Problem Solving Techniques and Data Structures

Course Objectives

- Problem Solving Techniques
- Array, List, Stack, Queue
- Sorting Technique
- Searching Techniques
- Tree Data structure

Introduction to Problem Solving Techniques

Skills of Software Developer

- The following are the ten skills to be possessed by a software Developer
  - Analytical ability
  - Analysis
  - Design
  - Technical knowledge
  - Programming ability
  - Testing
  - Quality planning and Practice
  - Innovation
  - Team working
  - Communication

Performance measures

- The following are the five points deciding the performance of a software developer
  - Timeliness
  - Quality of work
  - Customer Orientation
  - Optimal solution
  - Team satisfaction

Problem-Definition

- **Definition:** A *problem* is a puzzle that requires logical thought or mathematics to solve

- What is **Problem solving** ?

  The act of defining a problem; determining its cause; identifying, prioritizing and selecting alternatives for a solution; and implementing that solution.

Problem Solving-Steps

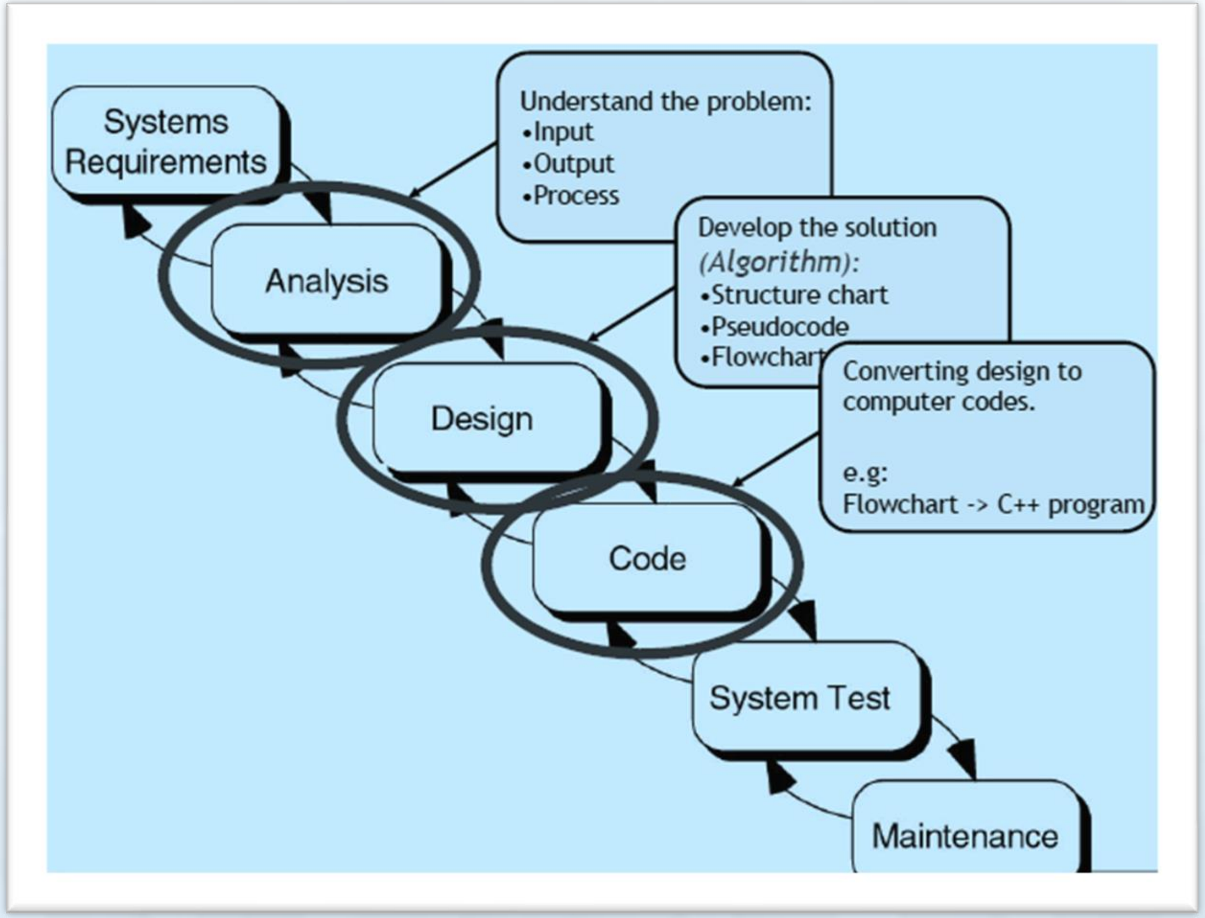
Analyze and understand the Problem

Select a method to solve the problem

Design a solution

Develop the solution

Test the solution



Problem Classification

- Concurrent: Operations overlap in time
- Sequential: Operations are performed in a step-by-step manner
- Distributed: Operations are performed at different locations
- Event-Based: Operations are performed based on the input

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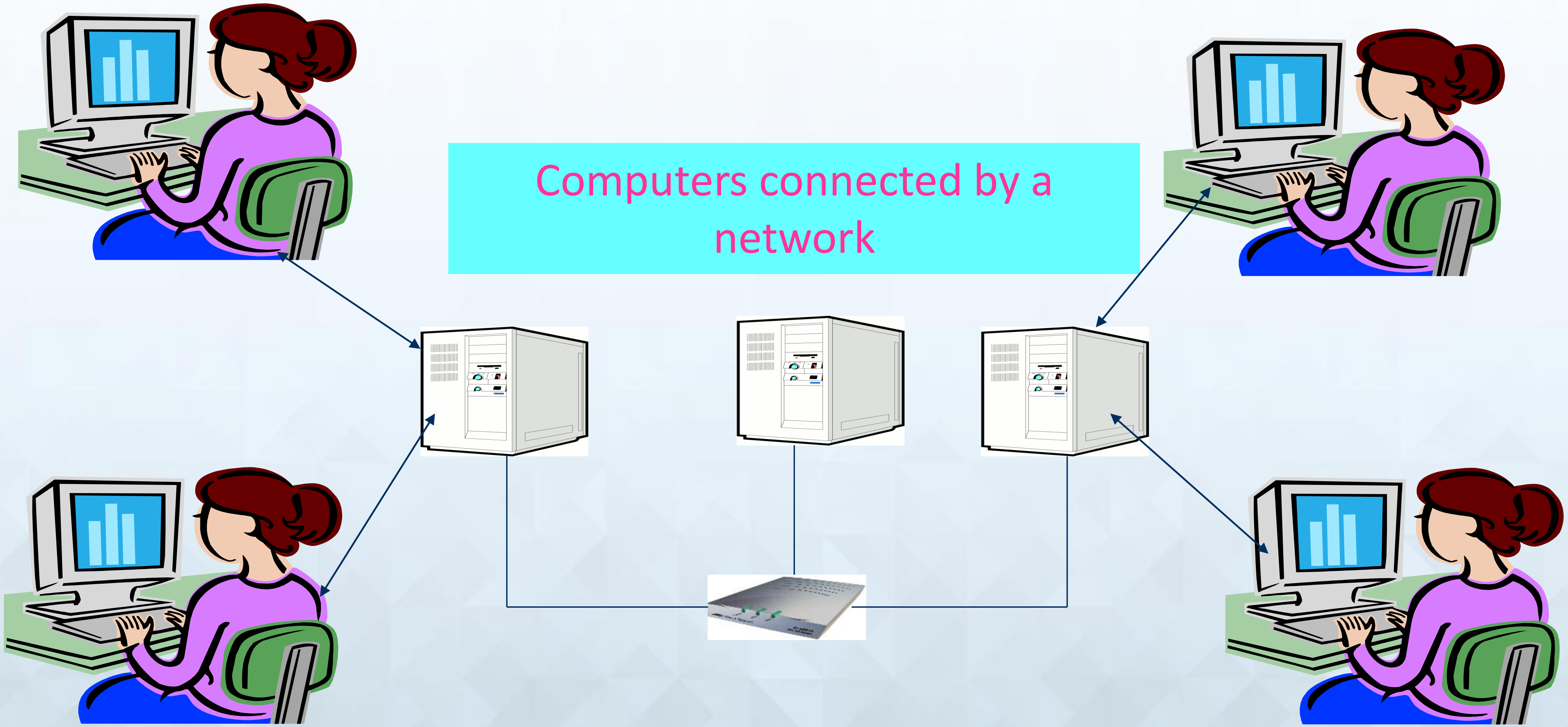
Distributed/Concurrent Problems



Sequential/Event based-Example

Problem solving methods

- Heuristic approach/ Brute Force technique
- Greedy approach
- Divide and Conquer technique
- Dynamic Programming technique

Heuristic/ Brute Force approach

- Brute force approach is a straight forward approach to solve the problem. It is directly based on the problem statement and the concepts

- Brute force is a simple but a very costly technique
- Example: Breaking Password

Watch the video to get more clarity on Heuristic approach

https://www.youtube.com/watch?v=ZINodNt-33g

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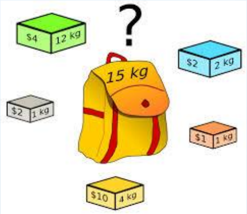
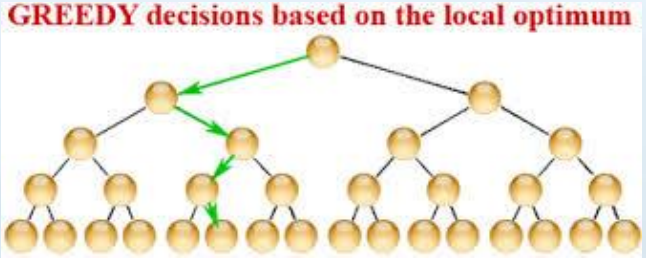
Greedy Approach

- Greedy design technique is primarily used in Optimization problems

- The Greedy approach helps in constructing a solution for a problem through a sequence of steps where each step is considered to be a partial solution. This partial solution is extended progressively to get the complete solution

- The choice of each step in a greedy approach is done based on the following
  - It must be feasible
  - It must be locally optimal
  - It must be irrevocable
- Example: TSP- Traveling Salesman Problem
- https://www.youtube.com/watch?v=SC5CX8drAtU





Divide-and-Conquer

The most-well known algorithm design strategy:

1. Divide instance of problem into two or more smaller instances

2. Solve smaller instances recursively

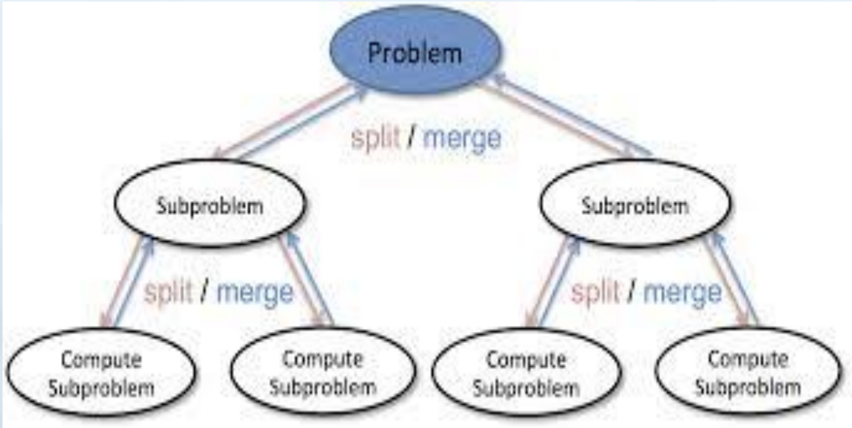
3. Obtain solution to original (larger) instance by combining these solutions

Example:

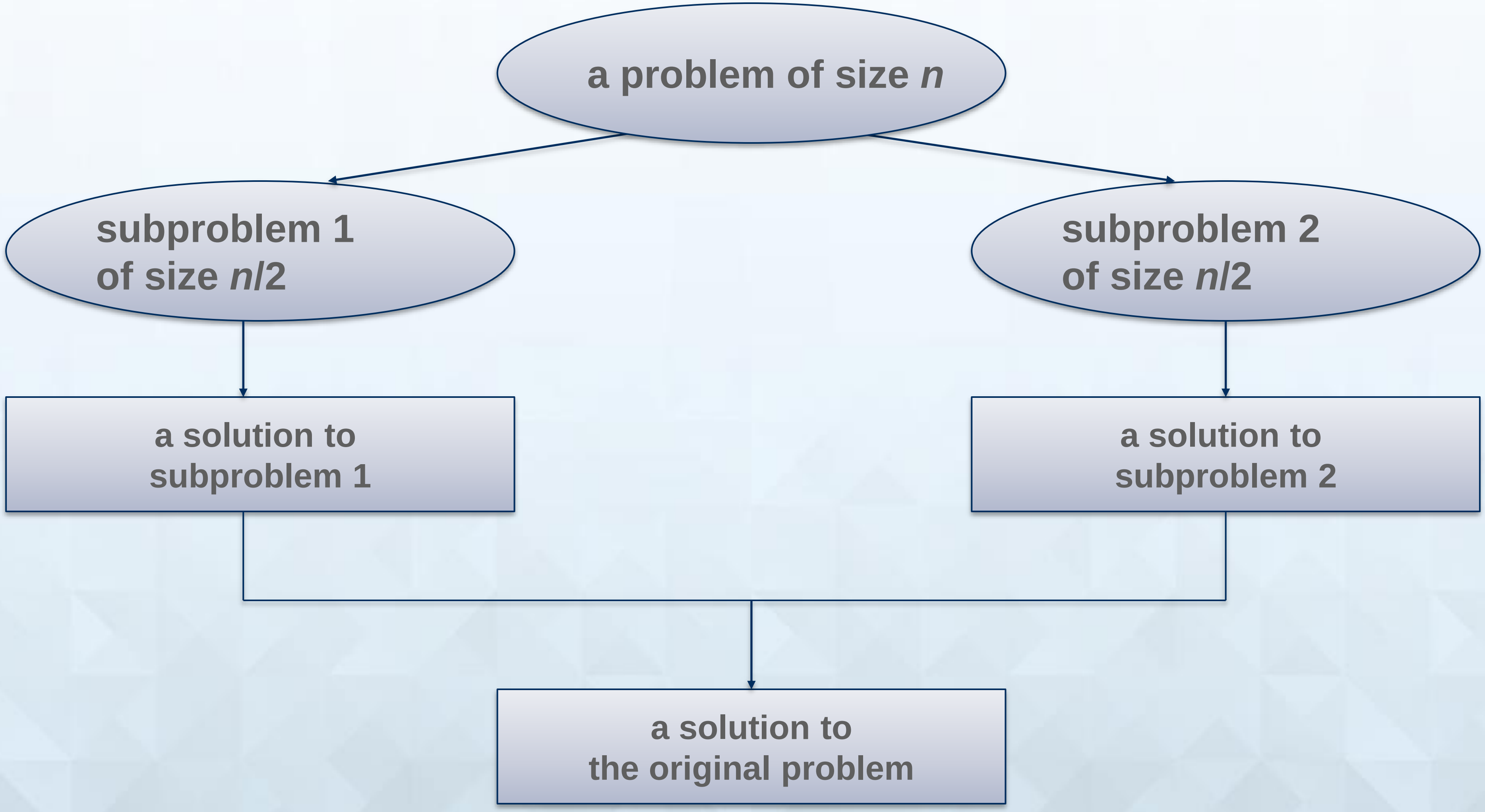
– Binary Search

Divide and Conquer

https://www.youtube.com/watch?v=wVPCT1VjySA



Divide-and-Conquer Technique (cont.)



Dynamic Programming

- Dynamic Programming is a design principle which is used to solve problems with overlapping sub problems
- It solves the problem by combining the solutions for the sub problems
- “Programming” here means “planning”
- Main idea:
  - set up a recurrence relating a solution to a larger instance to solutions of some smaller instances
  - solve smaller instances once
  - record solutions in a table
  - extract solution to the initial instance from that table
- The difference between Dynamic Programming and Divide and Conquer is that the sub problems in Divide and Conquer are considered to be disjoint and distinct whereas in Dynamic Programming they are overlapping

Dynamic Programming-Example

You have three jugs, which we will call A, B, and C. Jug A can hold exactly 8 cups of water, B can hold exactly 5 cups, and C can hold exactly 3 cups. A is filled to capacity with 8 cups of water. B and C are empty. We want you to find a way of dividing the contents of A equally between A and B so that both have 4 cups. You are allowed to pour water from jug to jug.

Solution

Step 1: First fill the 8L bucket full.

Step 2: Pour the water from 8L bucket to 5L bucket. Water remaining in 8L bucket is 3L.

Step 3: Pour the water from 5L bucket to 3L bucket. Water remaining in 5L bucket is 2L.

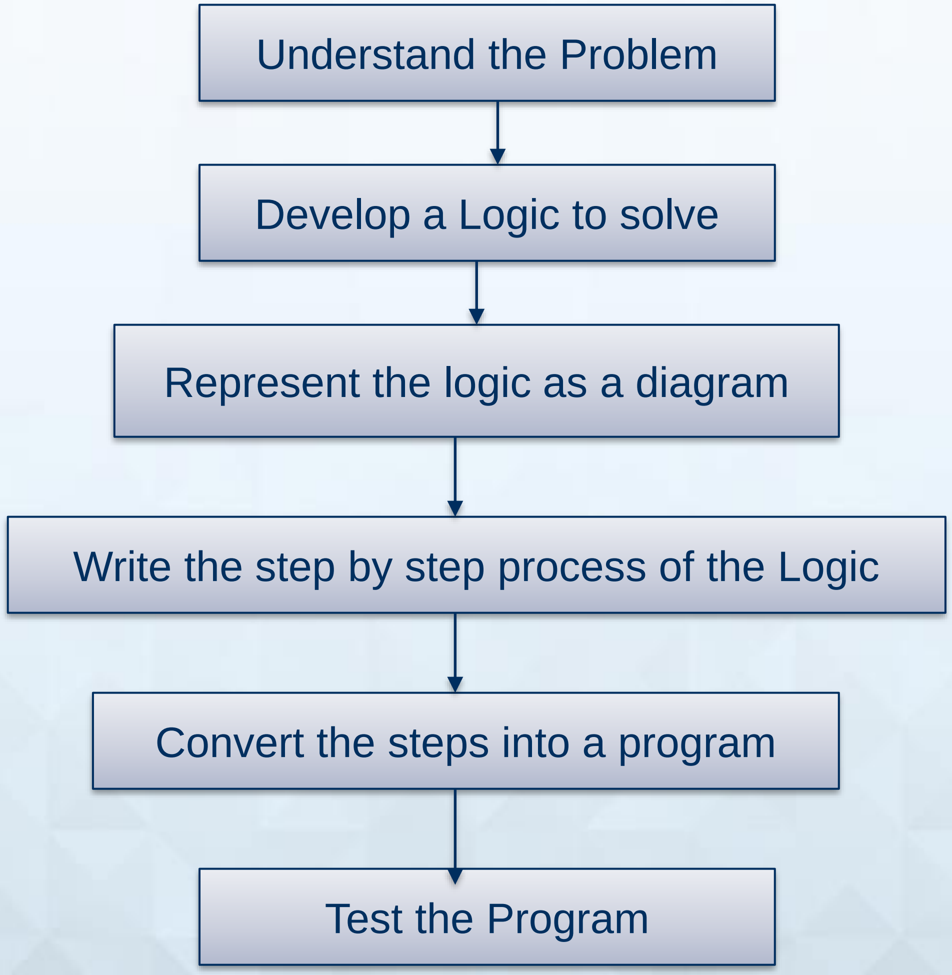
Step 4: Pour the water from 3L bucket to 8L bucket. Water in 8L bucket is 6L now and 3L bucket gets empty.

Step 5: Pour the water from 5L bucket to 3L bucket. Water in 3L bucket is 2L now and 5L bucket gets empty.

Step 6: Pour the water from 8L bucket to 5L bucket. Water remaining in 8L bucket is 1L 5L bucket gets full.

Step 7: Pour the water from 5L bucket to 3L bucket. Water remaining in 5L bucket is now 4L as 3L bucket already had 2L of water and when we poured water from 5l bucket to 3L bucket we poured 1L of water from 5L bucket and thus the remaining water in 5L bucket is now 4L.

Computer Based Problem Solving -Steps



- Analysis of the Problem
- Selecting a solution method
- Draw Flowcharts
- Develop Algorithms using Pseudo codes
- Develop Program using Programming language
- Test the program

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Modeling Tools

- Diagrammatic Representation of Logic

- Different Types:

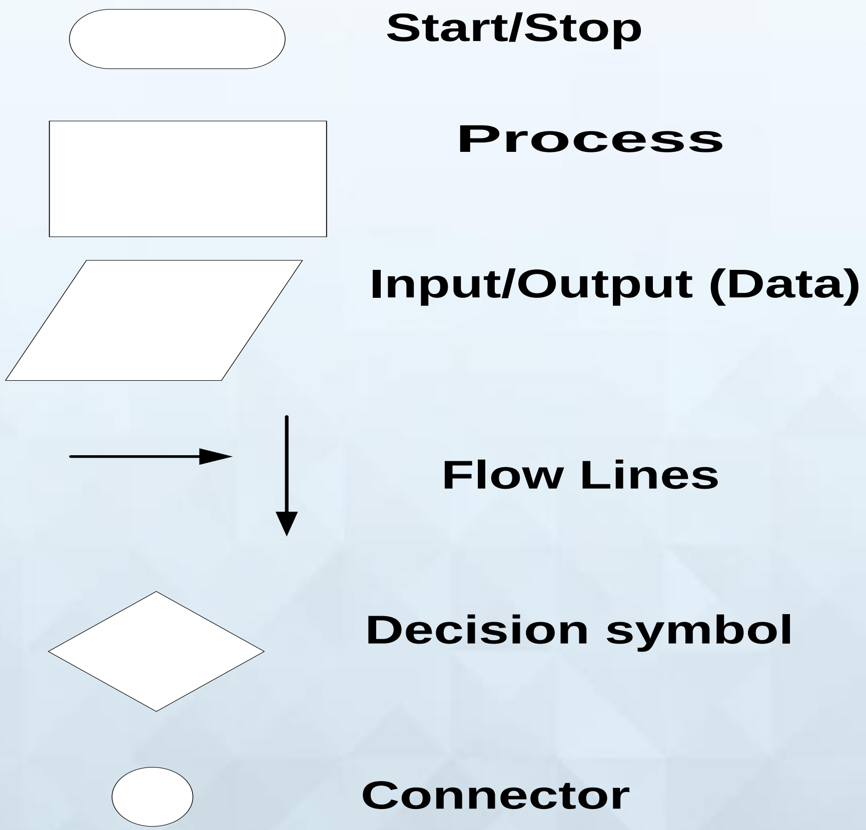
  - Flow Charts
  - Data flow Diagrams
  - Entity Relationship diagram
  - Unified Modeling Language

Flow Charts

Flow Charts

- A flowchart is a diagrammatic representation of an algorithm
- A flow chart is an organized combination of shapes, lines and text that graphically illustrates a process or structure

Symbols used



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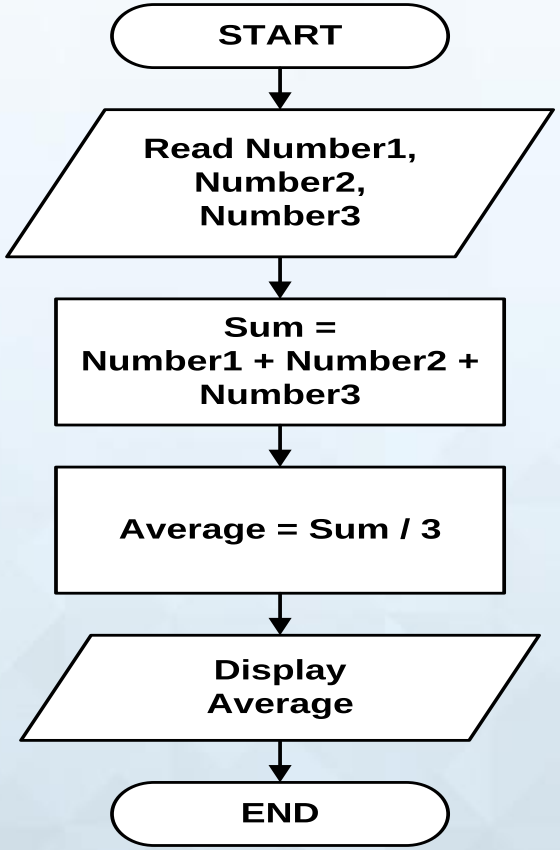
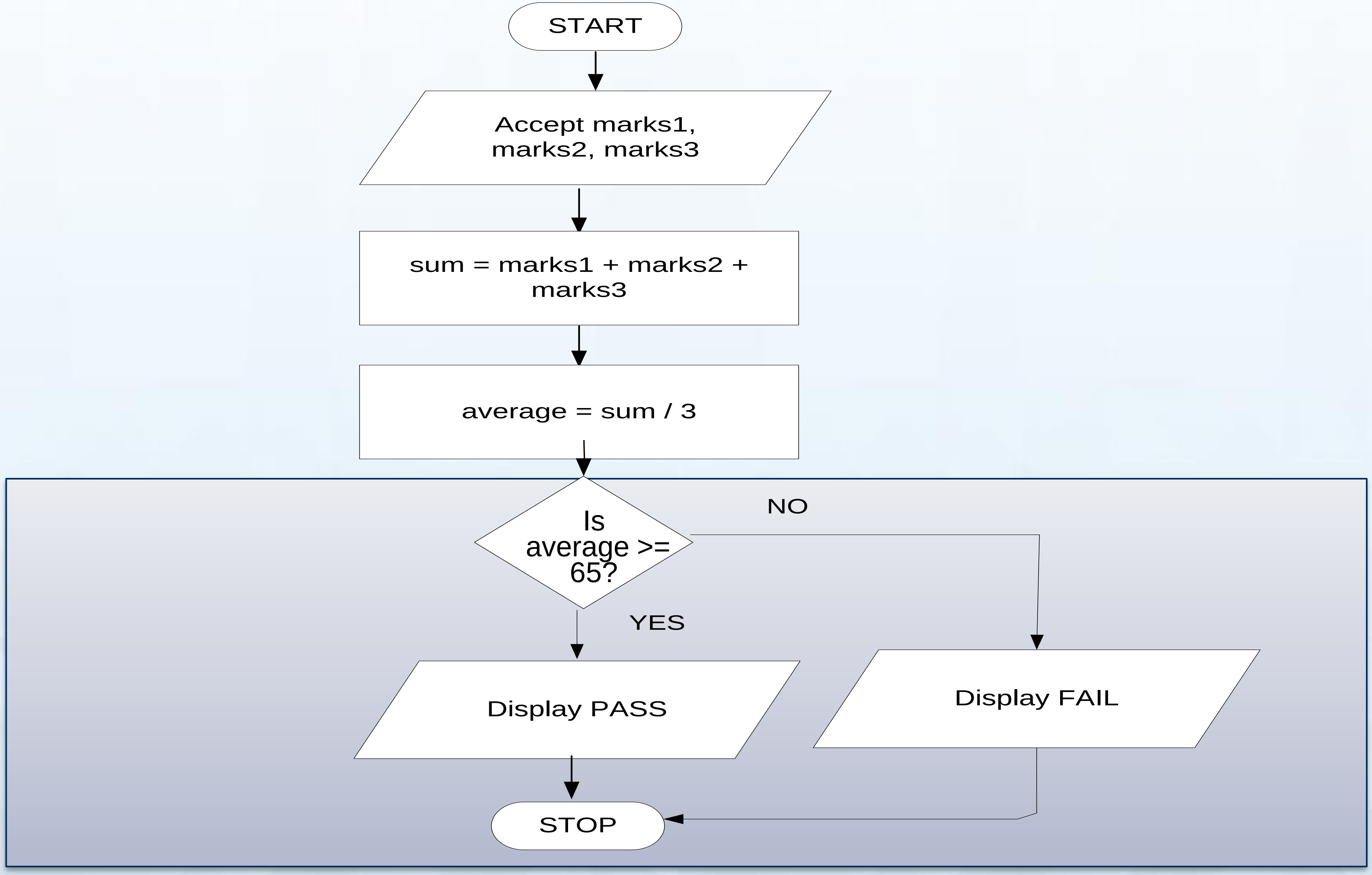
Example: Flow Chart (Sequential)

