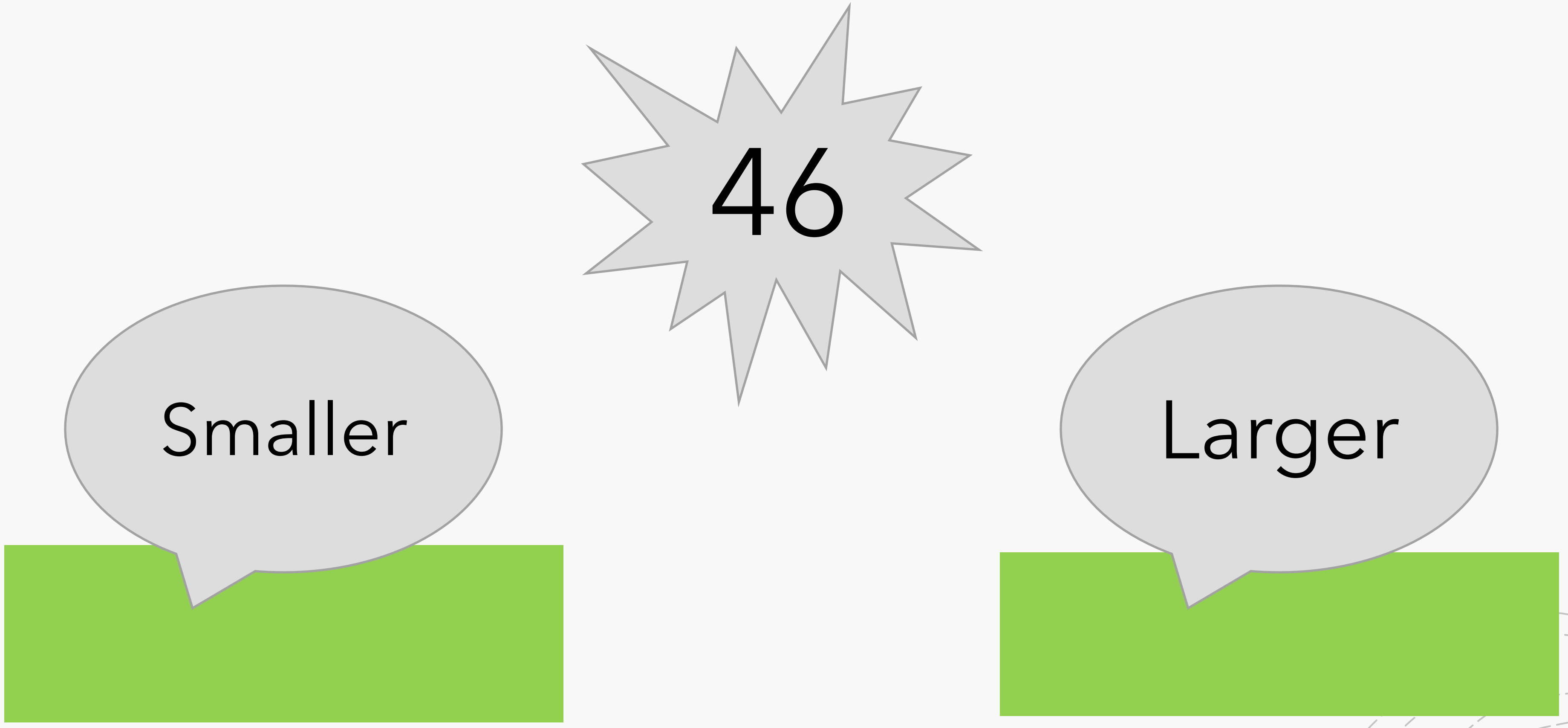
+ Look for '20'