Find the average of three numbers



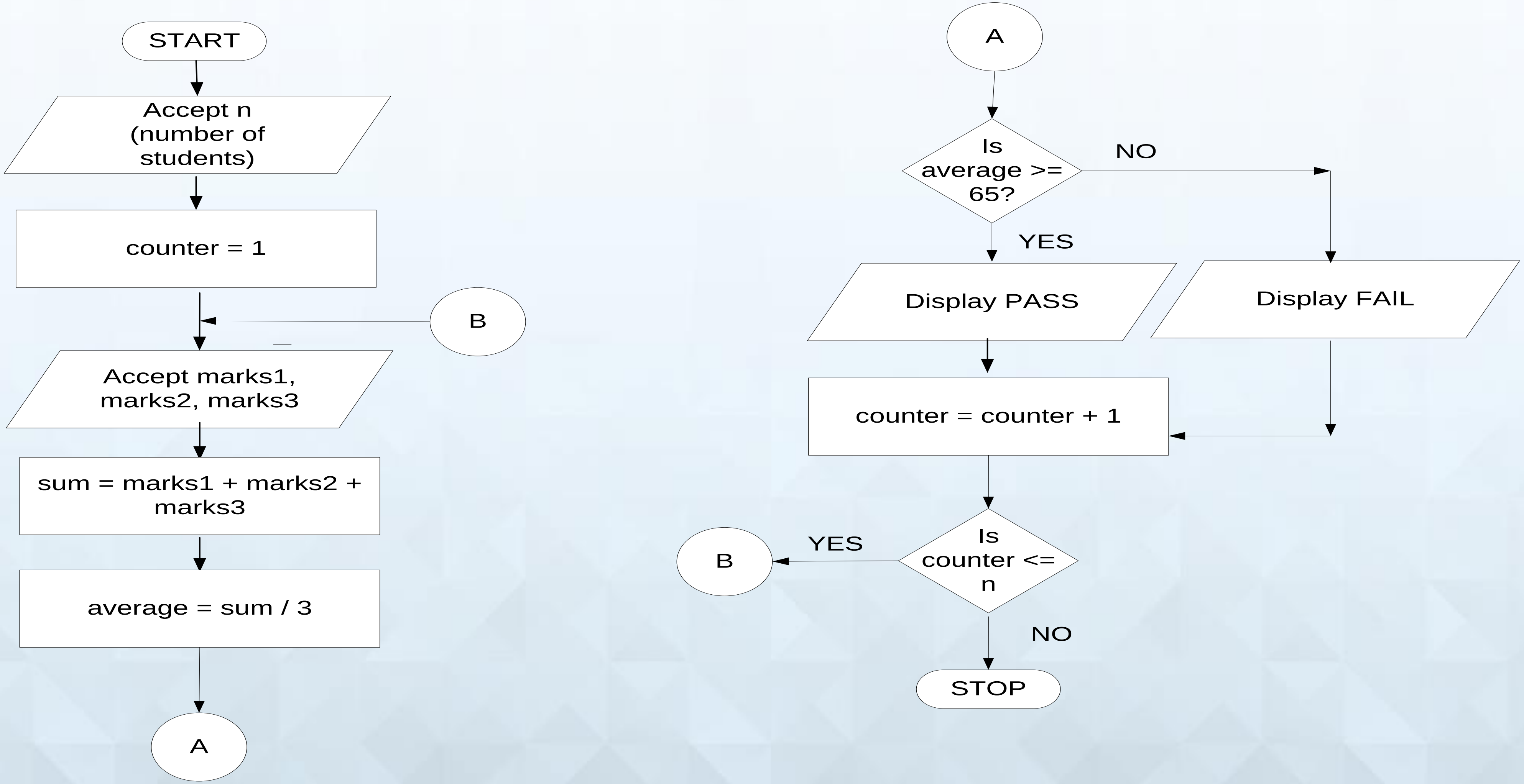
Flow Chart - Selectional



Example (Iterational)

- Do the following for N input values. Read N from user
  - Write a program to find the average of a student given the marks he obtained in three subjects.
  - Then test whether he passed or failed.
  - For a student to pass, average should not be less than 65.

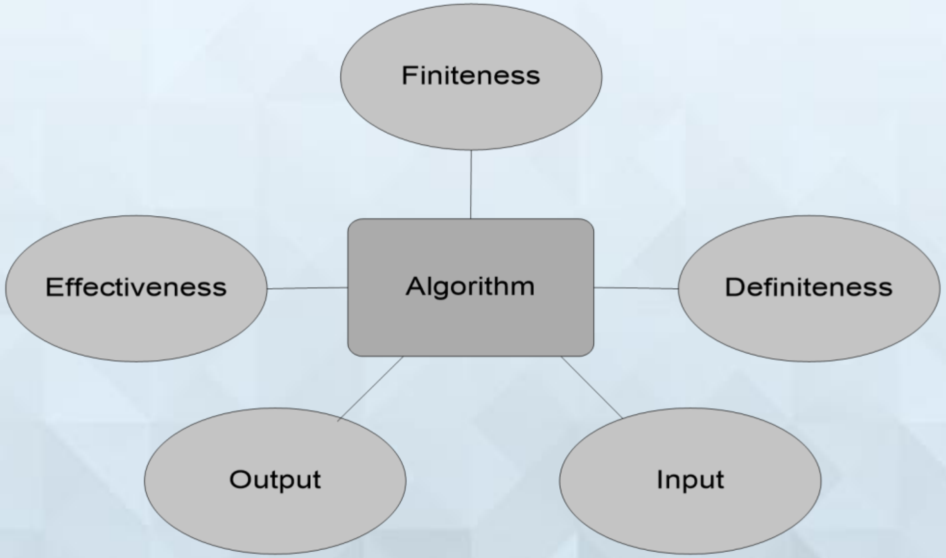
Flow Chart – Example (Iterational)



Algorithm

Algorithm

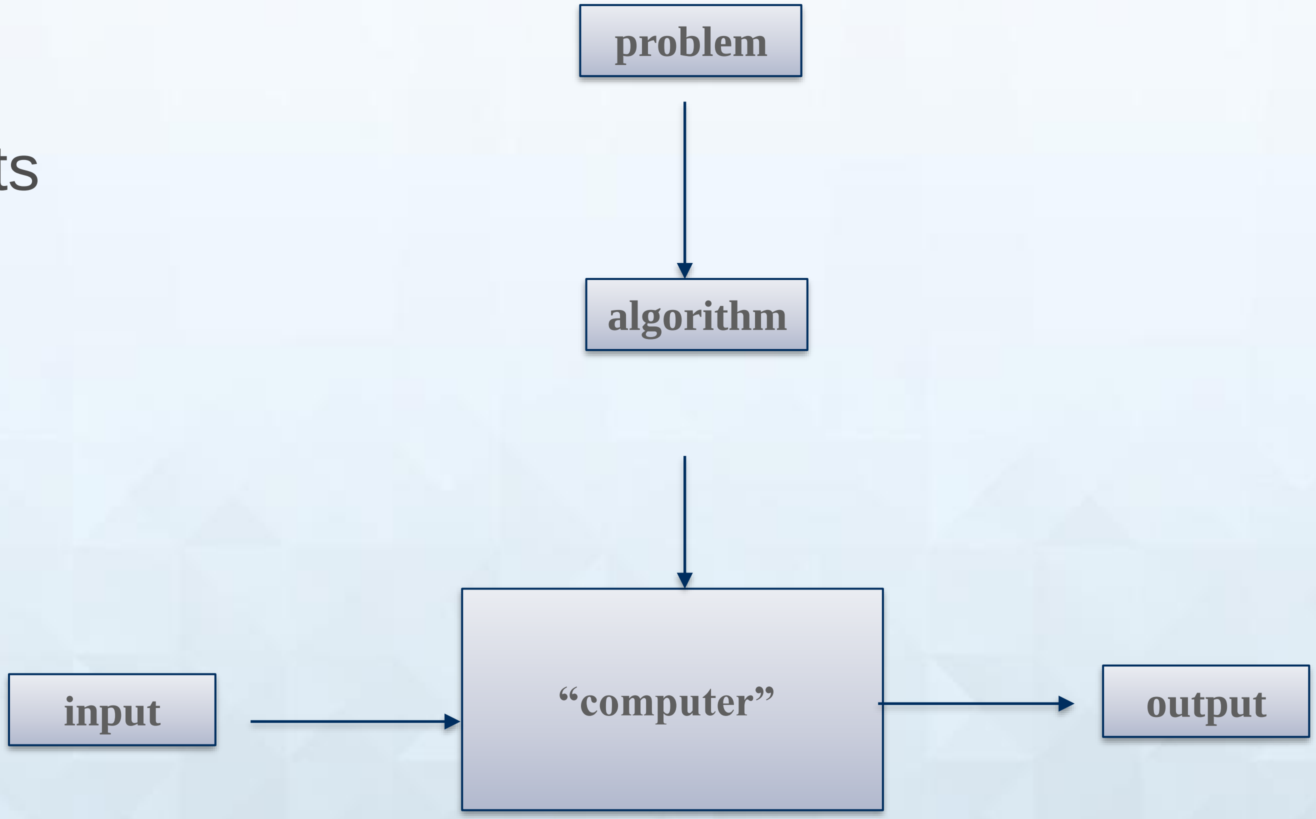
- An *algorithm* is a sequence of unambiguous instructions for solving a problem, i.e., for obtaining a required output for any legitimate input in a finite amount of time.
- Recipe, process, method, technique, procedure, routine,… with following requirements:
- The properties of an algorithm are as follows:



- ✓ Finiteness
  - terminates after a finite number of steps
- ✓ Definiteness
  - rigorously and unambiguously specified
- ✓ Input
  - valid inputs are clearly specified
- ✓ Output
  - can be proved to produce the correct output given a valid input
- ✓ Effectiveness
  - steps are sufficiently simple and basic

Steps to develop Algorithm

- Identify the Inputs and Outputs
- Identify any other data and constants required to solve the problem
- Identify what needs to be computed
- Write an algorithm



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Algorithm – Example (1 of 2)

Find the average marks scored by a student in 3 subjects:

BEGIN

Step 1 : Accept 3 marks say Marks1, Marks2, Marks3 scored by the student

Step 2 : Add Marks1, Marks2, Marks3 and store the result in Total

Step 3 : Divide Total by 3 and find the Average

Step 4 : Display Average

END

Algorithm-Example (2 of 2)

Find the average marks scored by a student in 3 subjects:

BEGIN

Step 1 : Read Marks1, Marks2, Marks3

Step 2 : Sum = Marks1 + Marks2 + Marks3

Step 3 : Average = Sum / 3

Step 4 : Display Average

END

Different Patterns in Algorithms

- **Sequential**
  - Sequential constructs execute the program in the order in which they appear in the program
- **Selectional (Conditional)**
  - Selectional constructs control the flow of statement execution in order to achieve the required result
- **Iterational (Loops)**
  - Iterational constructs are used when a part of the program is to be executed several times

Example - Selectional

- Write an algorithm to find the average marks of a student. Also check whether the student has passed or failed.
- For a student to pass, average marks should not be less than 65.

BEGIN
Step 1 : Read Marks1, Marks2, Marks3
Step 2 : Total = Marks1 + Marks2 + Marks3
Step 3 : Average = Total / 3
Step 4 : Set Output = “Student Passed”
Step 5 : if Average < 65 then Set Output = “Student Failed”
Step 6 : Display Output
END

Example - Iterational

Find the average marks scored by ‘N’ number of students

BEGIN
Step 1 : Read NumberOfStudents
Step 2 : Counter = 1
Step 3 : Read Marks1, Marks2, Marks3
Step 4 : Total = Marks1 + Marks2 + Marks3
Step 5 : Average = Total / 3
Step 6 : Set Output = “Student Passed”
Step 7 : If (Average < 65) then Set Output = “Student Failed”
Step 8 : Display Output
Step 9 : Counter = Counter + 1
Step 10 : If (Counter <= NumberOfStudents) then goto step 3
END

Recap

- Skills of a software developer
- Problem classification
- Problem solving approaches
- Flow Chart
- Algorithm patterns

Data Structures

Data Structures

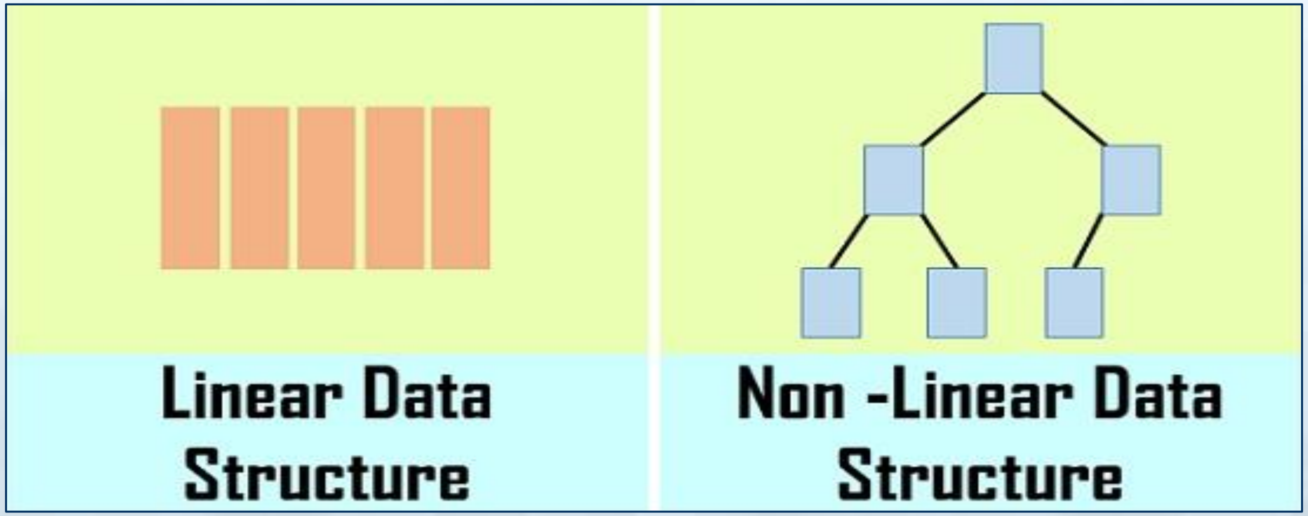
- Data structures is concerned with the representation and manipulation of data
- All programs manipulate data
- So, all programs represent data in some way
- Data manipulation requires an algorithm
- The study of Data Structure is fundamental to computer programming

Types of Data Structure

There are basically two types of data structure

1.Linear Data Structure

2.Non-Linear Data Structure.



Basic data structures: *data collections*

- Linear structures
  - Array: Fixed-size
  - Linked List: Add to top, bottom or in the middle
  - Stack: Add to top and remove from top
  - Queue: Add to back and remove from front
  - Priority queue: Add anywhere, remove the highest priority

- Non- Linear Data Structure
  - Tree: A branching structure with no loops
  - Graph: A more general branching structure, with less stringent connection conditions than for a tree

Static vs. Dynamic Structures

- A static data structure has a fixed size

  This meaning is different from the meaning of the static modifier (variable shared among all instances of a class)

- Arrays are static; once you define the number of elements it can hold, the number doesn't change

- A dynamic data structure grows and shrinks at execution time as required by its contents

- A dynamic data structure is implemented using links

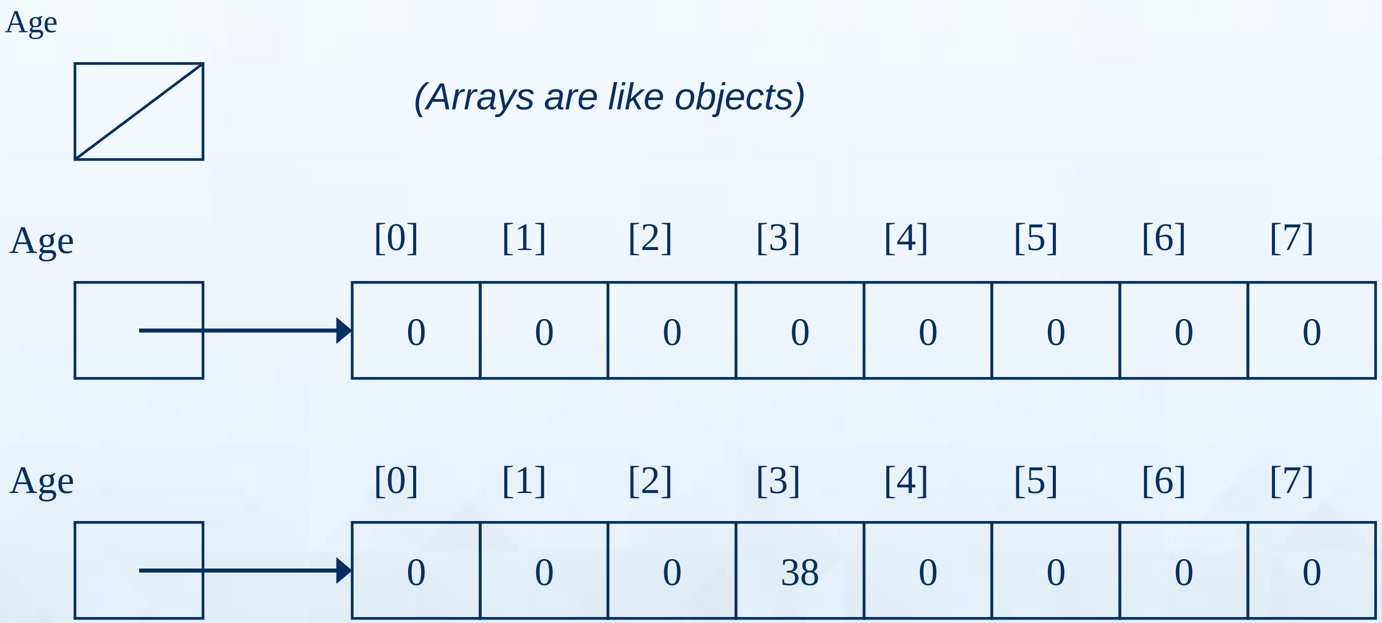
Array

An array of integers

1 int [ ] Age;

2 Age= new int[8];

3 Age [3] = 38;



(Arrays are like objects)

Declaration — Allocation — Initialization

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Linked List

- a **linked list** is a linear collection of data elements, in which linear order is not given by their physical placement in memory.

- Elements may be added in front, end of list as well as middle of list.
- Linked List may be use for dynamic implementation of stack and queue.

Stack

- Stack is a linear data structure which works on LIFO order. So that Last In First Out .
- In stack element is always added at top of stack and also removed from top of the stack.
- Stack is useful in recursive function, function calling, mathematical expression calculation, reversing the string etc.

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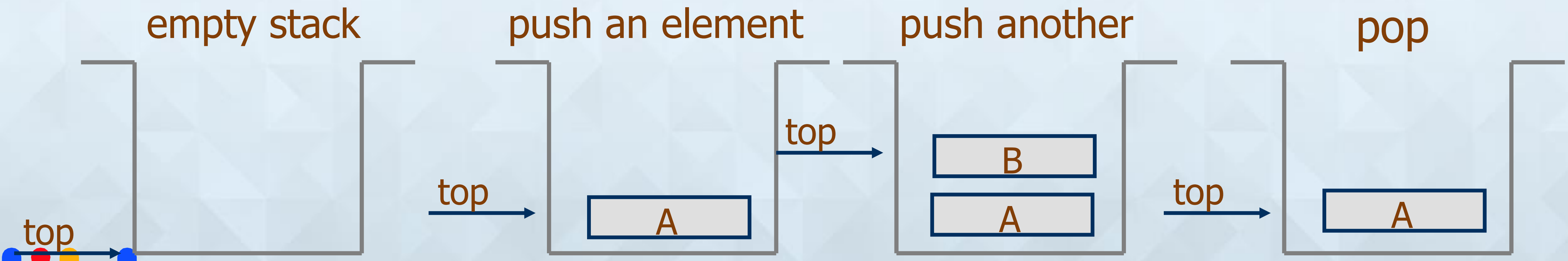
Data Structure -- Stacks

- LIFO (Last In, First Out) in Stack:
  The last element inserted will be the first to be retrieved, using Push and Pop
- Push
  - Add an element to the *top* of the stack
- Pop
  - Remove the element at the *top* of the stack



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Data Structures -- Stacks

Attributes of `Stack`

- `maxTop`: the max size of stack
- `top`: the index of the top element of stack

• Operations of `Stack`

- `empty`: return true if stack is empty, return false otherwise
- `full`: return true if stack is full, return false otherwise
- `top`: return the element at the top of stack
- `push`: add an element to the top of stack
- `pop`: delete the element at the top of stack
- `displayStack`: print all the data in the stack

Data Structure -- Stacks

- Real life analogy:
  - Elevator
  - Dish holders (stacks)
- Typical uses of stacks:
  - Prefix-/Postfix- calculators
- Any list implementation could be used to implement a stack
  - Arrays (static: the size of stack is given initially)
  - Linked lists (dynamic: never becomes full)

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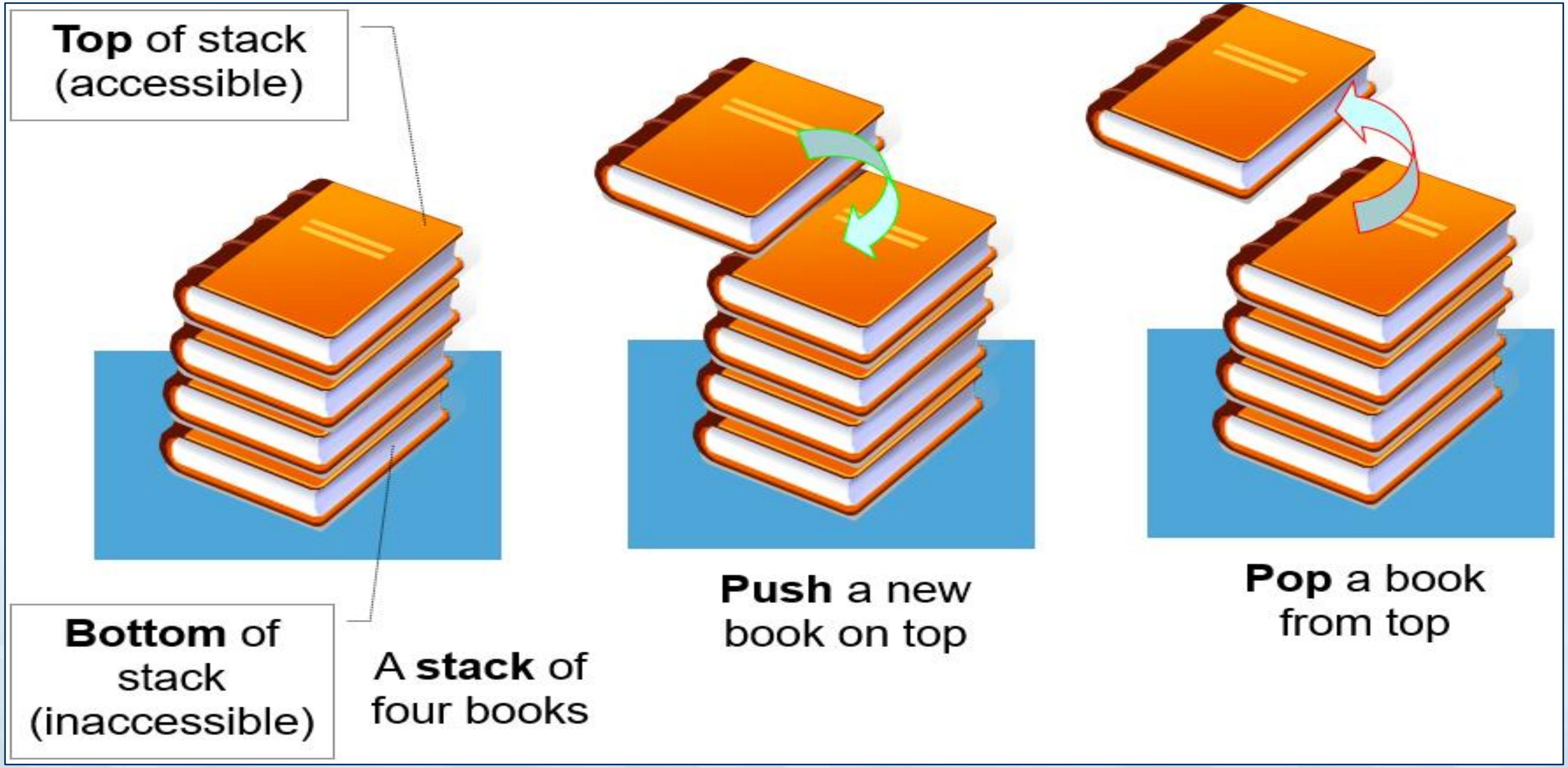
Data Structure -- Stacks



Data Structure -- Queues

- Like a stack, a *queue* is also a list. However, with a queue, insertion is done at one end, while deletion is performed at the other end
  - The insertion end is called *rear*
  - The deletion end is called *front*

Data Structure -- Queues

- Attributes of `Queue`
  - `front/rear`: front/rear index
  - `counter`: number of elements in the queue
  - `maxSize`: capacity of the queue
- Operations of `Queue`
  - `IsEmpty`: return true if queue is empty, return false otherwise
  - `IsFull`: return true if queue is full, return false otherwise
  - `Enqueue`: add an element to the rear of queue
  - `Dequeue`: delete the element at the front of queue
  - `DisplayQueue`: print all the data

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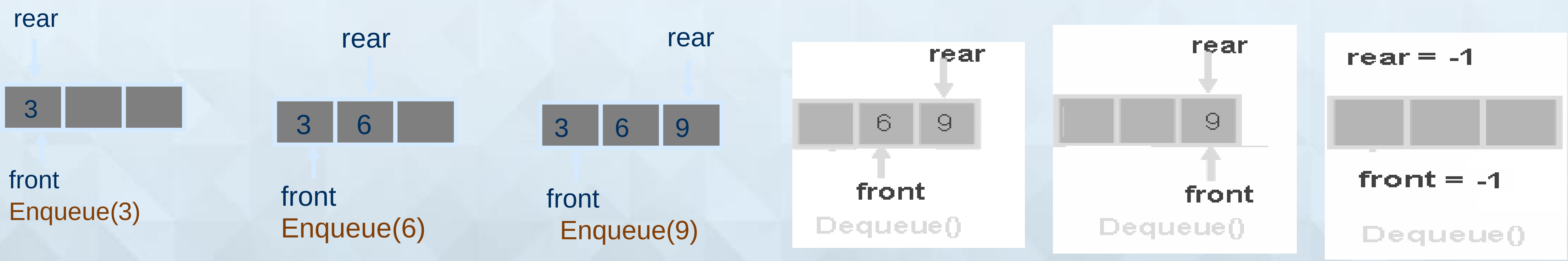
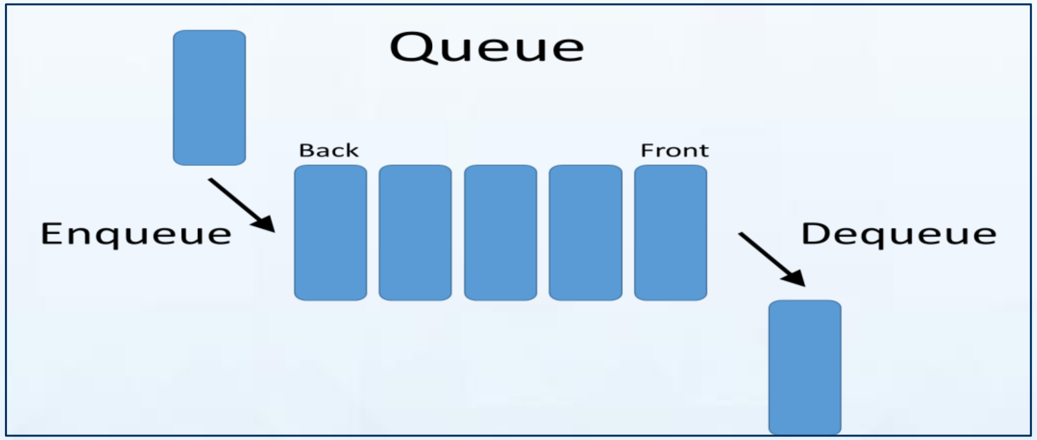
Data Structure -- Queues

- Accessing the elements of queues follows a FIFO (First In, First Out) order
  The first element inserted will be the first to be retrieved, using Enqueue and Dequeue
  - Enqueue
    - Add an element after the *rear* of the queue
  - Dequeue
    - Remove the element at the *front* of the queue



Data Structure -- Queues

- Real life analogy:
  - Check-out lines in a store (queuing up)
- Typical uses of queues:
  - Waiting lists of course registration
  - Simple scheduling in routers
- Any list implementation could be used to implement a queue
  - Arrays (static: the size of queue is given initially)
  - Linked lists (dynamic: never becomes full)



Algorithm Design

Searching and Sorting

- Searching refers to finding whether a data item is present in the set of items or not
- Sorting refers to the arrangement of data in a particular order. That is, arranging items in a particular way
- Sorting and searching have many applications in the area of computers

Searching Algorithms

- The time required to search depends on the following factors:
  - Whether the data is arranged in a particular order or not
  - The location of the data to be searched
  - The total number of searches to be done

- When the data is arranged in a particular order then, the time taken to search for the item is less.

- Searching algorithms
  - Linear Search
  - Binary Search

Sorting Techniques

Sorting

- Arranging the data elements in a particular sequence – in the ascending order (increasing order) or in the descending order (decreasing order)

- Sorting Algorithms:
  - Selection Sort
  - Insertion Sort
  - Bubble Sort

Sorting

Sorting is any process of arranging items systematically, and has two common, yet distinct meanings: ordering: arranging items in a sequence ordered by some criterion; categorizing: grouping items with similar properties.

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Sorting

- **Sorting takes an unordered collection and makes it an ordered one.**

1	2	3	4	5	6
77	42	35	12	101	5

1	2	3	4	5	6
5	12	35	42	77	101

Complexity of sorting Algorithm

The complexity of sorting algorithm calculates the running time of a function in which 'n' number of items are to be sorted. The choice for which sorting method is suitable for a problem depends on several dependency configurations for different problems. The most noteworthy of these considerations are:

The length of time spent by the programmer in programming a specific sorting program

Amount of machine time necessary for running the program

The amount of memory necessary for running the program

Types of Sorting Techniques

- Bubble Sort
- Selection Sort
- Merge Sort
- Insertion Sort
- Quick Sort
- Heap Sort

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Bubble Sort

Bubble sort - "Bubbling Up" the Largest Element

- Traverse a collection of elements
  - Move from the front to the end
  - “Bubble” the **largest value** to the end using **pair-wise comparisons and swapping**

1	2	3	4	5	6
77	42	35	12	101	5

"Bubbling Up" the Largest Element

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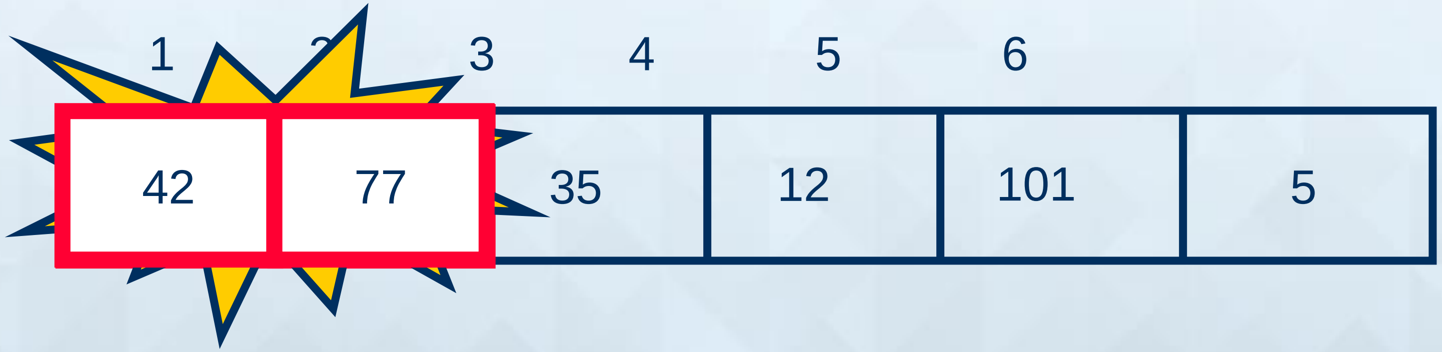

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1	2	3	4	5	6
42	35	12	77	101	5

No need to swap

"Bubbling Up" the Largest Element

- Traverse a collection of elements
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"Bubbling Up" the Largest Element

- Traverse a collection of elements
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1	2	3	4	5	6
42	35	12	77	5	101

Largest value correctly placed

Items of Interest

- Notice that only the largest value is correctly placed
- All other values are still out of order
- So we need to repeat this process

1	2	3	4	5	6
42	35	12	77	5	101

Largest value correctly placed

Insertion sort

Insertion Sort

- Idea:
  - Find the smallest element in the array
  - Exchange it with the element in the first position
  - Find the second smallest element and exchange it with the element in the second position
  - Continue until the array is sorted
- Disadvantage:
  - Running time depends only slightly on the amount of order in the file

Insertion Sort

- To insert 12, we need to make room for it by moving first 36 and then 24.

Insertion Sort

Insertion Sort

Initial Array	8	6	4	20	24	2	10	12	
Since, 6 < 8	8	6	4	20	24	2	10	12	6 will get inserted before 8
Since, 4 < 6	6	8	4	20	24	2	10	12	4 will get inserted before 6
20 is at correct position, no insertion needed	4	6	8	20	24	2	10	12	
24 is at correct position, no insertion needed	4	6	8	20	24	2	10	12	
Since, 2 < 4	4	6	8	20	24	2	10	12	2 will get inserted before 4
Since, 10 < 20	2	4	6	8	20	24	10	12	10 will get inserted before 20
Since, 12 < 20	2	4	6	8	10	20	24	12	12 will get inserted before 20
	2	4	6	8	10	12	20	24	

Selection sort

Selection Sort

- Idea:
  - Find the smallest element in the array
  - Exchange it with the element in the first position
  - Find the second smallest element and exchange it with the element in the second position
  - Continue until the array is sorted
- Disadvantage:
  - Running time depends only slightly on the amount of order in the file

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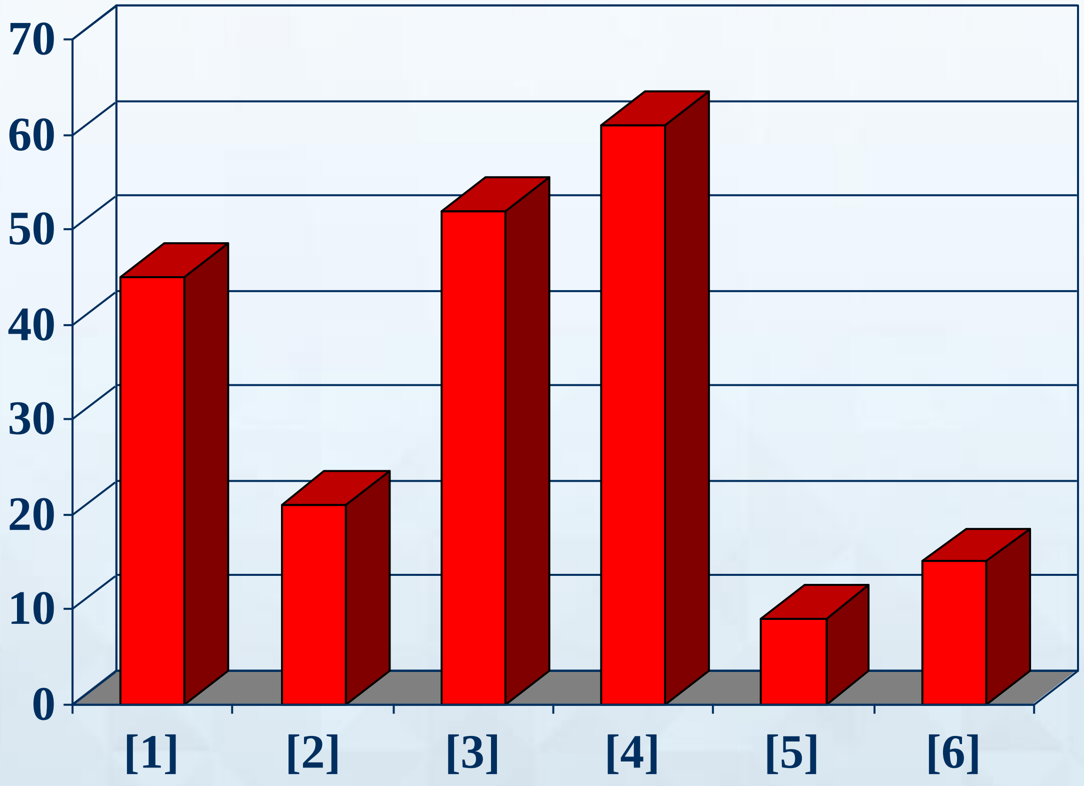
Selection Sort

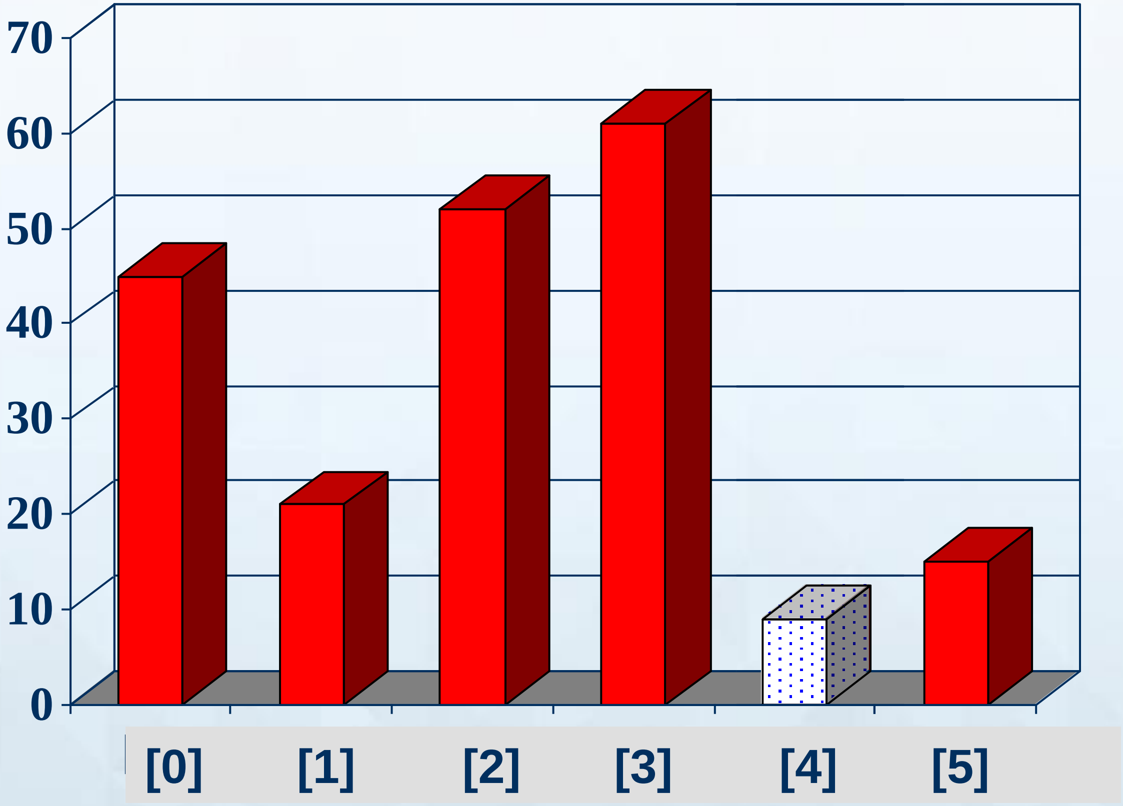
- Example: we are given an array of six integers that we want to sort from smallest to largest



[0] [1] [2] [3] [4] [5]

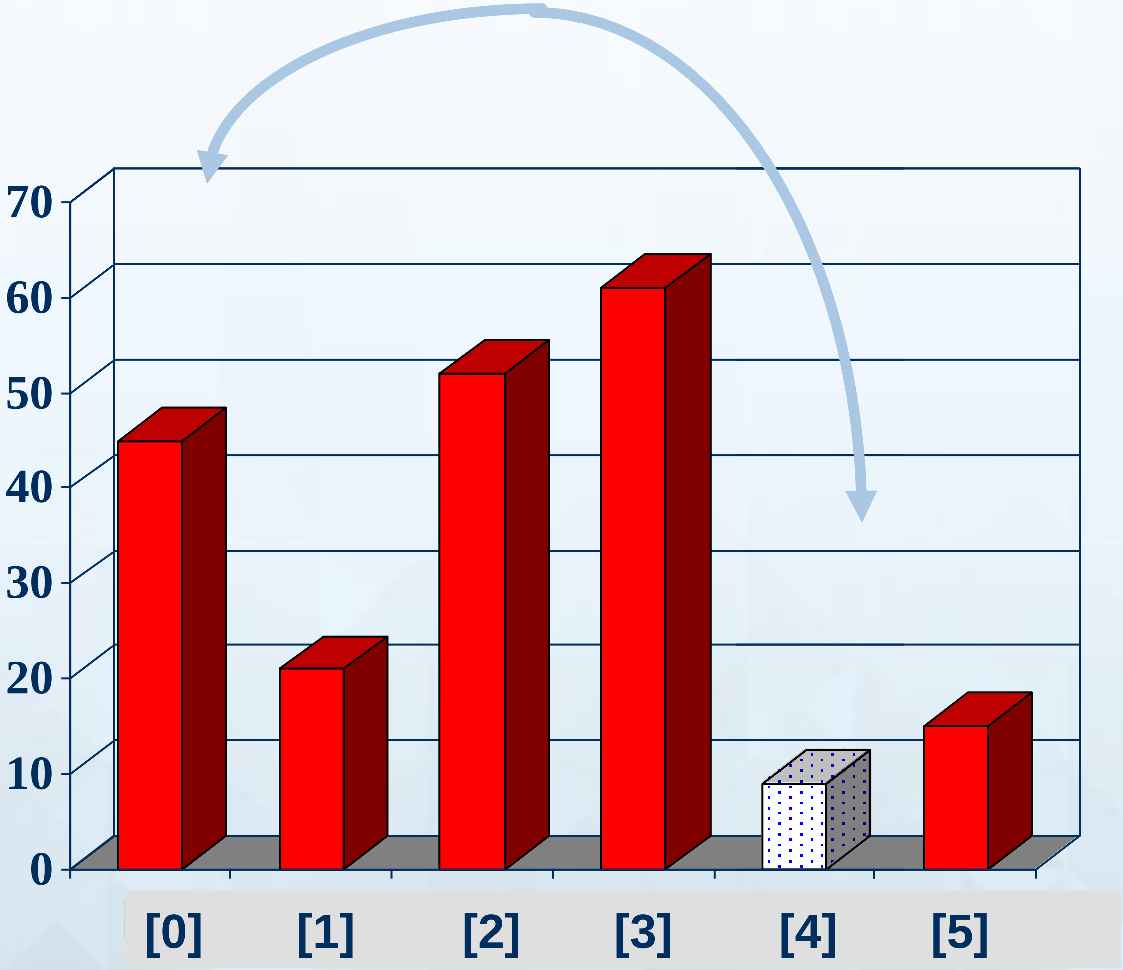
Selection Sort

- Start by finding the **smallest** entry.



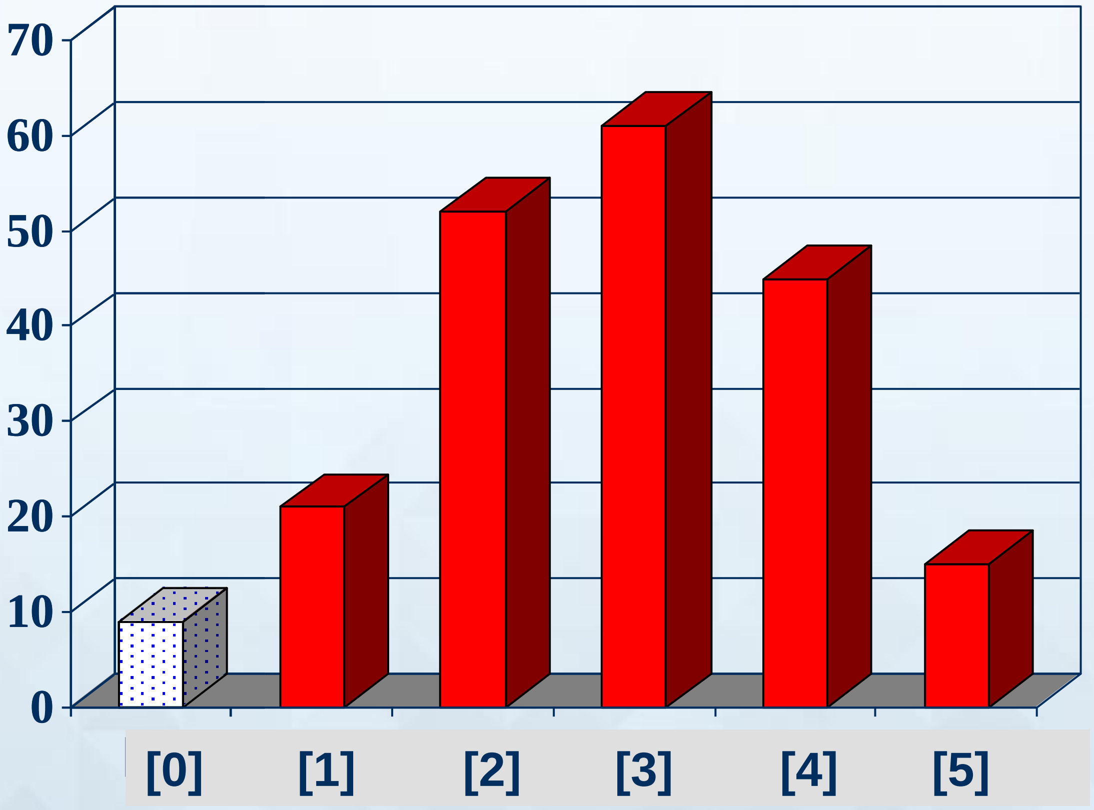
Selection Sort

- Swap the smallest entry with the <u>**first entry**</u>.



Selection Sort

- Swap the smallest entry with the **first entry**.

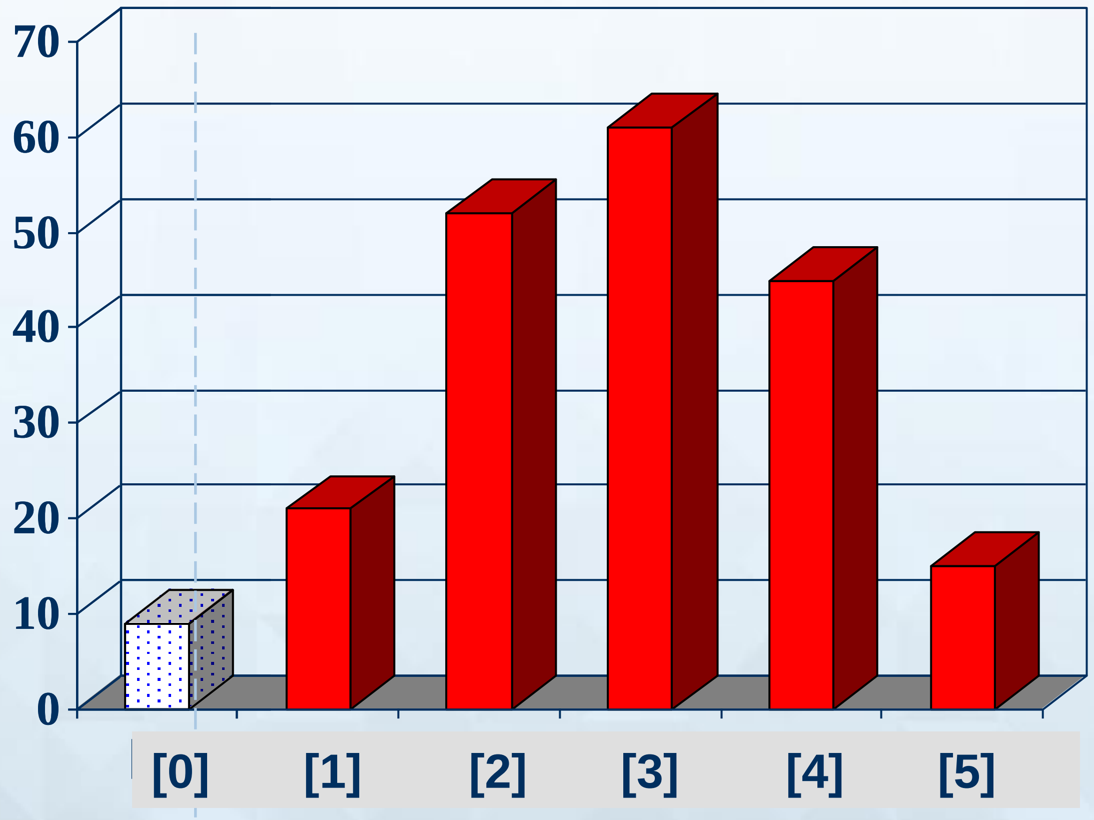


Selection Sort

Sorted side

Unsorted side

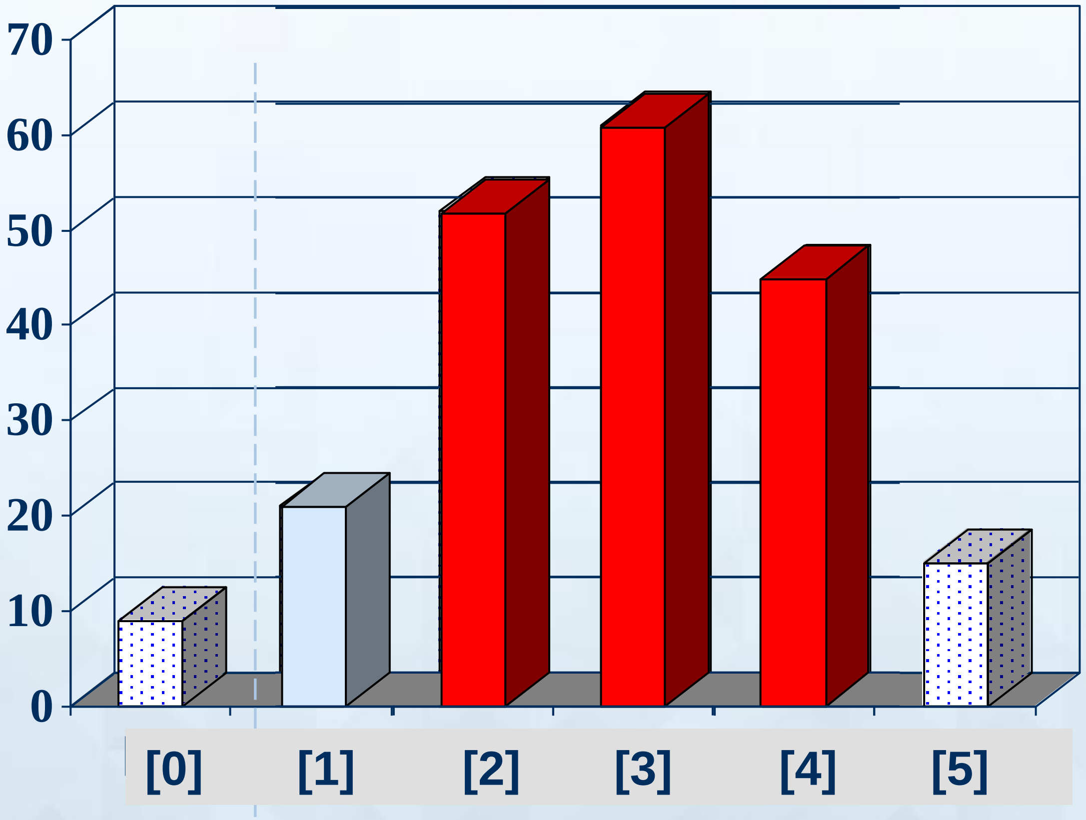
- Part of the array is now sorted.