A	412	123	25	20	19
index	*0*	*1*	*2*	*3*	*4*

A2	19	20	25	123	412
Index	*0*	*1*	*2*	*3*	*4*

Binary searching technique

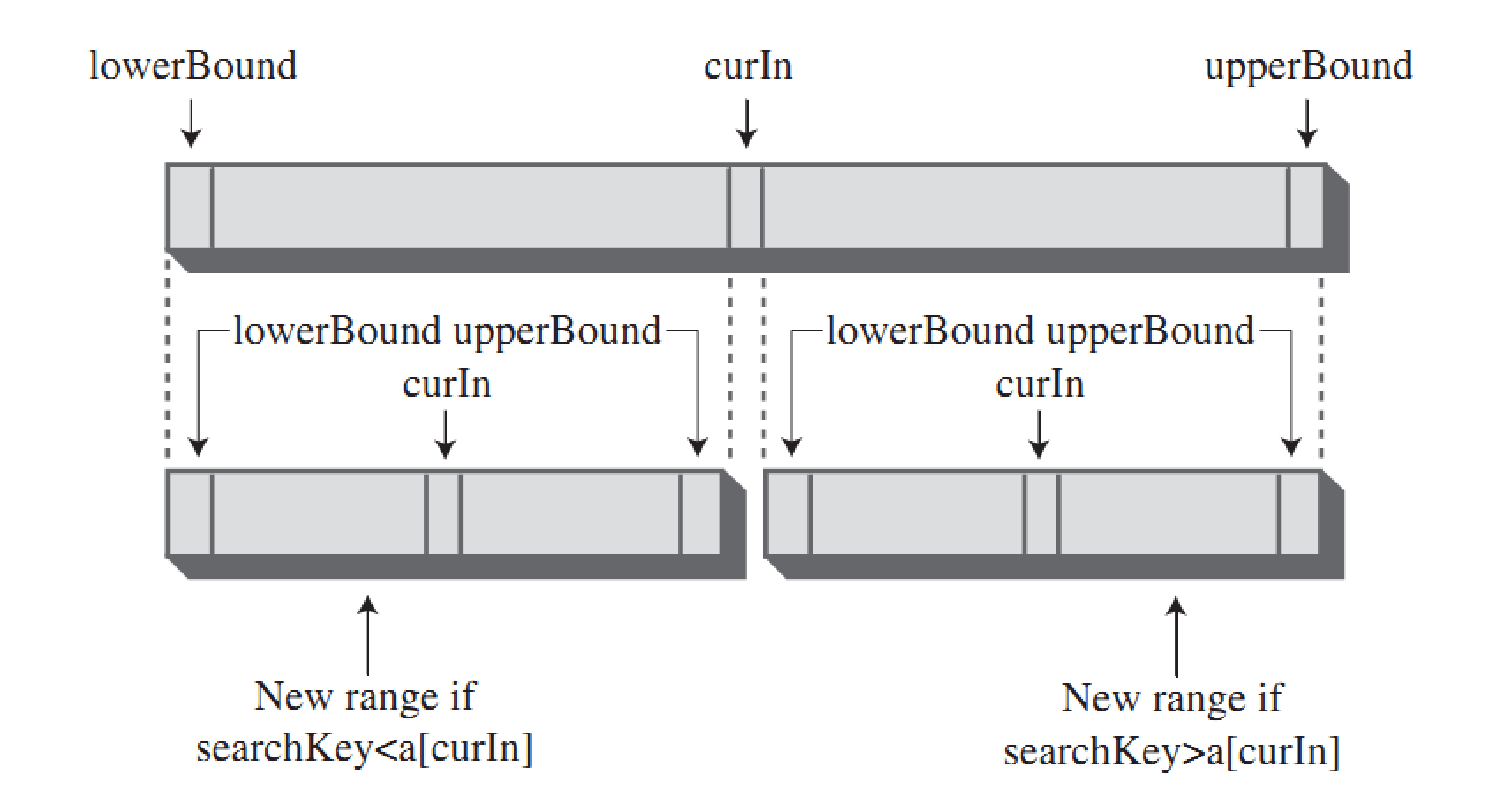
+ Guess the number between 1 and 100



Binary searching technique

Step #	Number guessed	Result	Range of possible value
0			0-100

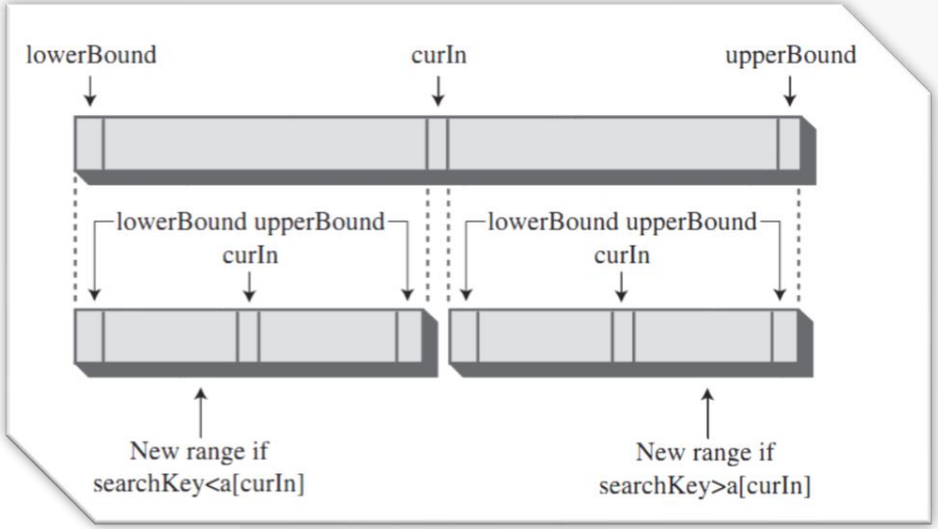
Algorithm



Binary search
Data structures and algorithms in Java – p.57

```java
public int find(long searchKey)
   {
   int lowerBound = 0;
   int upperBound = nElems-1;
   int curIn;

   while(true)
      {
      curIn = (lowerBound + upperBound ) / 2;
      if(a[curIn]==searchKey)
         return curIn;              // found it
      else if(lowerBound > upperBound)
         return nElems;             // can't find it
      else                          // divide range
         {
         if(a[curIn] < searchKey)
            lowerBound = curIn + 1; // it's in upper half
         else
            upperBound = curIn - 1; // it's in lower half
         }  // end else divide range
      }  // end while
   }  // end find()
```



In class work