Selection Sort

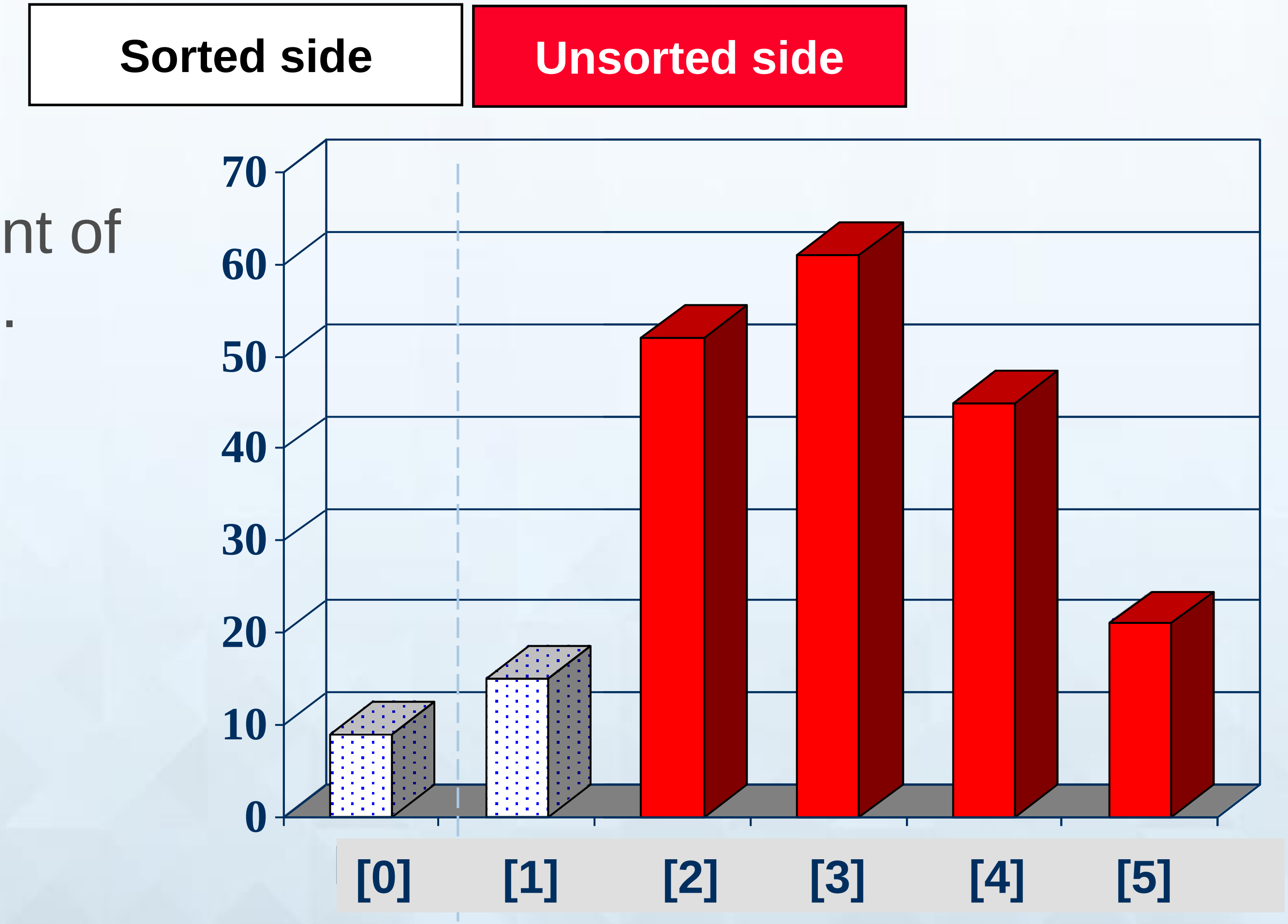
Sorted side | Unsorted side

- Find the smallest element in the unsorted side.



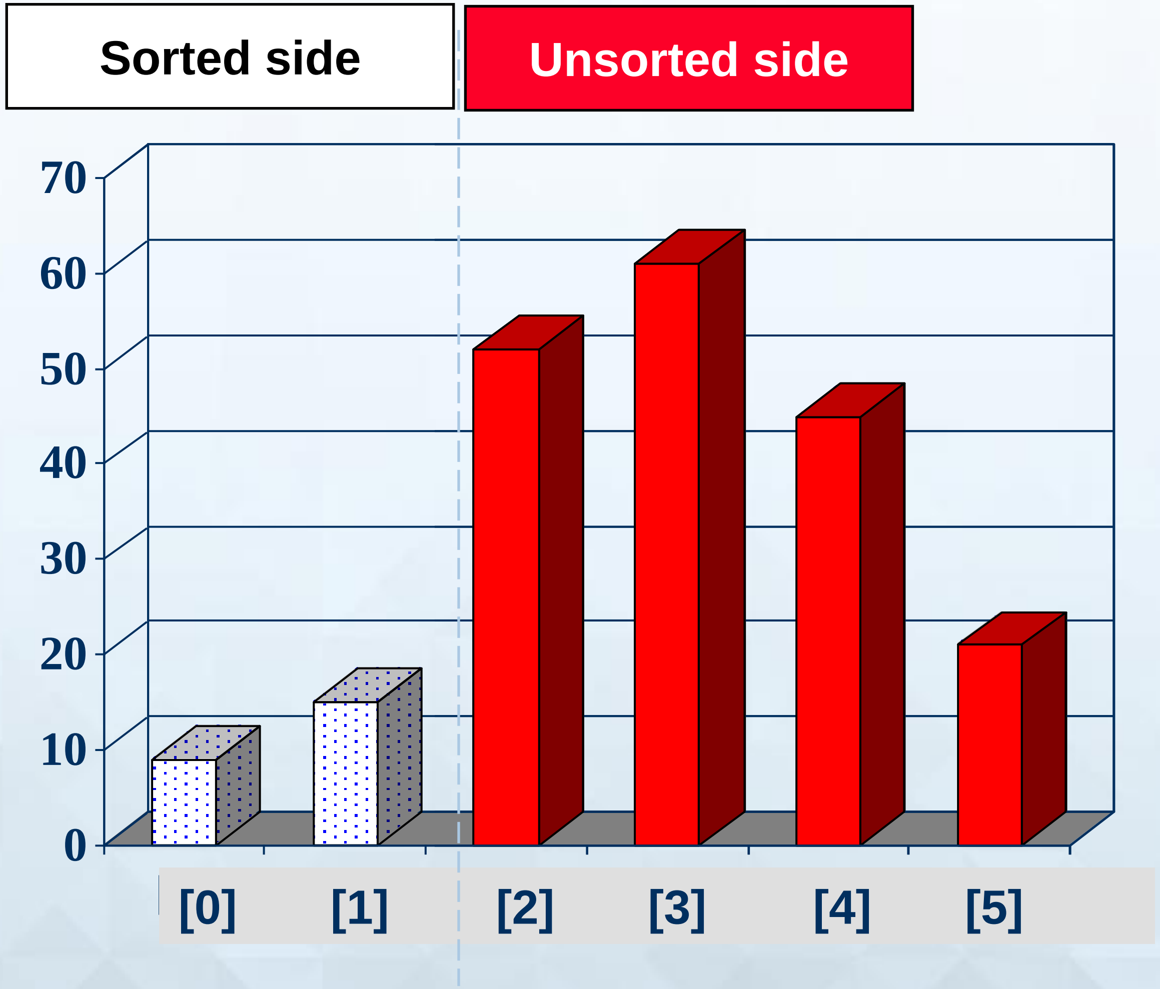
Selection Sort

- Swap with the front of the unsorted side.



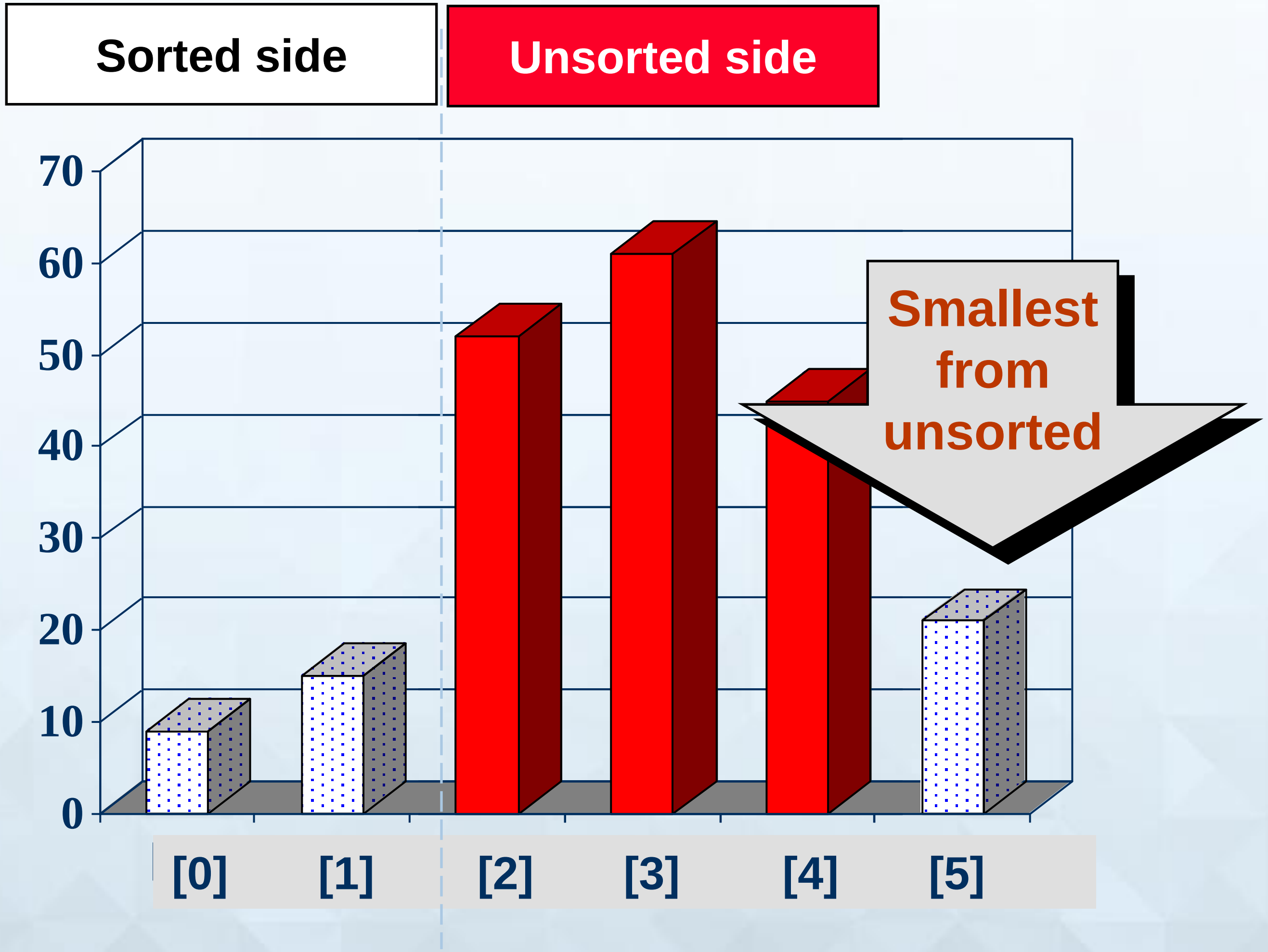
Selection Sort

- We have increased the size of the sorted side by one element.



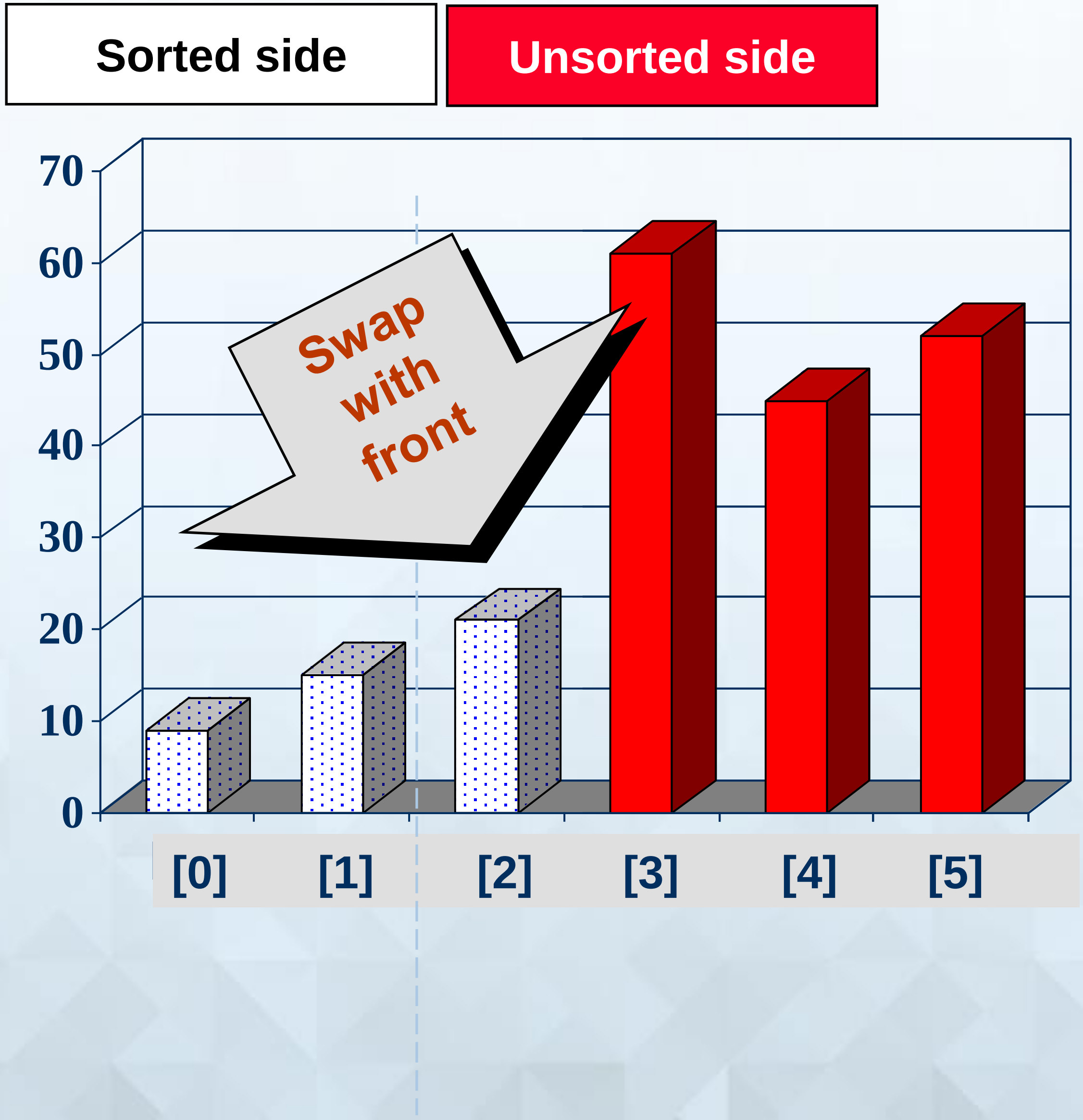
Selection Sort

- The process continues...



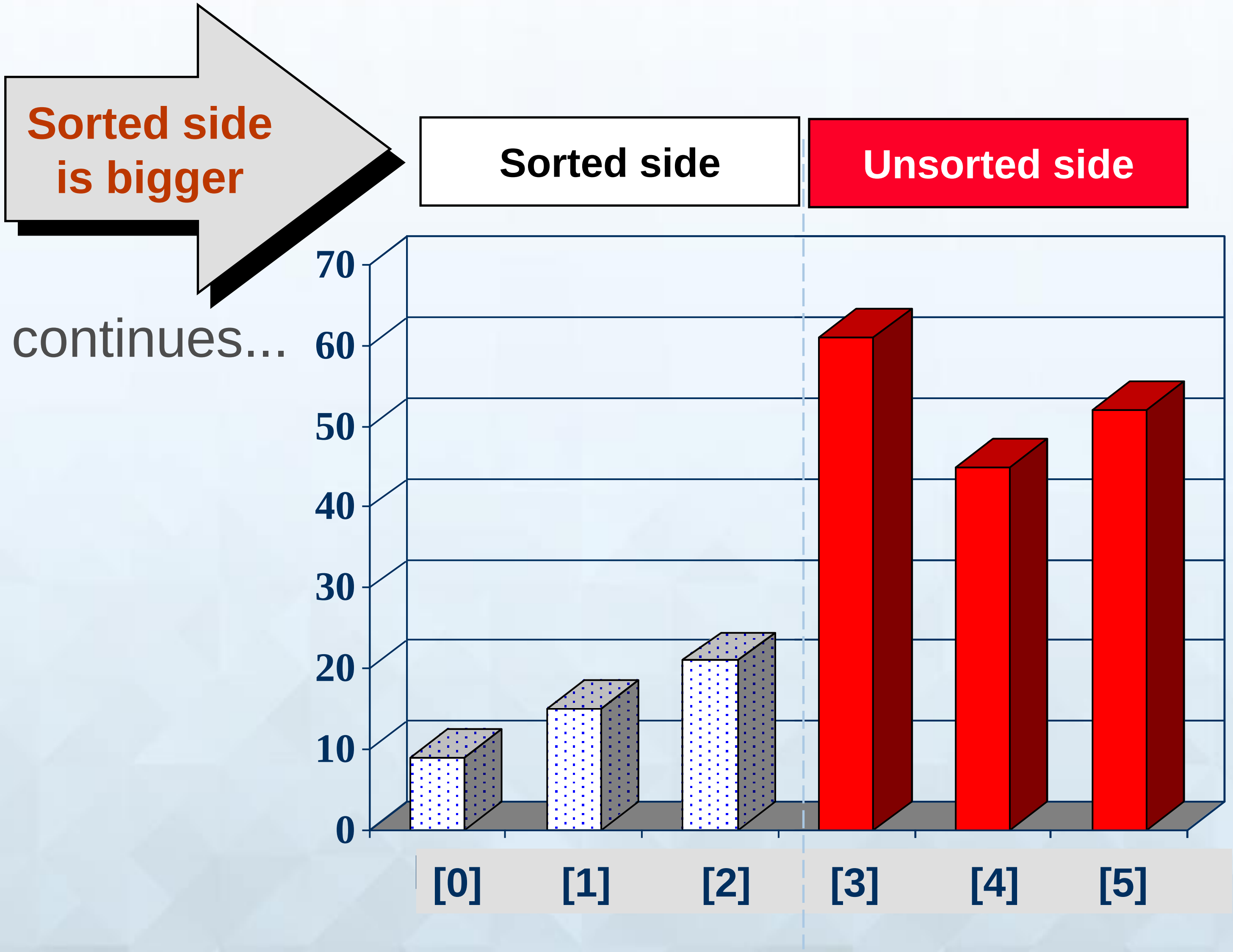
Selection Sort

- The process continues...



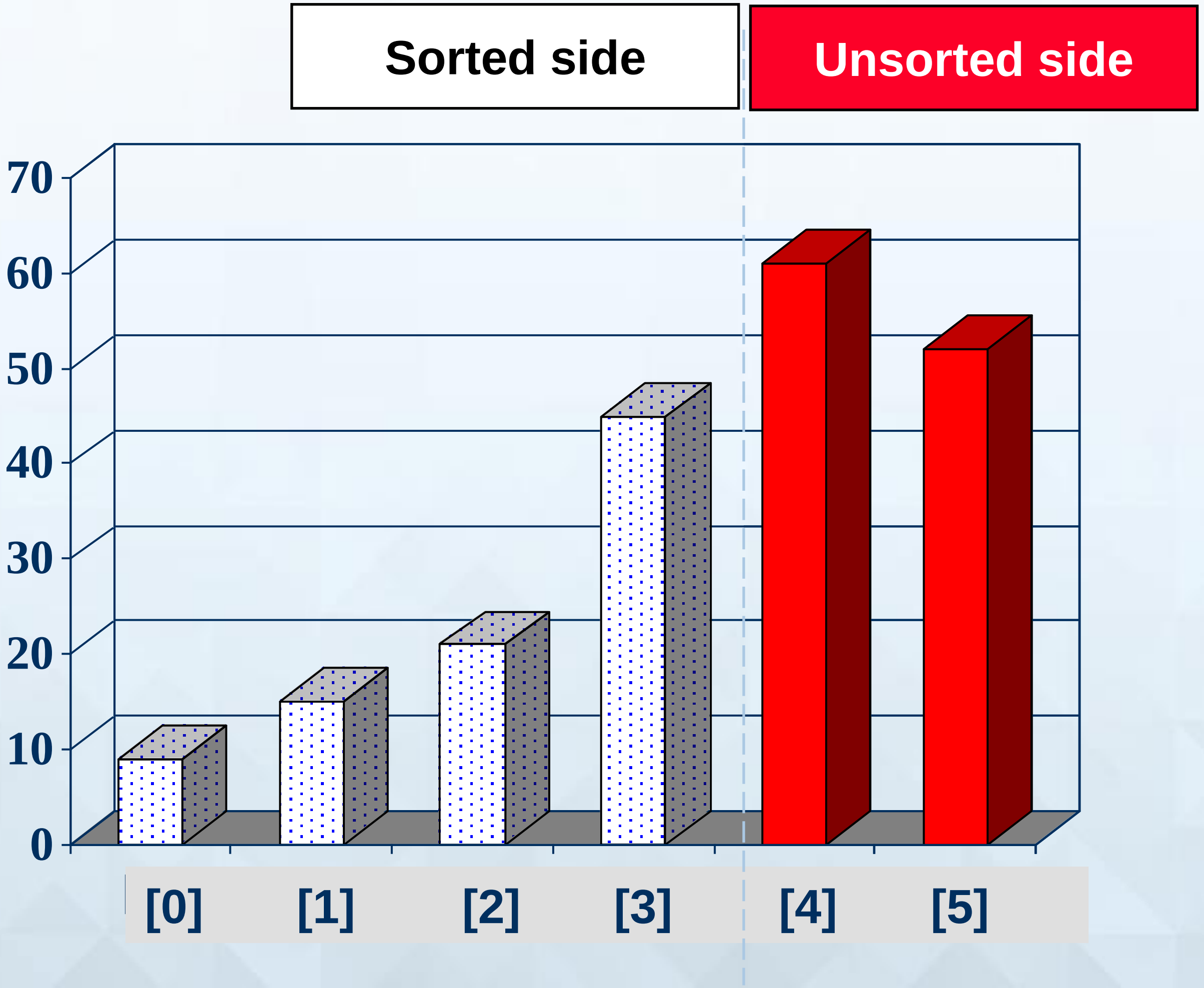
Selection Sort

- The process continues...



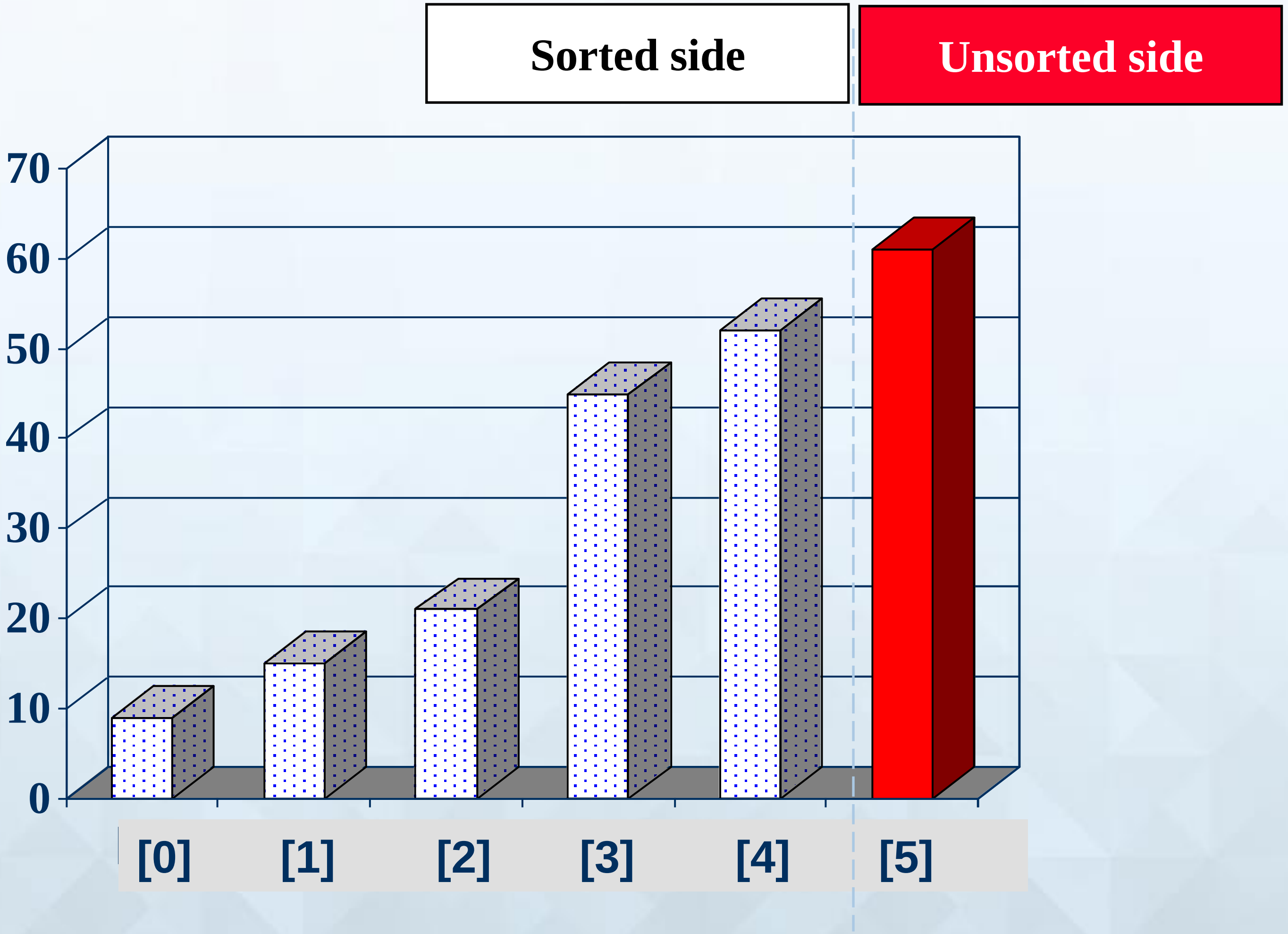
Selection Sort

- The process keeps adding one more number to the sorted side.
- The sorted side has the smallest numbers, arranged from small to large.



Selection Sort

- We can stop when the unsorted side has just one number, since that number must be the largest number.



Merge sort

Merge Sort

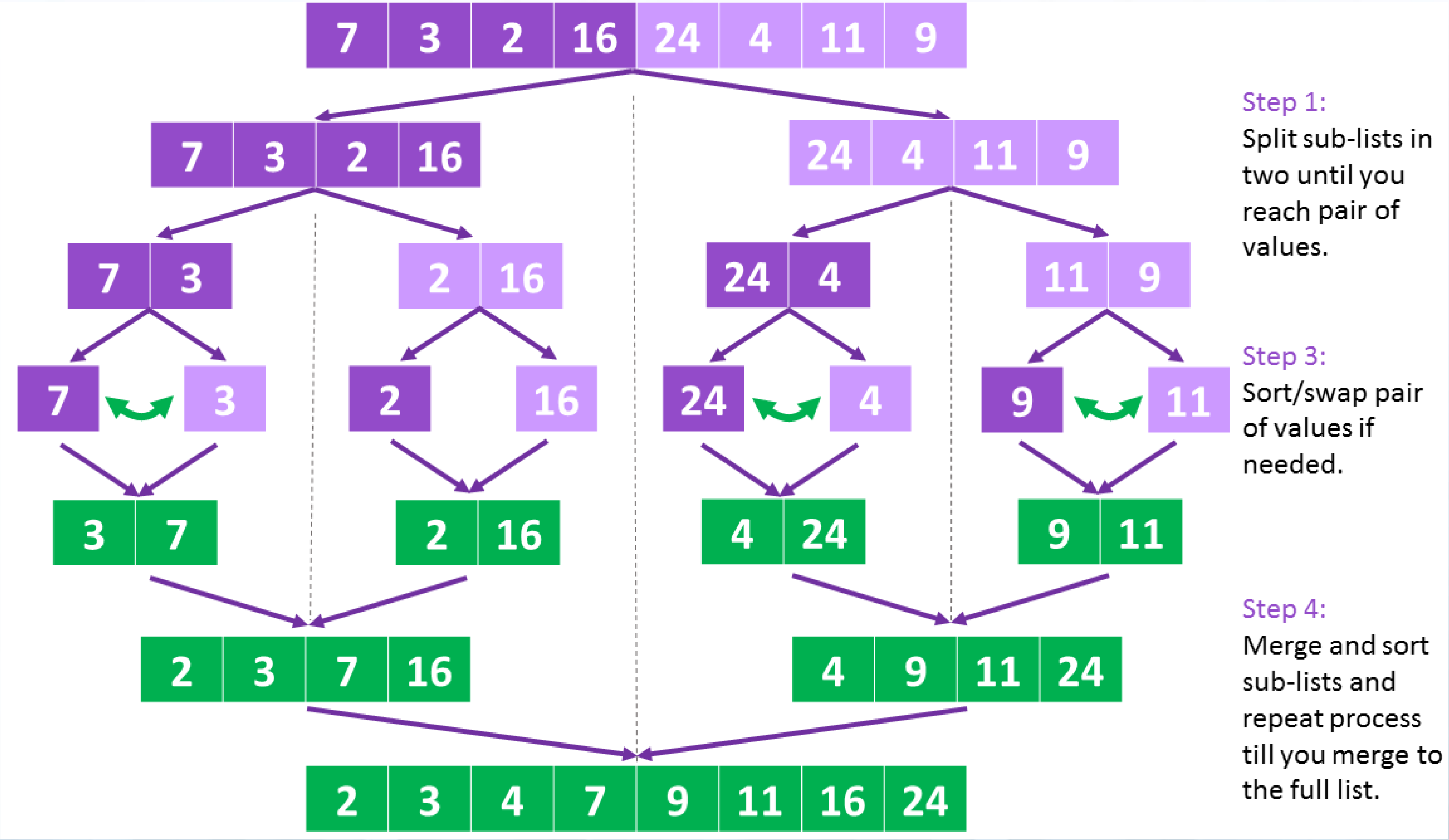
- Merge sort is a divide-and-conquer algorithm based on the idea of breaking down a list into several sub-lists until each sublist consists of a single element and merging those sublists in a manner that results into a sorted list.

- *Idea:*
  - Divide the unsorted list into *N* sublists, each containing 1 element.
  - Take adjacent pairs of two singleton lists and merge them to form a list of 2 elements. *N* will now convert into *N*/2 lists of size 2.
  - Repeat the process till a single sorted list of obtained.

"Divide and Conquer"

- Very important strategy in computer science:
  - Divide problem into smaller parts
  - Independently solve the parts
  - Combine these solutions to get overall solution
- **Idea 1**: Divide array into two halves, *recursively* sort left and right halves, then *merge* two halves → Mergesort
- **Idea 2 :** Partition array into items that are "small" and items that are "large", then recursively sort the two sets → Quicksort

Mergesort



7 3 2 16 24 4 11 9
7 3 2 16
24 4 11 9
7 3
2 16
24 4
11 9
7
3
2
16
24
4
9
11
3 7
2 16
4 24
9 11
2 3 7 16
4 9 11 24
2 3 4 7 9 11 16 24
Step 1:
Split sub-lists in two until you reach pair of values.
Step 3:
Sort/swap pair of values if needed.
Step 4:
Merge and sort sub-lists and repeat process till you merge to the full list.

Quick sort

Quick Sort

- Quick Sort is based on the **Divide and Conquer rule.**
- It is also called **partition-exchange sort**. This algorithm divides the list into three main parts:
- Elements less than the **Pivot** element
- Pivot element(Central element)
- Elements greater than the pivot element

Quick Sort

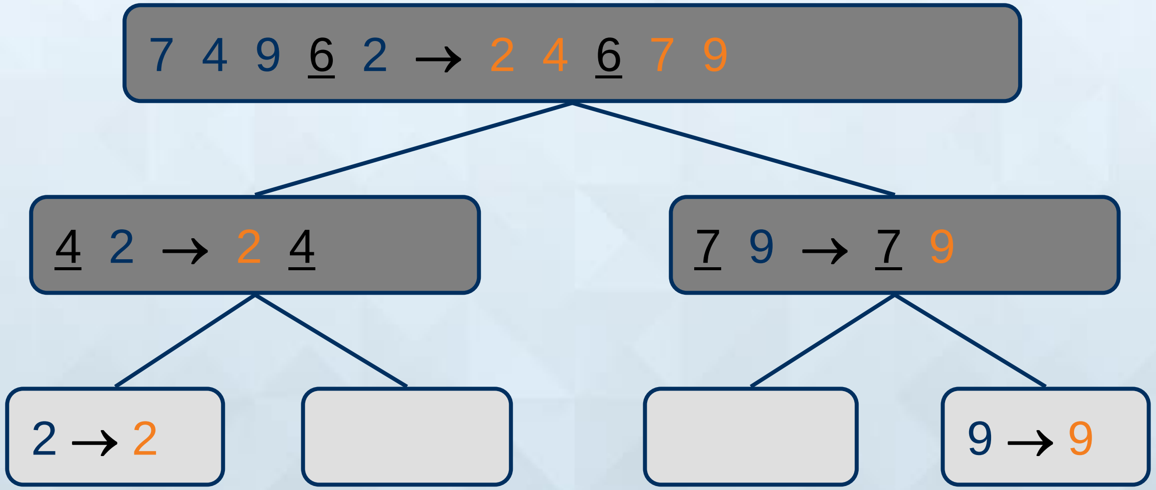
- Pivot element can be any element from the array, it can be the first element, the last element or any random element, we will take the rightmost element or the last element as pivot.

- For example: In the array {52, 37, 63, 14, 17, 8, 6, 25}, we take 25 as pivot. So after the first pass, the list will be changed like this.

- {6 8 17 14 25 63 37 52}

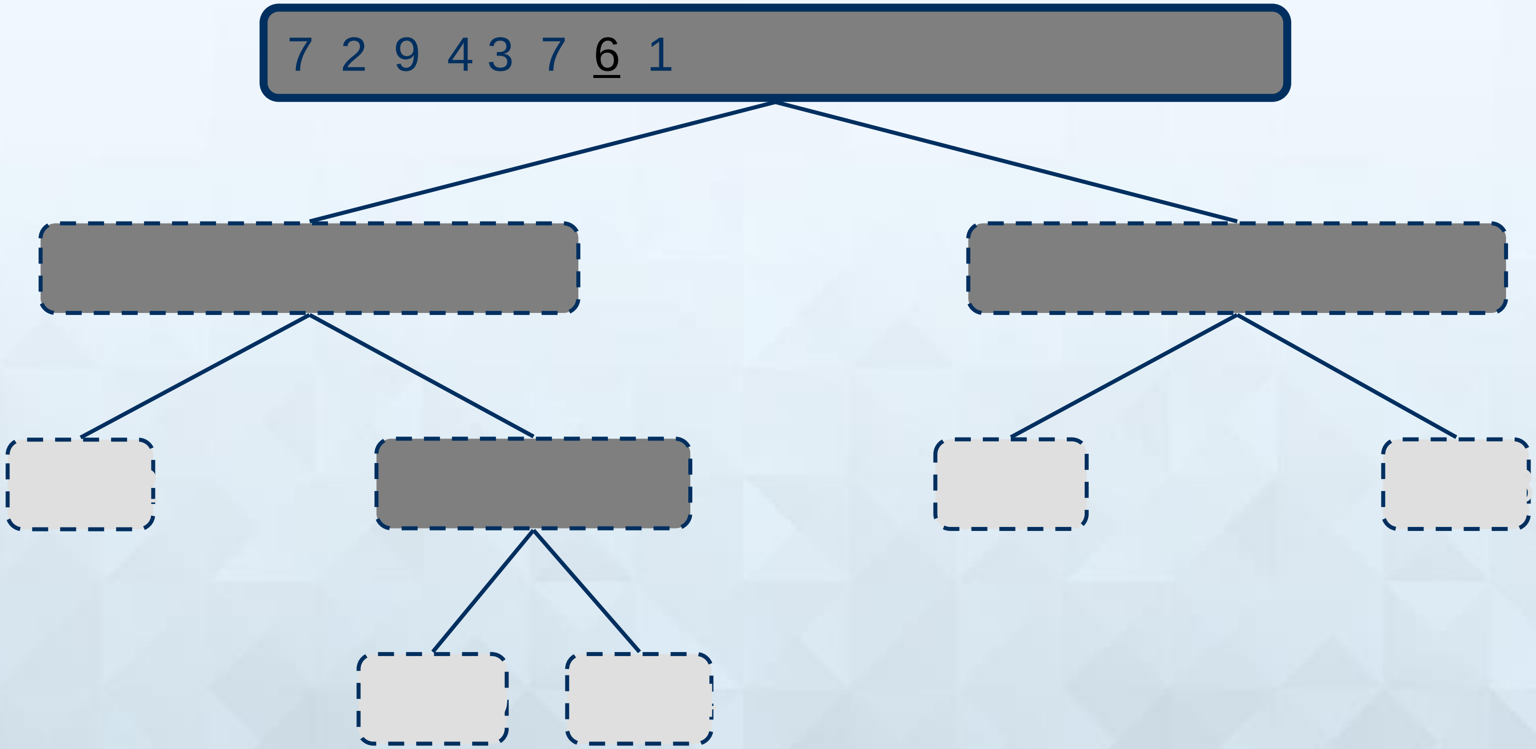
Quick-Sort Tree

- An execution of quick-sort is depicted by a binary tree
  - Each node represents a recursive call of quick-sort and stores
    - Unsorted sequence before the execution and its pivot
    - Sorted sequence at the end of the execution
  - The root is the initial call
  - The leaves are calls on subsequences of size 0 or 1



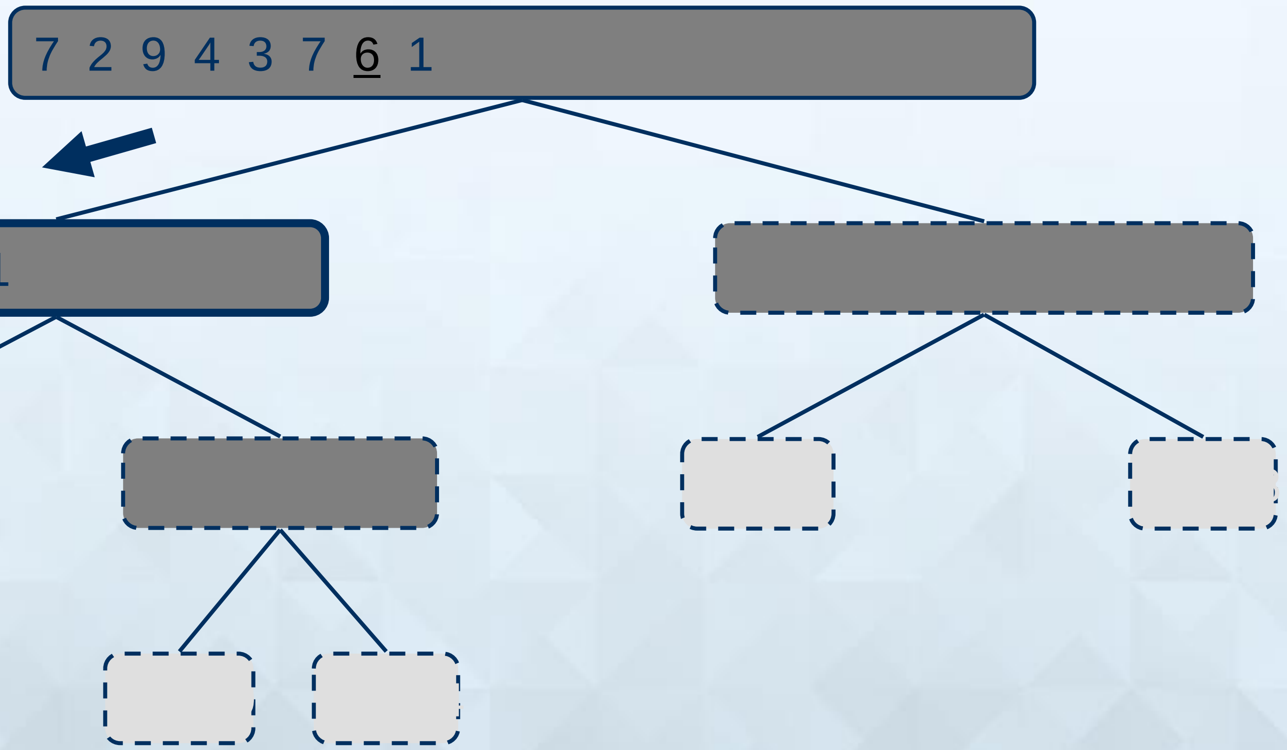
Execution Example

- Pivot selection



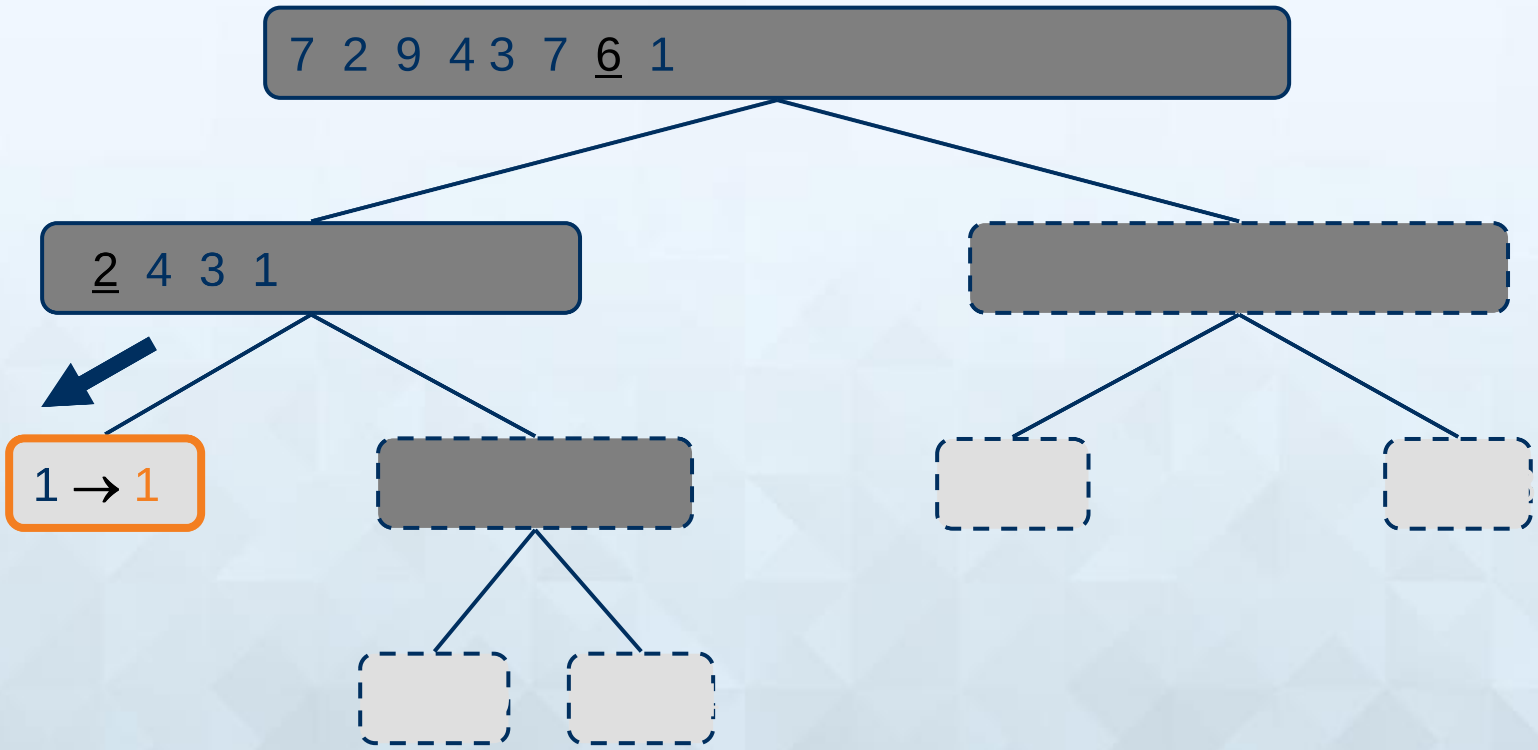
Execution Example (cont.)

- Partition, recursive call, pivot selection



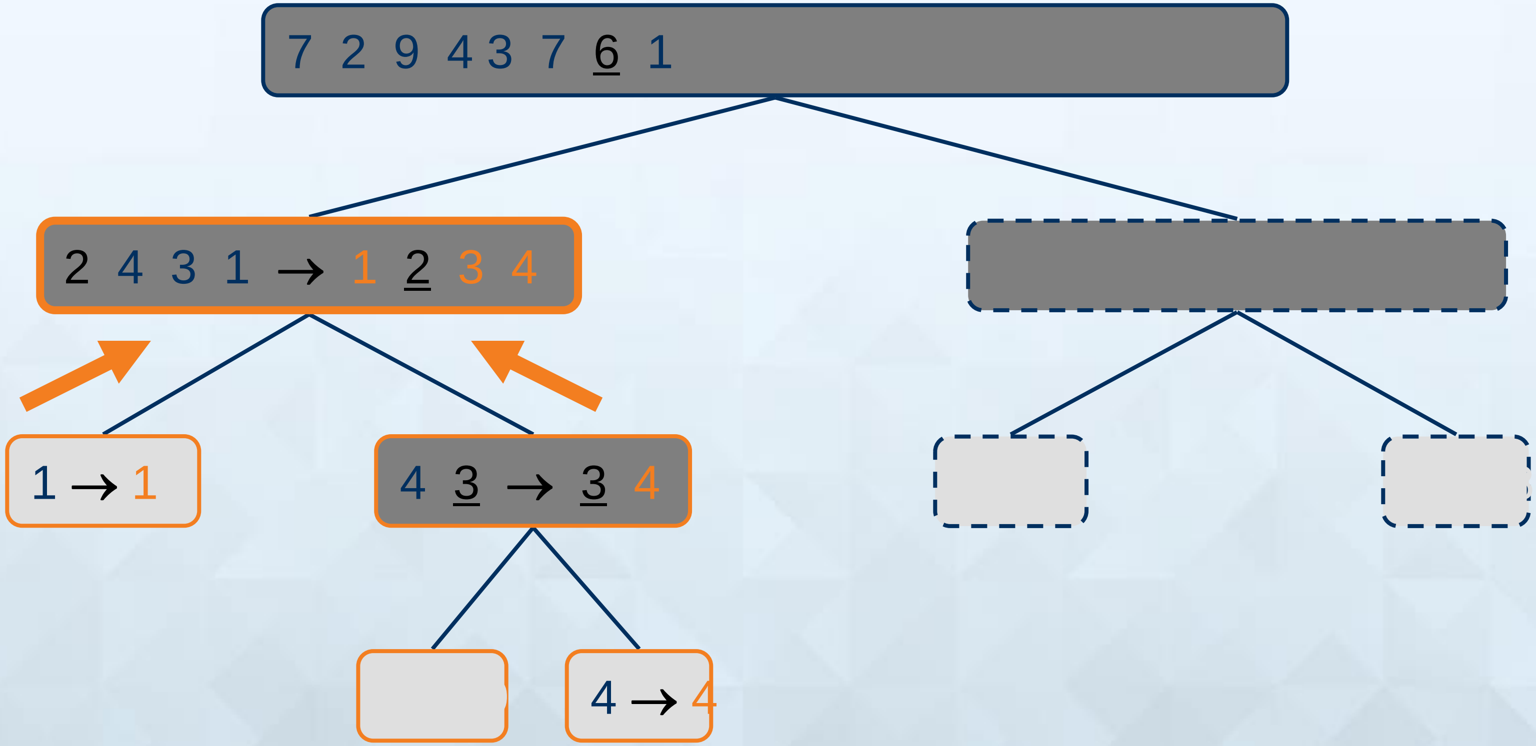
Execution Example (cont.)