- Modify the Binary search algorithm for a descending array

Advantage of ordered arrays

- Searching time : Good
- Inserting time : Not good
- Deleting time : Not good

- → Useful when
  - Searches are frequent
  - Insertions and deletions are not

Logarithm

+ Binary search

→ $Log_2(N)$

Range	Comparisons needed
10	4
100	7
1,000	10
10,000	14
100,000	17
1,000,000	20
10,000,000	24
100,000,000	27
1,000,000,000	30

Must known

2^i	n	$\log_2 n$		2^i	n	$\log_2 n$
2^0	1	0		2^6	64	6
2^1	2	1		2^7	128	7
2^2	4	2		2^8	256	8
2^3	8	3		2^9	512	9
2^4	16	4		2^{10}	1024	10
2^5	32	5		2^{11}	2048	11

Storing objects

We need to

- Store a collections of Students
- Search student by Student name
- Insert a new student, delete a student

In class work:

- Read the sample code in p.65-69
  - The ***Person*** Class
  - The ***classDataArray.java*** Program

Big O notation

- To measure the EFFICIENCY of algorithms
- Some notions
  - Constant
  - Proportional to N
  - Proportional to log(N)
- Big O relationships between time and number of items

Algorithms

- Are sequences of instructions
  - To solve a problem
  - In a finite amount of time

Analysis of Algorithms

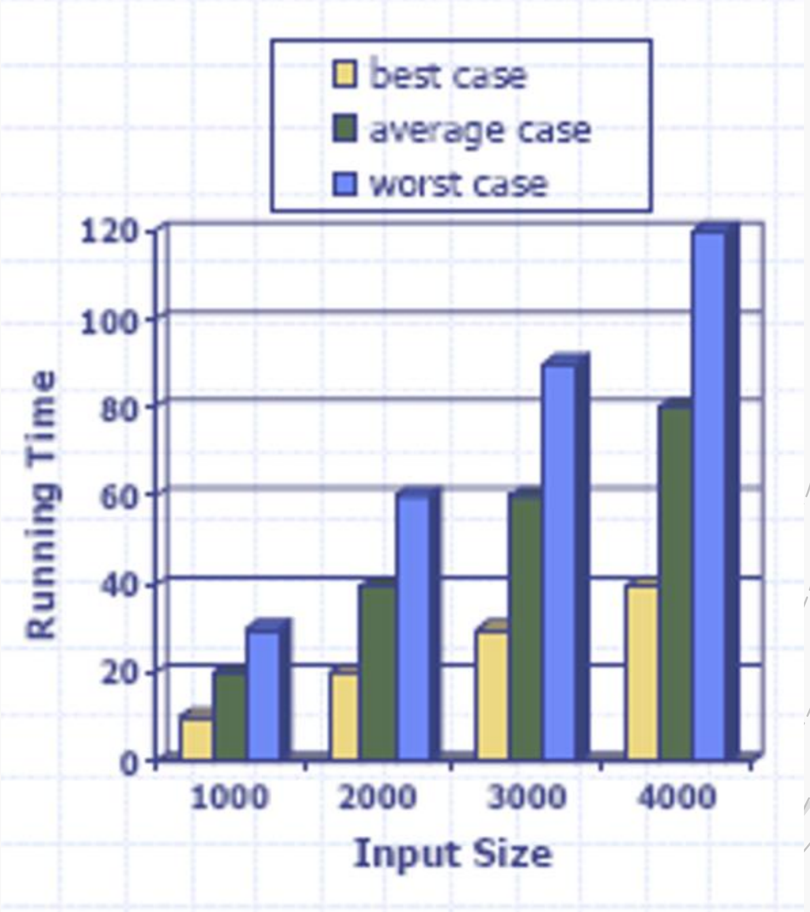
- What are requirements for a good algorithm?
- Precision:
  - Proved by mathematics
  - Implementation and test
- Simple
- Effectiveness:
  - Run time duration (time complexity)
  - Memory space (space complexity)

What is a computational complexity?

- The same problem can be solved with various algorithms that differ in efficiencies.
- The computational complexity (or simply speaking, complexity) of an algorithm is a measure of how “complex” the algorithm is.
  - How difficult is to compute something that we know to be computable?
  - What resources (time, space, machines, ...) will it take to get a result?
- We also often talk instead about how “efficient” the algorithm is
- Measuring efficiency (or complexity) allows us to compare one algorithm to another
- Here we’ll focus on one complexity measure: **the computation time** of an algorithm.

Running time

- Most algorithms transform input objects into output objects
- The running time of an algorithm typically grows with the input size
- Average case time is often difficult to determine
- We focus on the **worst-case** running time



Time complexity of an algorithm

- Run time duration of a program depend on
  - Size of data input
  - Computing system (platform: operation system, speed of CPU, type of statement…)
  - Programming languages
  - State of data

➔ It is necessary to evaluate the run time of a program such that it does not depend on computing system and programming languages.

Time complexity of an algorithm

- Time complexity = the number of operations given an input size.
  - What is meant by “number of operations”?
  - What is meant by “size”?
- The number of operations performed = **function of the input size n**.
- What if there are many different inputs of size n?
  - Worst case
  - Best case
  - Average case
- *“number of operations”* = *“running time”*?

Big-Oh Notation

+ Given function $f(n)$ and $g(n)$, we say that $f(n)$ is $O(g(n))$ if there are positive constants c and n_0 such that