- Partition, recursive call, base case



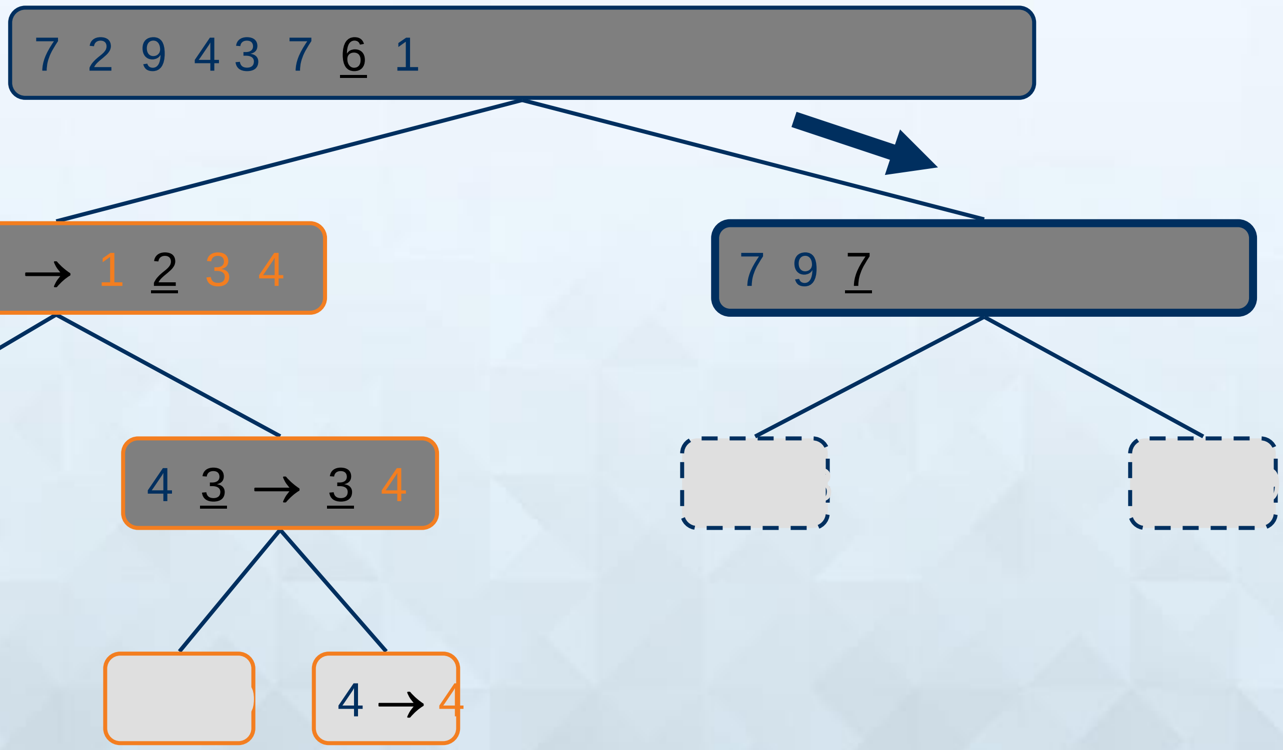
Execution Example (cont.)

- Recursive call, …, base case, join



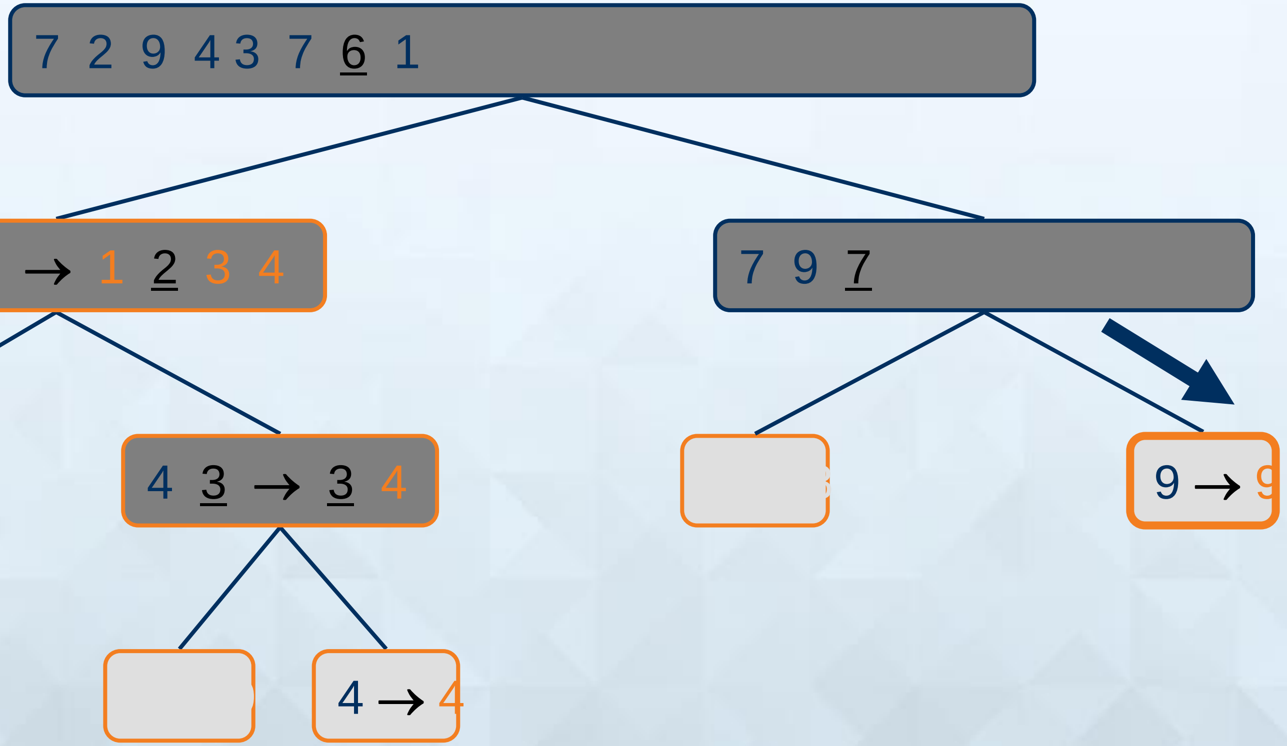
Execution Example (cont.)

- Recursive call, pivot selection



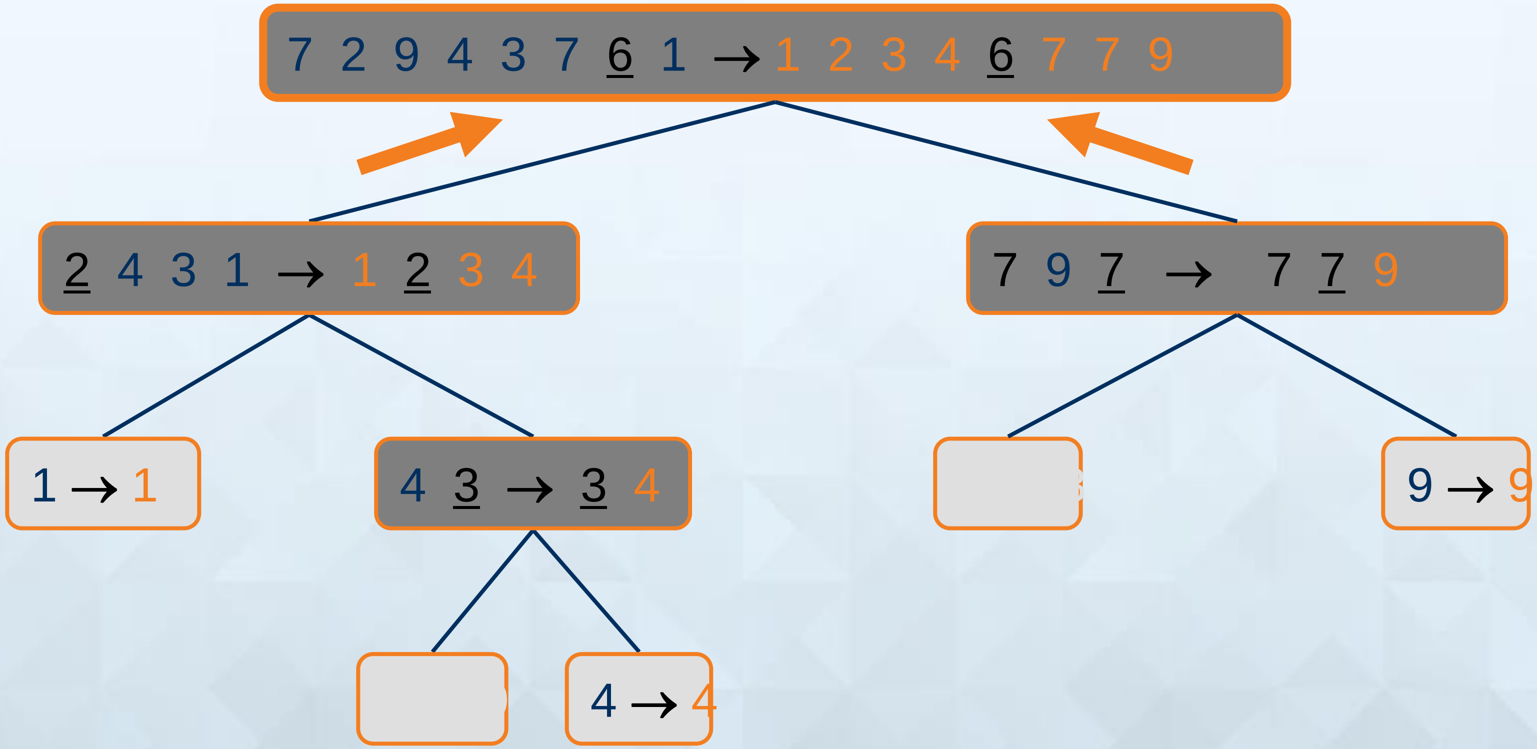
Execution Example (cont.)

- Partition, …, recursive call, base case



Execution Example (cont.)

- Join, join



Searching Algorithm

Linear Search: A Simple Search

- A search traverses the collection until
  - The desired element is found
  - Or the collection is exhausted

- If the collection is ordered, I might not have to look at all elements
  - I can stop looking when I know the element cannot be in the collection.

The Sscenario

- We have a sorted array

- We want to determine if a particular element is in the array
  - Once found, print or return (index, boolean, etc.)
  - If not found, indicate the element is not in the collection

7	12	42	59	71	86	104	212

Binary Search

- Requires a sorted array or a *binary search tree*.
- Cuts the “search space” in half each time.
- Keeps cutting the search space in half until the target is found or has exhausted the all possible locations.

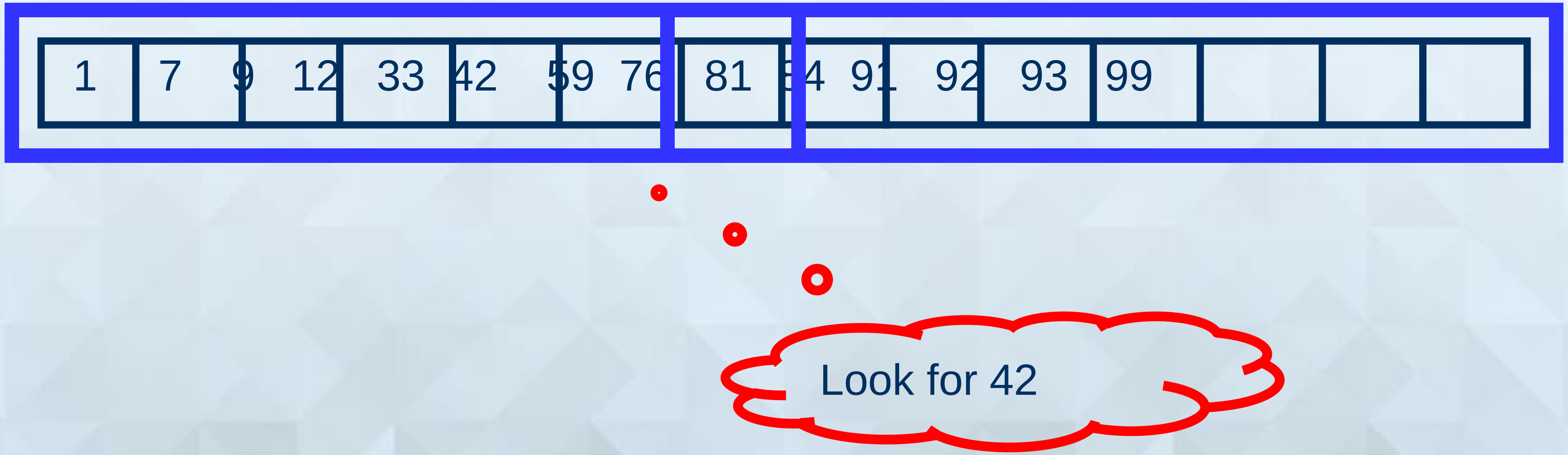
Binary Search Algorithm

look at “middle” element

if no match then

look *left* (if need smaller) or

right (if need larger)

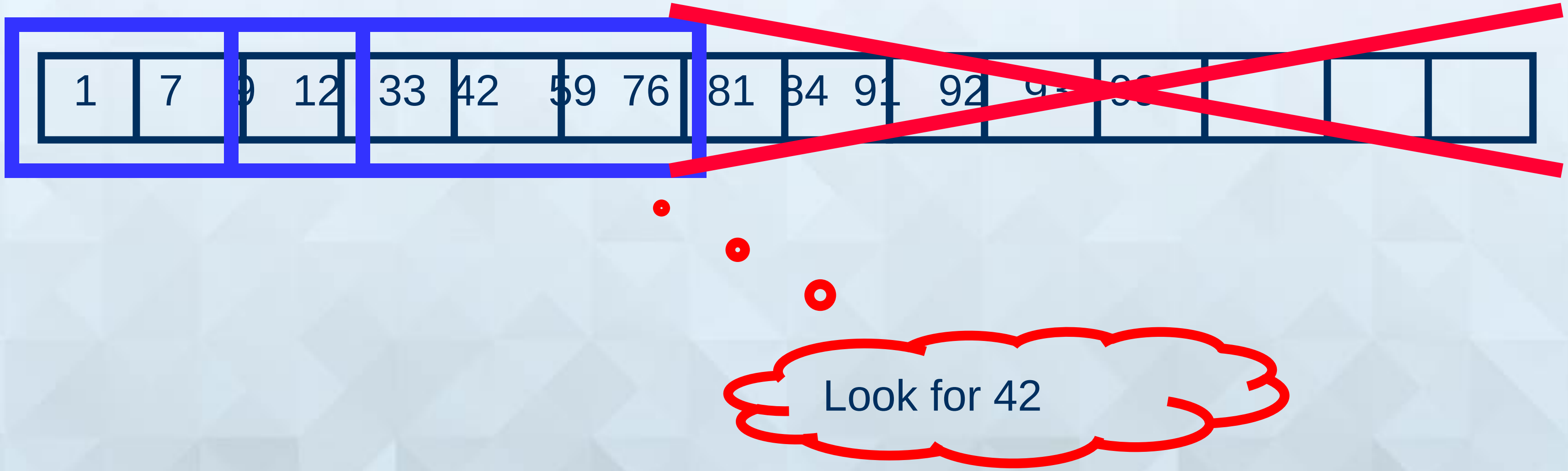


The Algorithm

look at "middle" element

if no match then

look left or right

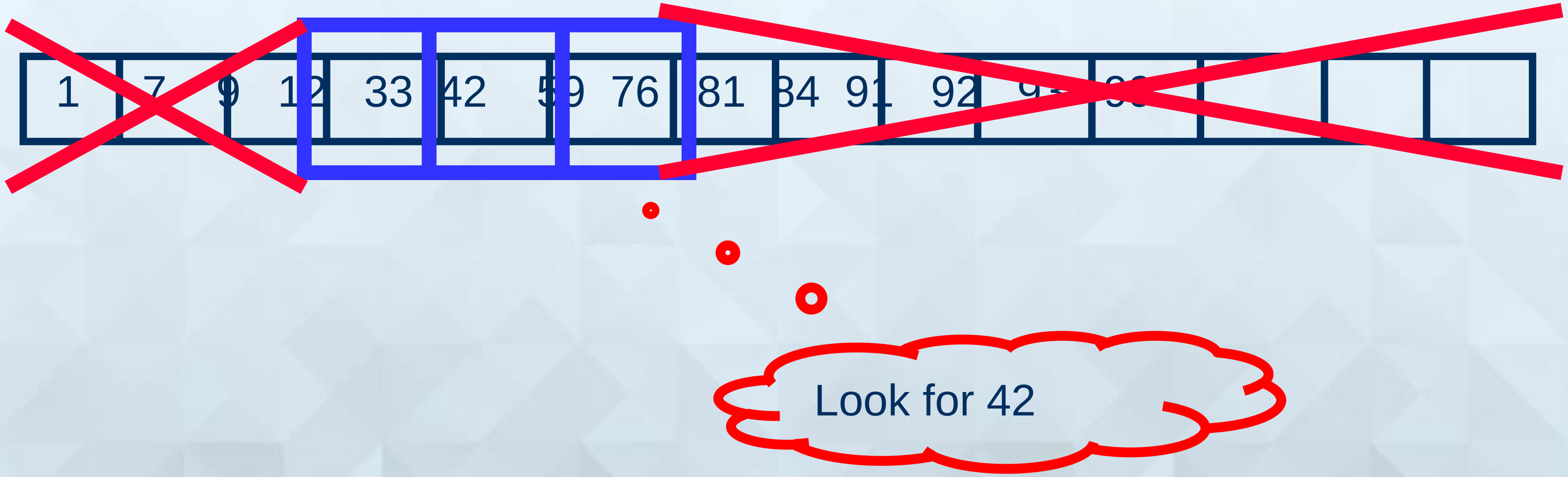


The Algorithm

look at “middle” element

if no match then

look left or right

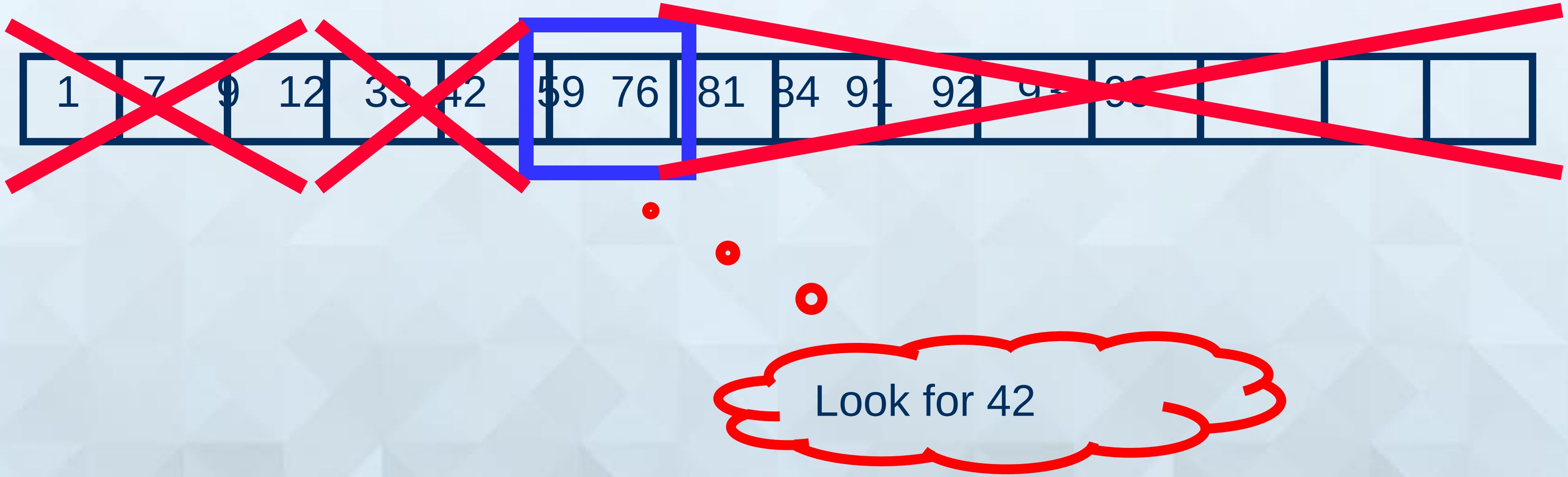


The Algorithm

look at "middle" element

if no match then

look left or right



The Binary Search Algorithm

- Return found or not found (true or false), so it should be a function.
- When move *left* or *right*, change the array boundaries
  - We need a first and last index value.

The Binary Search Algorithm

calculate middle position

if (first and last have “crossed”) then
  “Item not found”

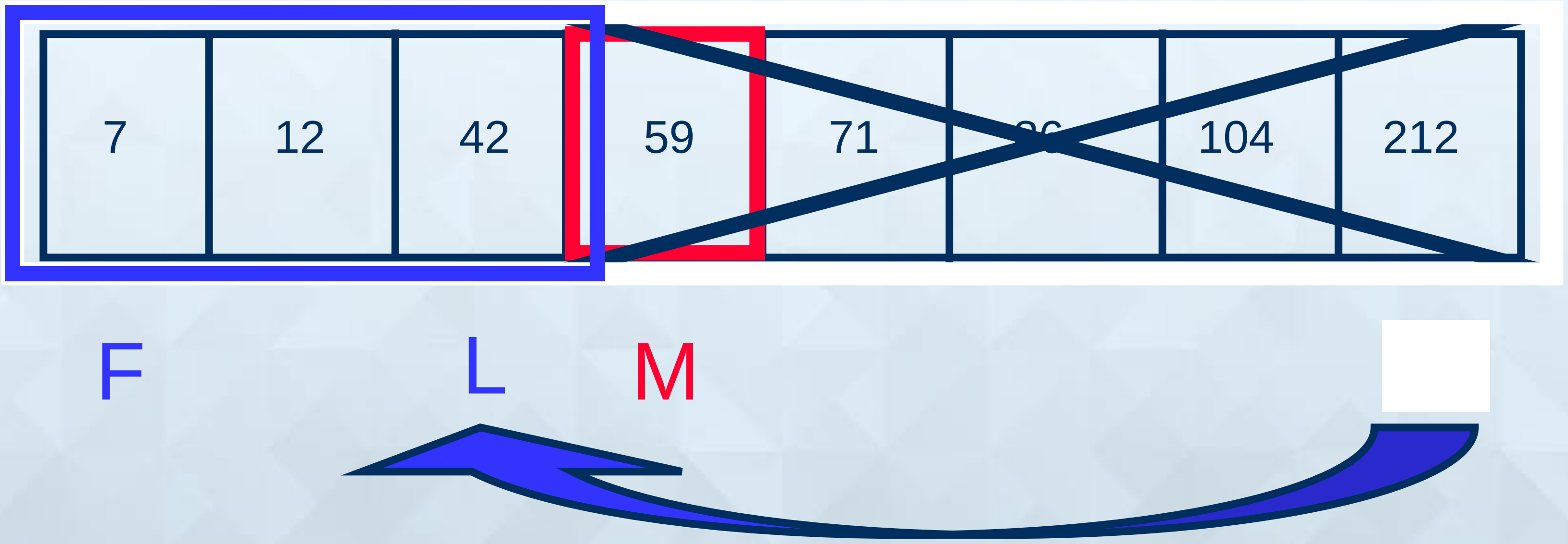
elseif (element at middle = to_find) then
  “Item Found”

elseif to_find < element at middle then
  Look to the left

else
  Look to the right

Looking Left

- Use indices “**first**” and “**last**” to keep track of where we are looking
- Move **left** by setting **last = middle – 1**



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Looking Right

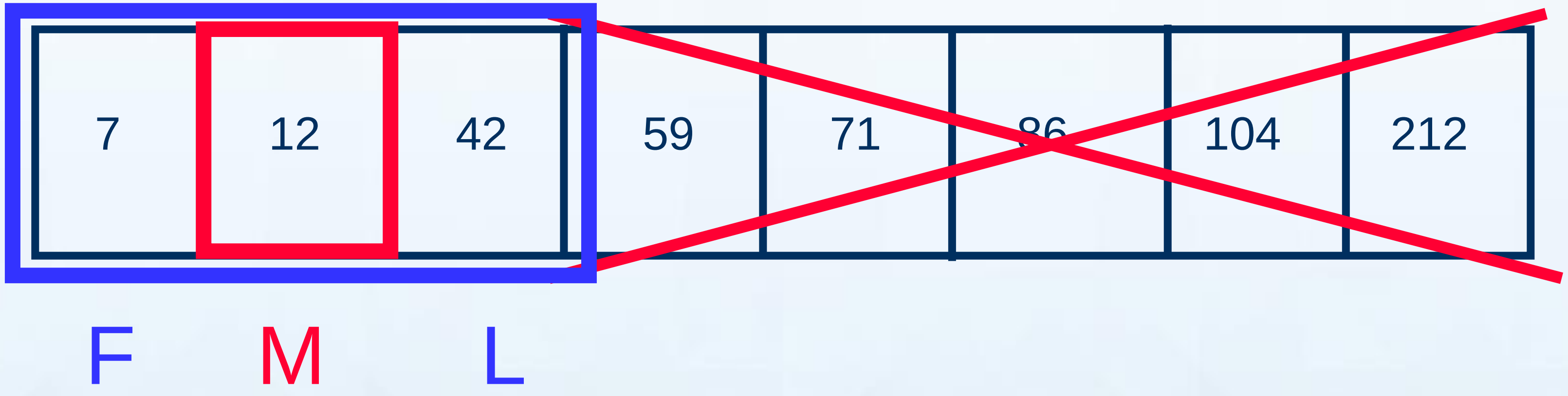
- Use indices “first” and “last” to keep track of where we are looking
- Move right by setting first = middle + 1