$f(n) \leq c^*g(n)$ for all $n \geq n_0$

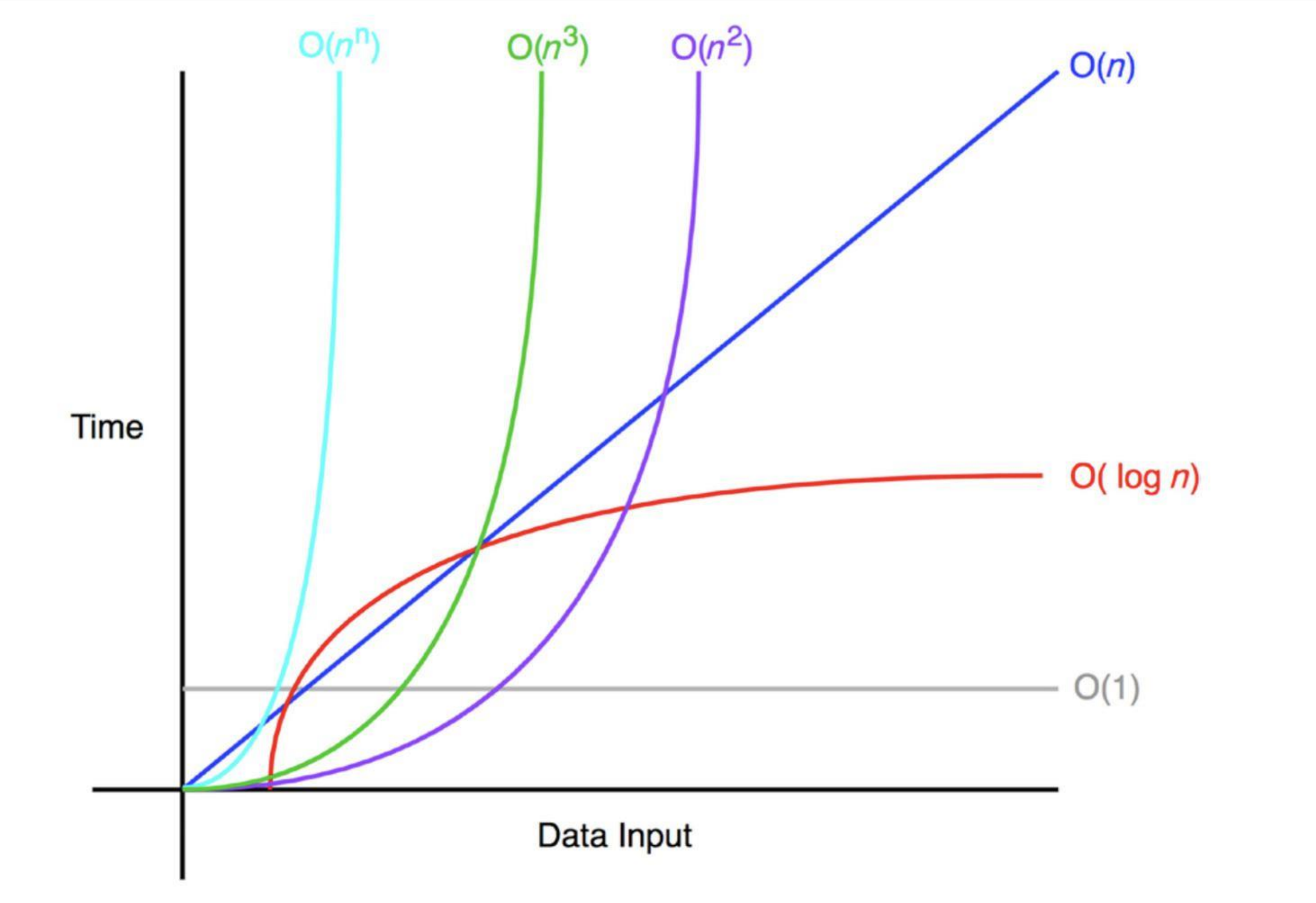
+ **Example**: $2n + 10$ is $O(n)$

  $2n + 10 \leq cn$

  $(c - 2)n \geq 10$

  $n \geq 10(c - 2)$

  ➔ Pick $c = 3$ and $n_0 = 10$



Big-Oh Notation

- **Another example:**
  - The function n^2 is not $O(n)$

    $n^2 \le cn$

    $n \le c$

  ➔ Cannot find a constant c and n_0 to satisfy this equation

O(1) – constant

- The time needed by the algorithm does not depend on the number of items
- Example
  - Insertion in an unordered array
  - Any others ?

O(N) – Proportional to N

+ Linear search of K items in an array of N items
  On average T = K * N /2

+ Average linear search times are proportional to size of array.

+ For an array of N′ items
  If   N′ = 2 * N
  Then   T′ = 2 * T

O(log N) – Proportional to log(N)

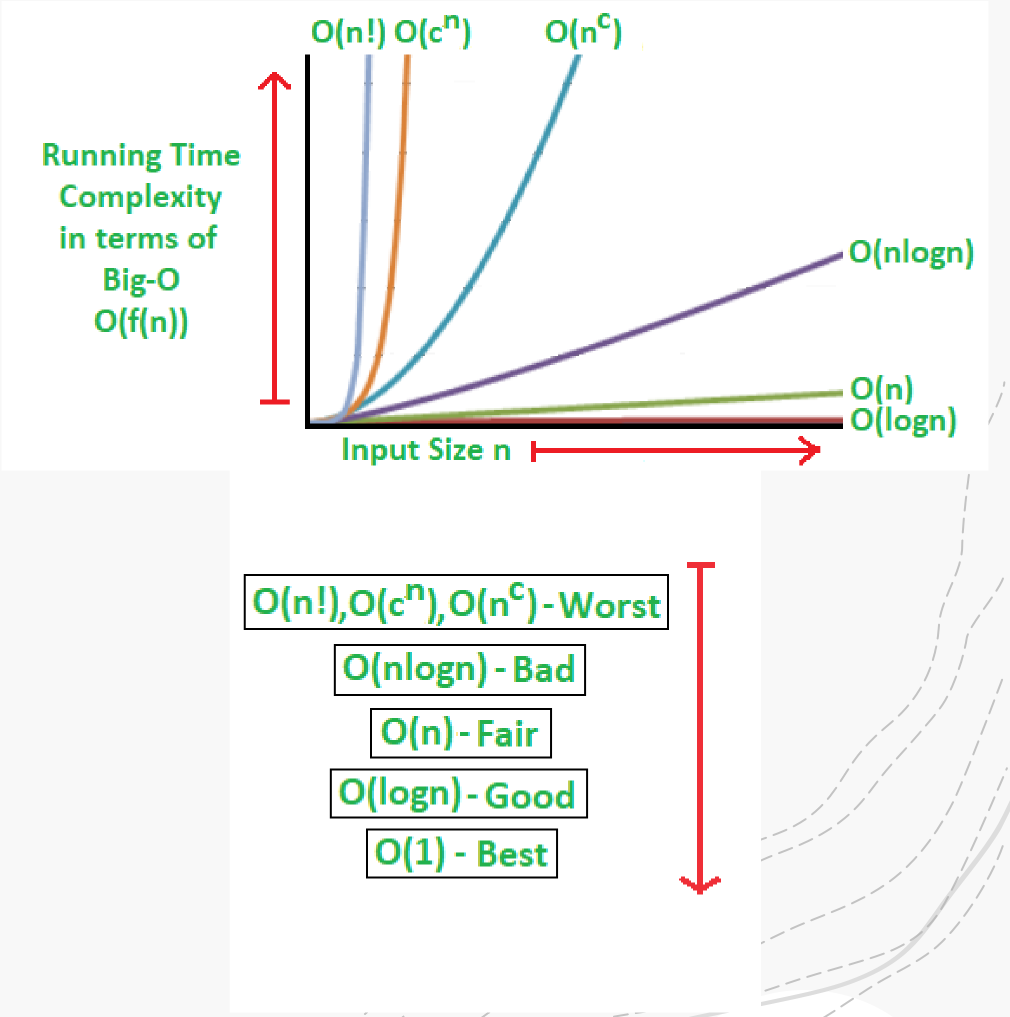
- For binary search:

$$T = K * \log_2(N)$$

- We can say : $T = K * \log(N)$
  - *any logarithm is related to any other logarithm by a constant (3.322 to go from base 2 to base 10*
  - *we can add the difference between* $\log_2$ *and log into K*

Some common growth orders of functions

constant	$O(1)$
logarithmic	$O(\log n)$
linear	$O(n)$
nlogn	$O(n \log n)$
quadratic	$O(n^2)$
polynomial	$O(n^b)$
exponential	$O(b^n)$
factorial	$O(n!)$



Summary

+ Arrays in Java are objects, created with new operator
+ Unordered arrays offer
  + fast insertion
  + slow searching and deletion
+ Binary search can be applied to an ordered array
+ Big O notation provides a convenient way to compare the speed of algorithms
+ An algorithm that runs in O(1) is the best, O(log N) is good, O(N) is fair and $O(N^2)$ is bad

Further reading

- Lafore, R. (2017). Data Structures and Algorithms in Java. United Kingdom: Pearson Education.
- Chapter 2: Arrays (p.33)

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THANK YOU

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