Binary Search Example – Found

7	12	42	59	71	86	104	212
F			M				L

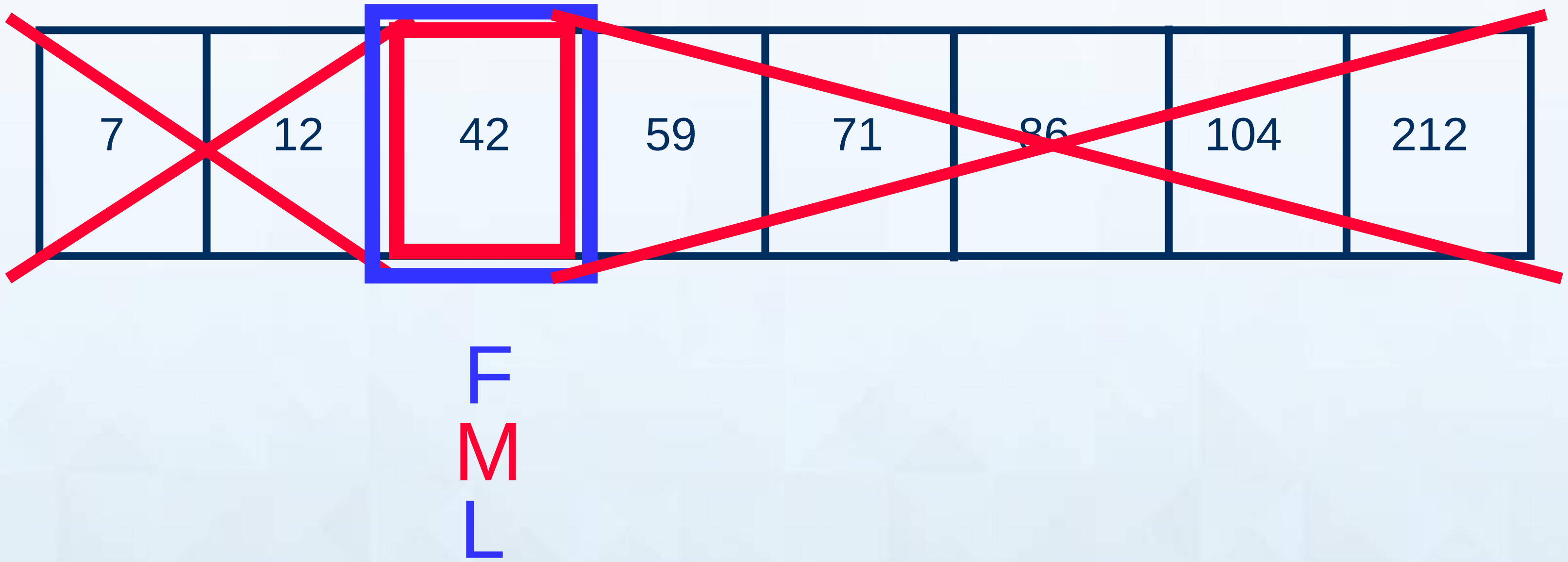
Looking for 42

Binary Search Example – Found



Looking for 42

Binary Search Example – Found



42 found – in 3 comparisons

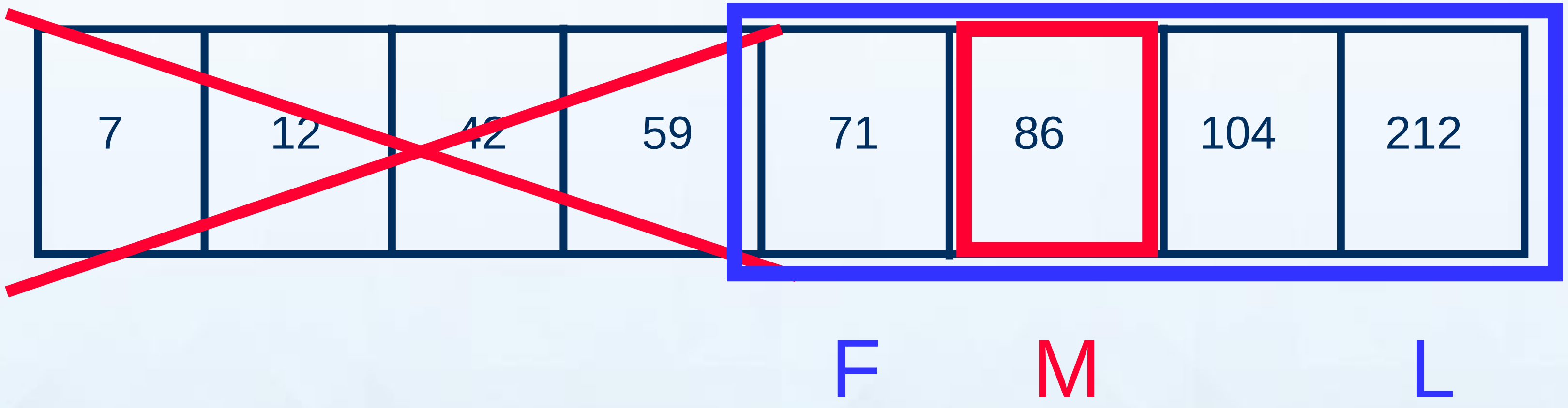
Binary Search Example – Not Found

7	12	42	59	71	86	104	212
F			M				L

Looking for 89

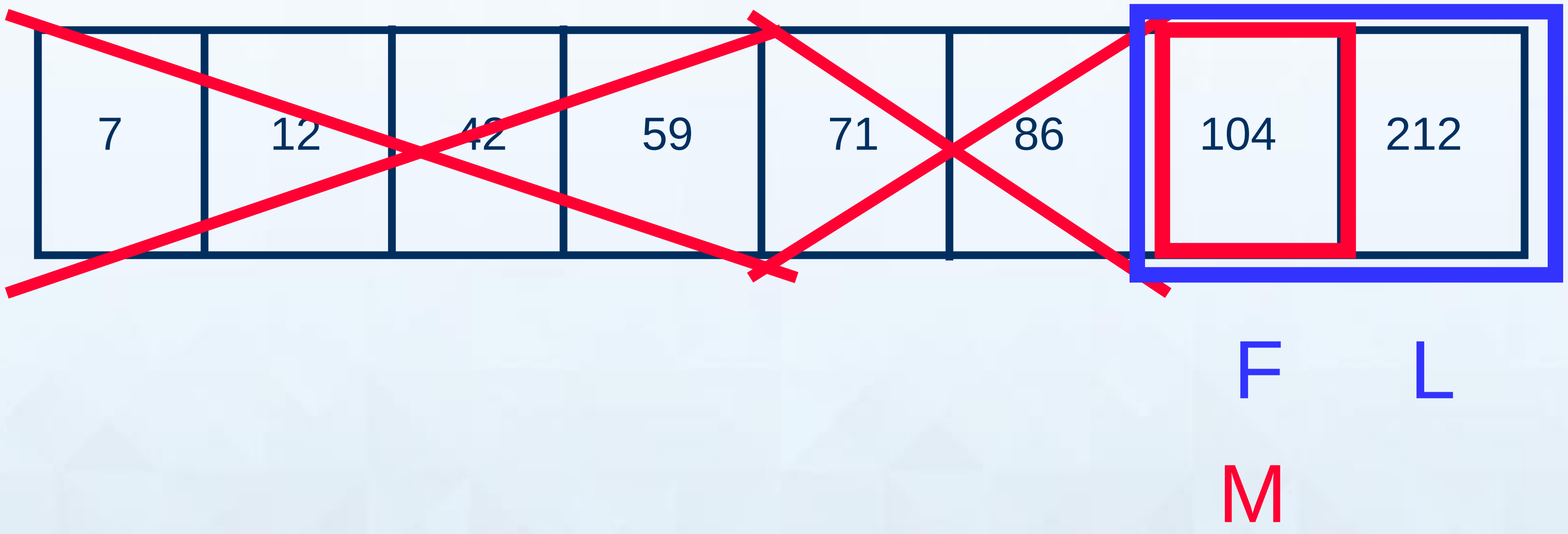
Binary Search Example – Not Found

HEXAWARE



Looking for 89

Binary Search Example – Not Found



Looking for 89

 |

Binary Search Example – Not Found

89 not found – 3 comparisons

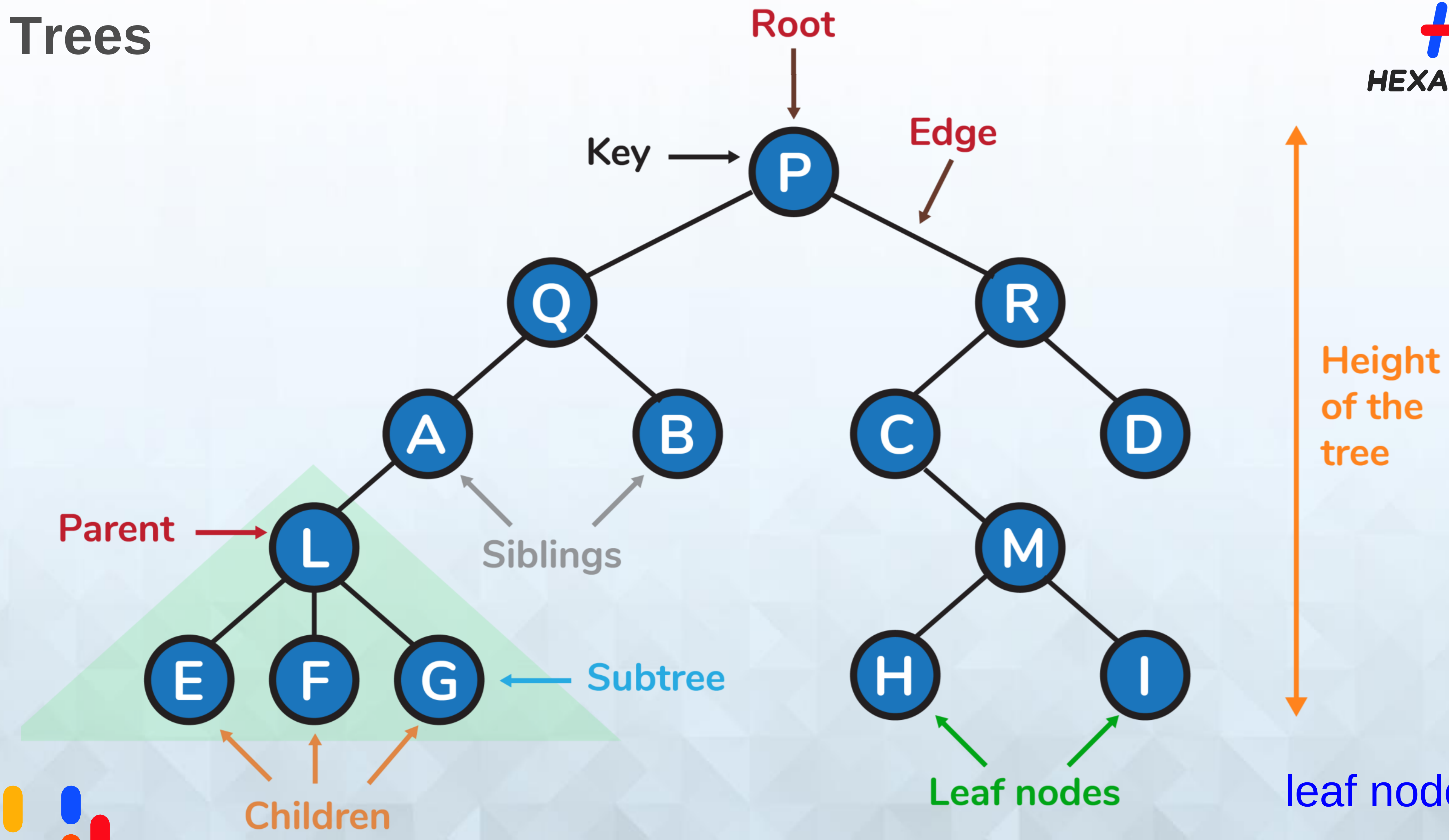
Tree Data Structure

Trees

- A tree is a non-linear data structure that consists of a root node and potentially many levels of additional nodes that form a hierarchy
- Nodes that have no children are called leaf nodes
- Non-root and non-leaf nodes are called internal nodes

leaf nodes

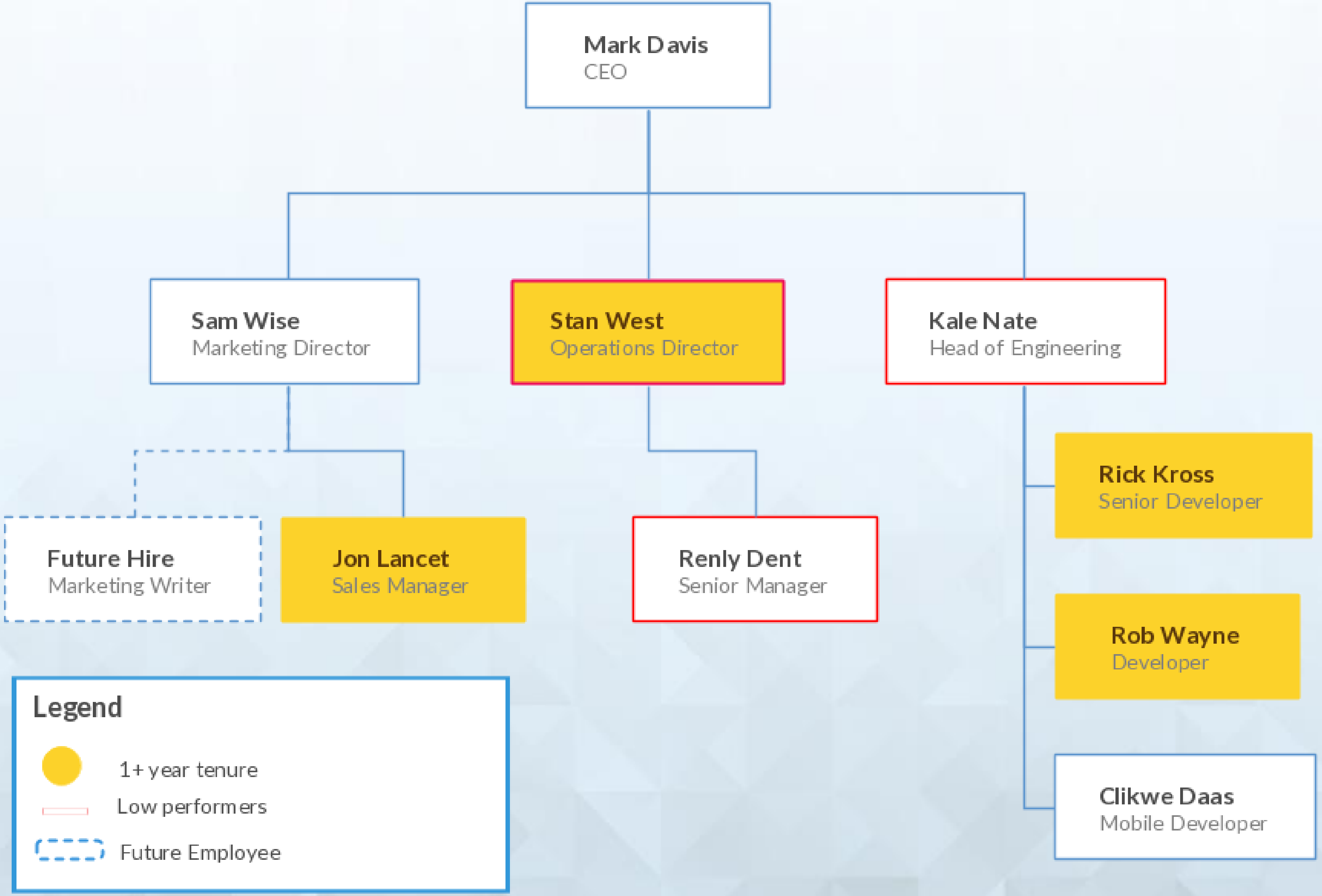
Trees



leaf nodes

Trees

Organization chart represented via a tree data structure



Tree Traversal

- Two main methods:
  - Inorder
  - Preorder
  - Postorder

- Inorder

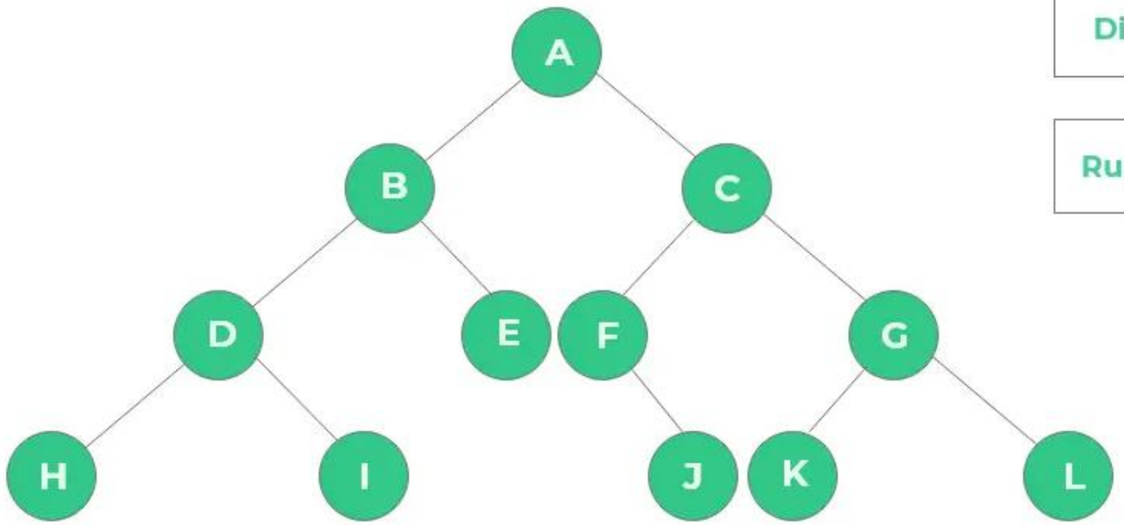
- Preorder:
  - visit the root
  - traverse in preorder the children (subtrees)

- Postorder
  - traverse in postorder the children (subtrees)
  - visit the root

 |

Tree traversal (cont..)

Inorder



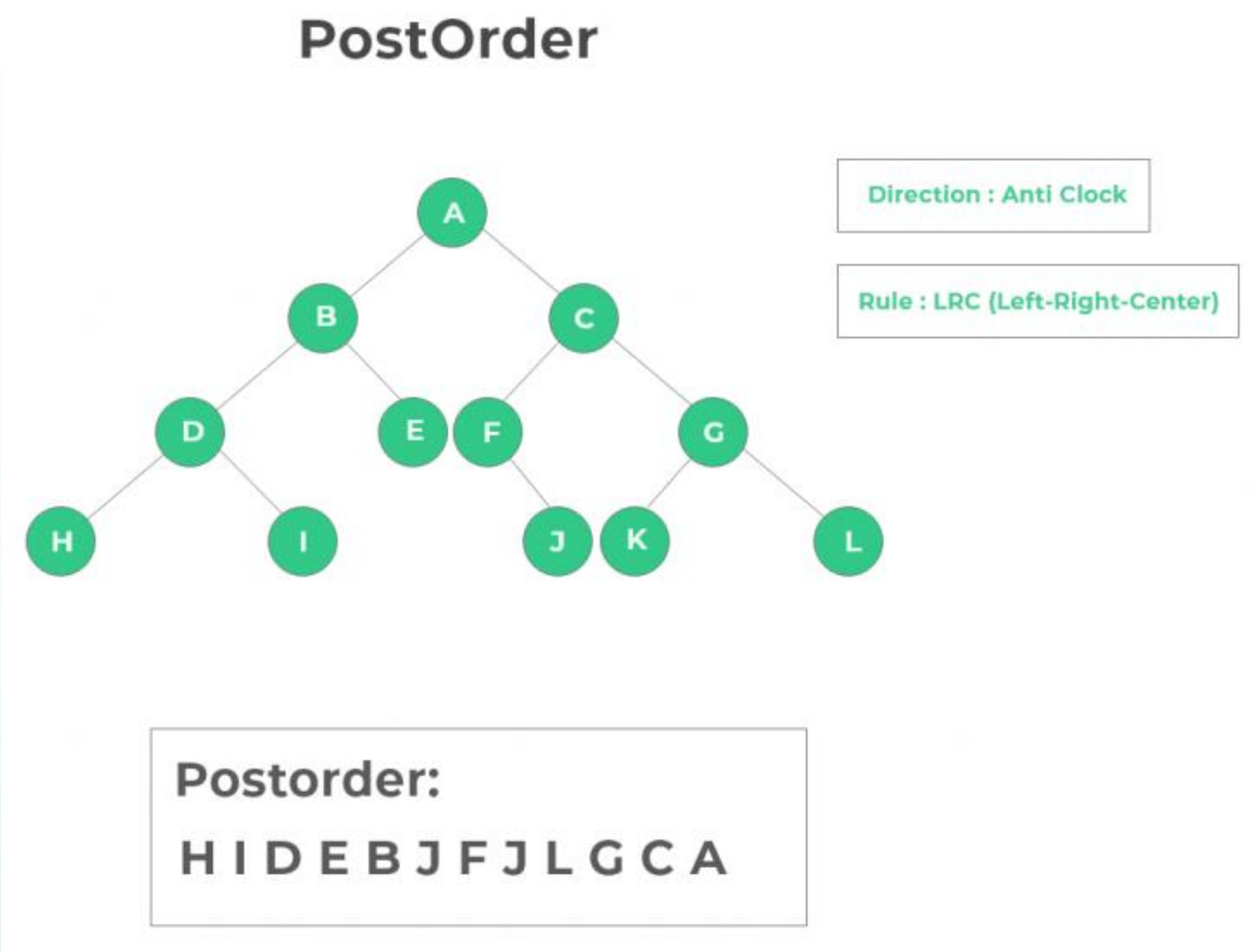
Direction : Clock

Rule : LRC (Left-Center-Right)

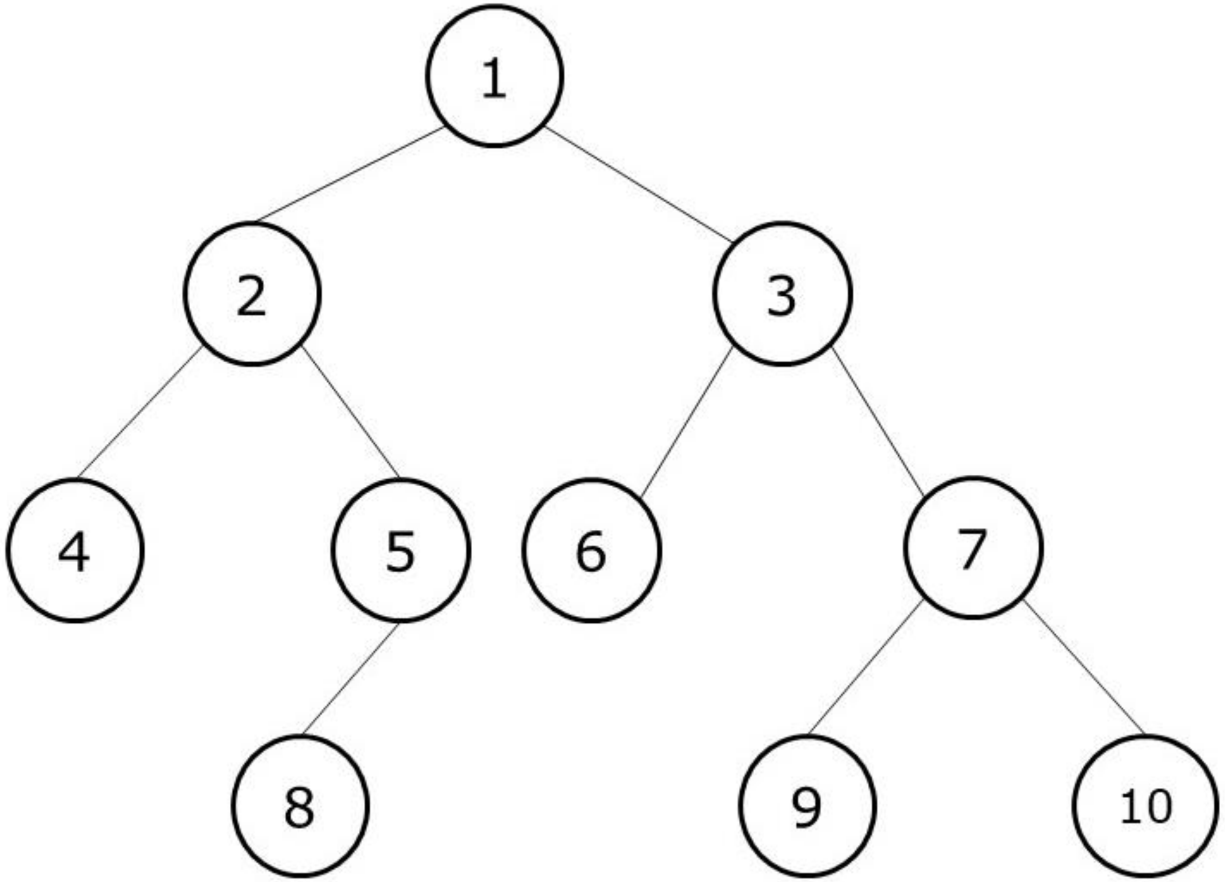
Inorder:

H D I B E A F J C K G L

Tree traversal (cont..)



Tree traversal (cont..)



Preorder Traversal:

[root, left, right]

1	2	4	5	8	3	6	7	9	10

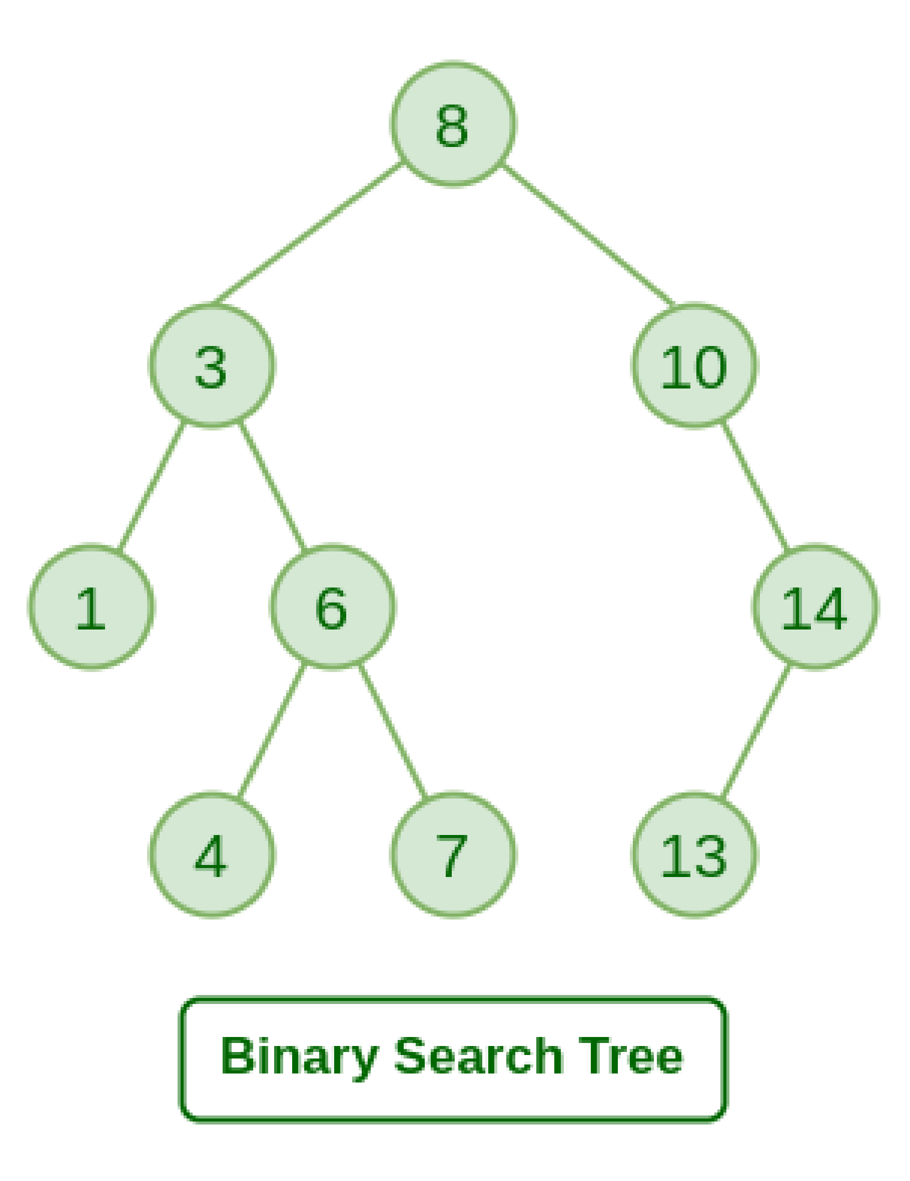
Binary Search Tree

- Binary Search Tree is a node-based binary tree data structure which has the following properties:
  - The left subtree of a node contains only nodes with keys lesser than the node’s key.
  - The right subtree of a node contains only nodes with keys greater than the node’s key.
  - The left and right subtree each must also be a binary search tree.

Binary Search Tree

Following are the basic operations of a tree

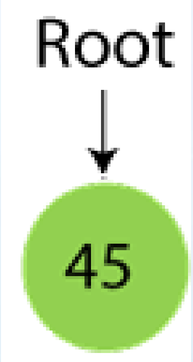
- Search
- Insert
- Pre-order Traversal
- In-order Traversal
- Post-order Traversal



creating a binary search tree

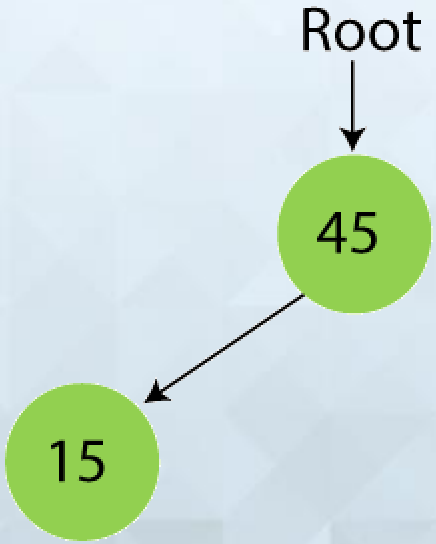
Suppose the data elements are - 45, 15, 79, 90, 10, 55, 12, 20, 50

Step 1 - Insert 45.



Step 2 - Insert 15.

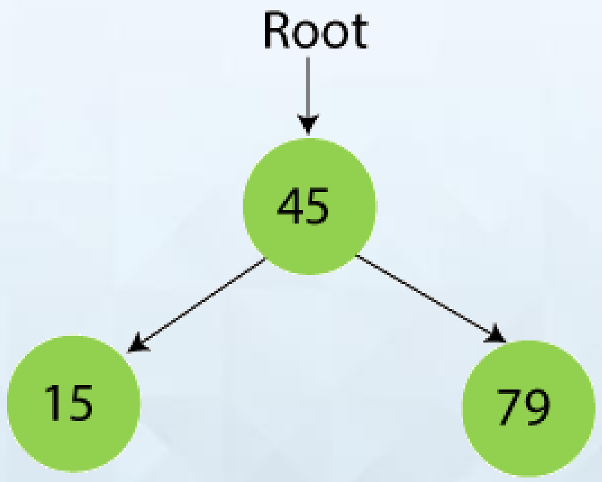
As 15 is smaller than 45, so insert it as the root node of the left subtree.



creating a binary search tree

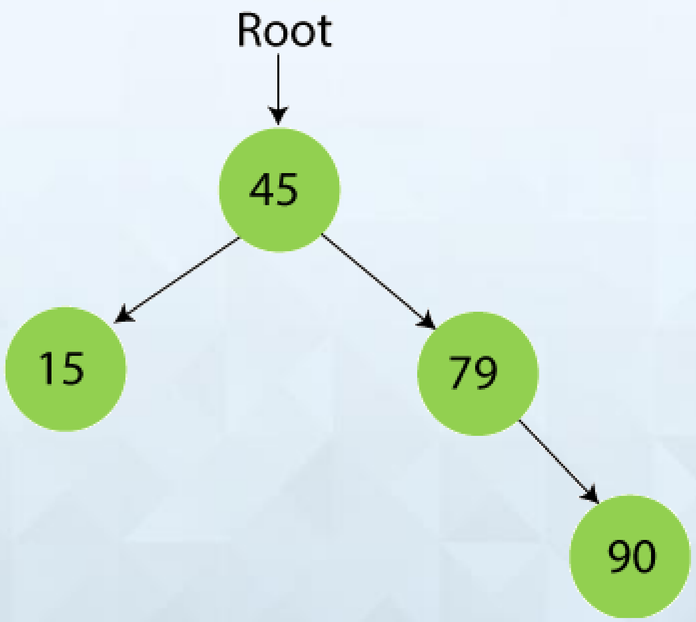
Step 3 - Insert 79.

As 79 is greater than 45, so insert it as the root node of the right subtree.



Step 4 - Insert 90.

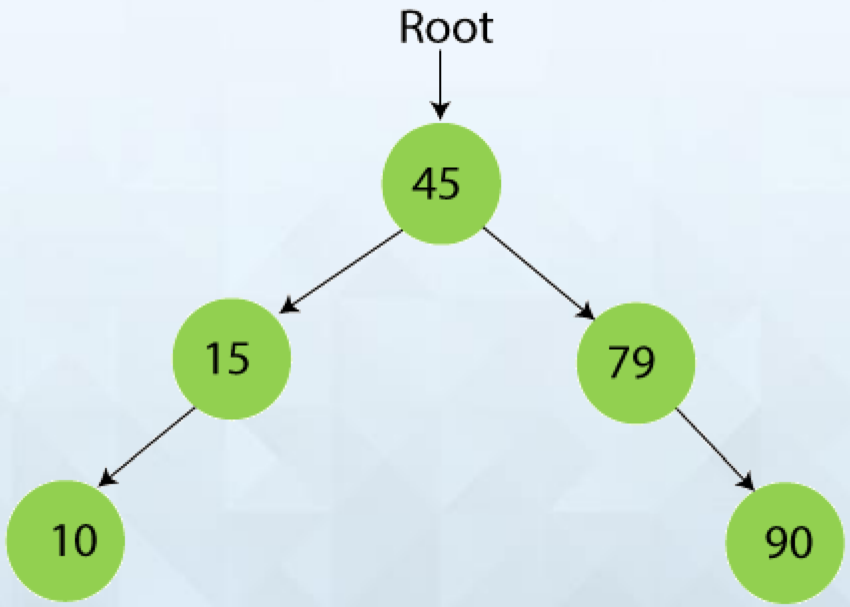
90 is greater than 45 and 79, so it will be inserted as the right subtree of 79.



creating a binary search tree

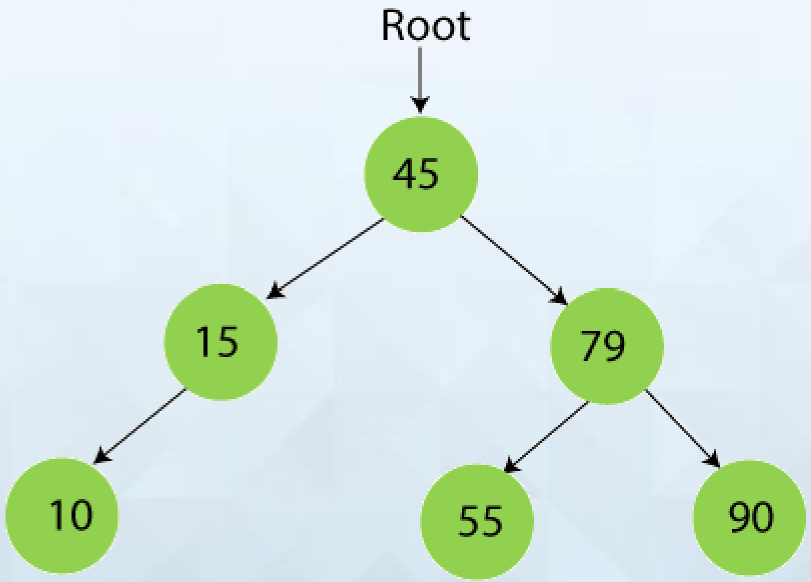
Step 5 - Insert 10.

10 is smaller than 45 and 15, so it will be inserted as a left subtree of 15.



Step 6 - Insert 55.

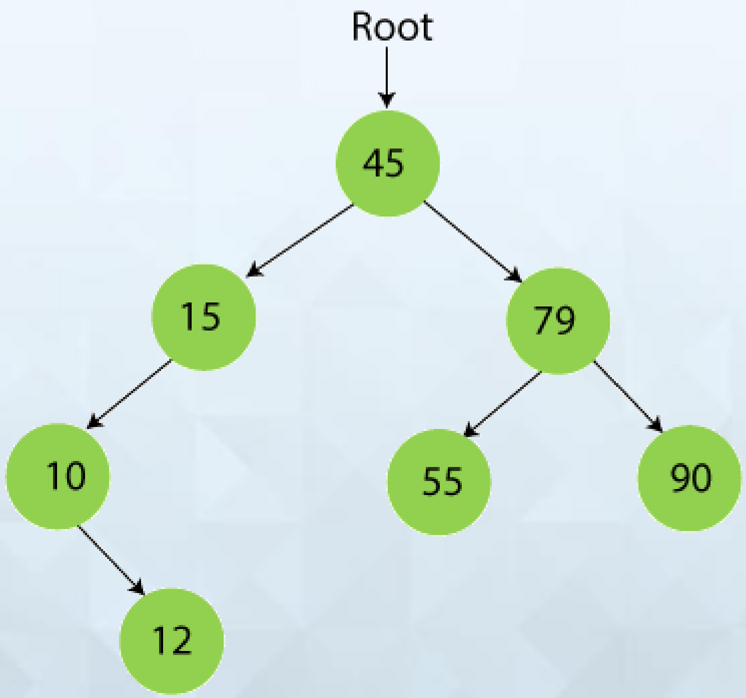
55 is larger than 45 and smaller than 79, so it will be inserted as the left subtree of 79.



creating a binary search tree

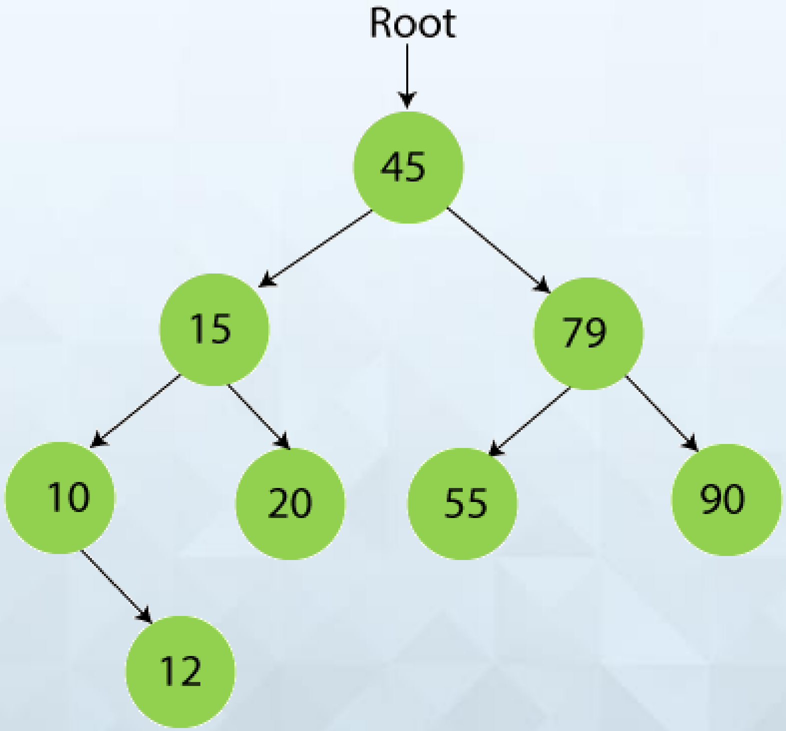
Step 7 - Insert 12.

12 is smaller than 45 and 15 but greater than 10, so it will be inserted as the right subtree of 10.



Step 8 - Insert 20.

20 is smaller than 45 but greater than 15, so it will be inserted as the right subtree of 15.



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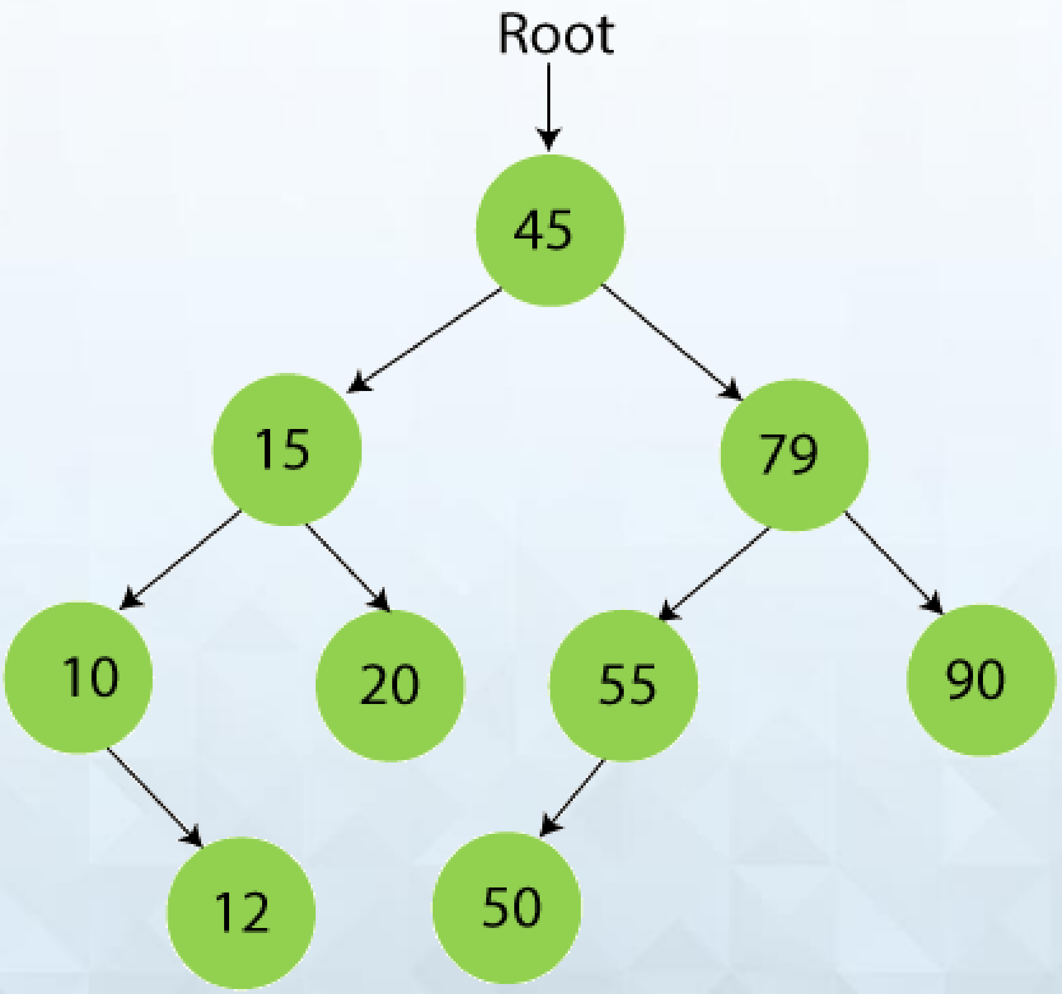
creating a binary search tree

Step 9 - Insert 50.

50 is greater than 45 but smaller than 79 and 55. So, it will be inserted as a left subtree of 55.



AVL Tree

- AVL Tree can be defined as height balanced binary search tree in which each node is associated with a balance factor which is calculated by subtracting the height of its right sub-tree from that of its left sub-tree.

- Tree is said to be balanced if balance factor of each node is in between -1 to 1, otherwise, the tree will be unbalanced and need to be balanced.

- Balance Factor (k) = height (left(k)) - height (right(k))

Why AVL Tree?

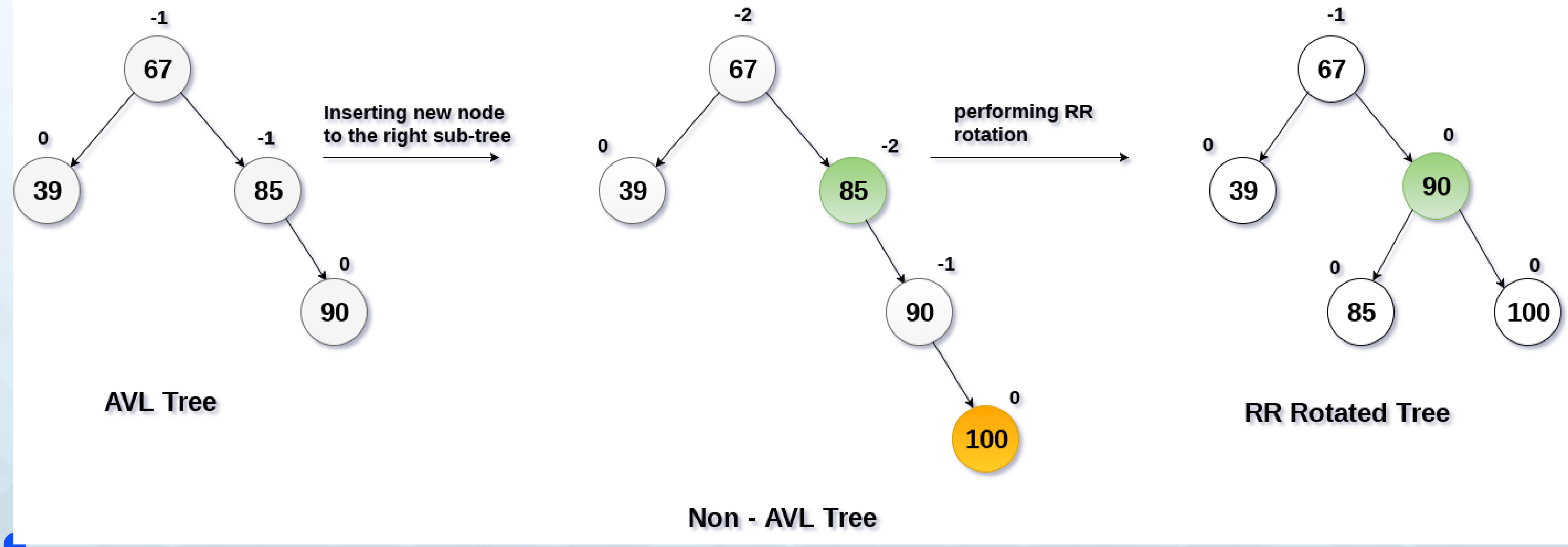
- AVL tree controls the height of the binary search tree by not letting it to be skewed.

- We perform rotation in AVL tree only in case if Balance Factor is other than -1, 0, and 1.

- There are basically four types of rotations which are as follows:
  - L L rotation: Inserted node is in the left subtree of left subtree of A
  - R R rotation : Inserted node is in the right subtree of right subtree of A
  - L R rotation : Inserted node is in the right subtree of left subtree of A
  - R L rotation : Inserted node is in the left subtree of right subtree of A

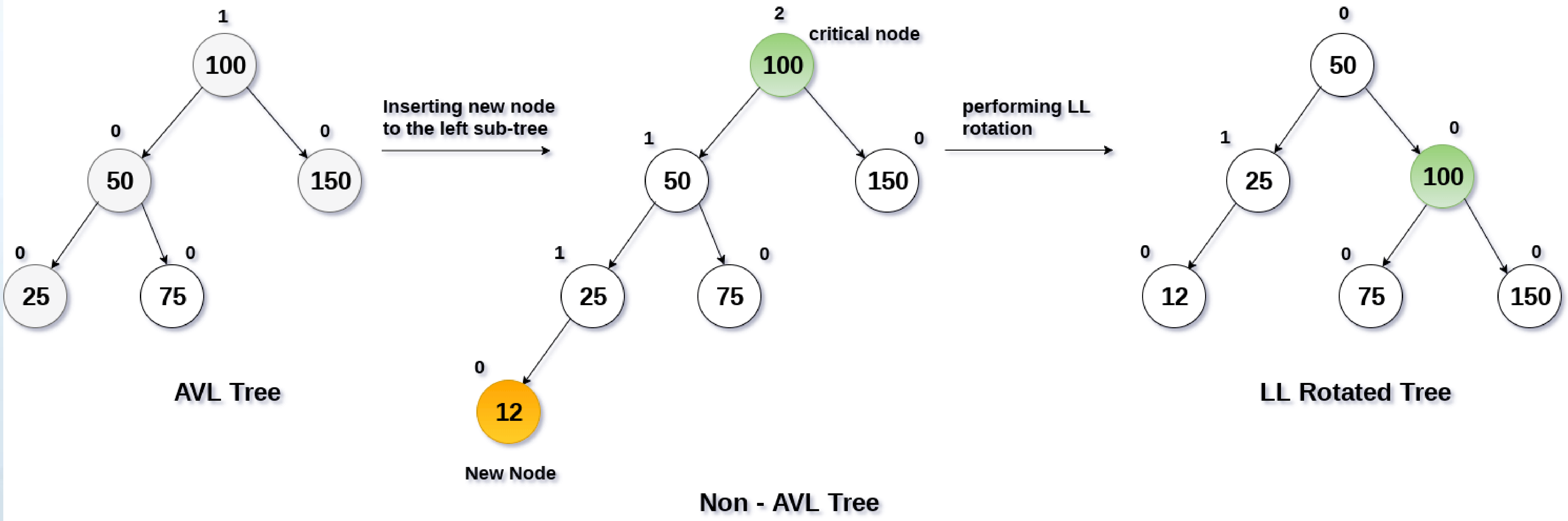
RR Rotation

- When BST becomes unbalanced, due to a node is inserted into the right subtree of the right subtree of A, then we perform RR rotation, RR rotation is an anticlockwise rotation, which is applied on the edge below a node having balance factor -2



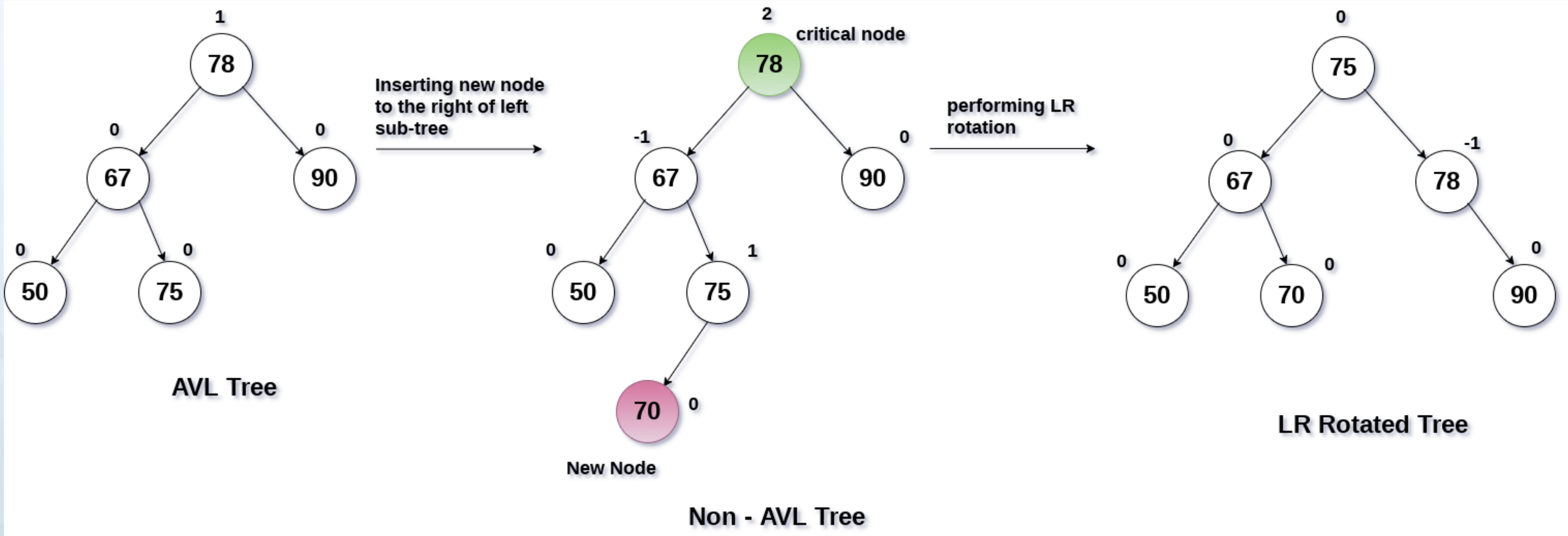
LL Rotation

- When BST becomes unbalanced, due to a node is inserted into the left subtree of the left subtree of C, then we perform LL rotation, LL rotation is clockwise rotation, which is applied on the edge below a node having balance factor 2.



LR Rotation

- Double rotations are bit tougher than single rotation which has already explained above. LR rotation = RR rotation + LL rotation, i.e.,
- first RR rotation is performed on subtree and then LL rotation is performed on full tree, by full tree we mean the first node from the path of inserted node whose balance factor is other than -1, 0, or 1.



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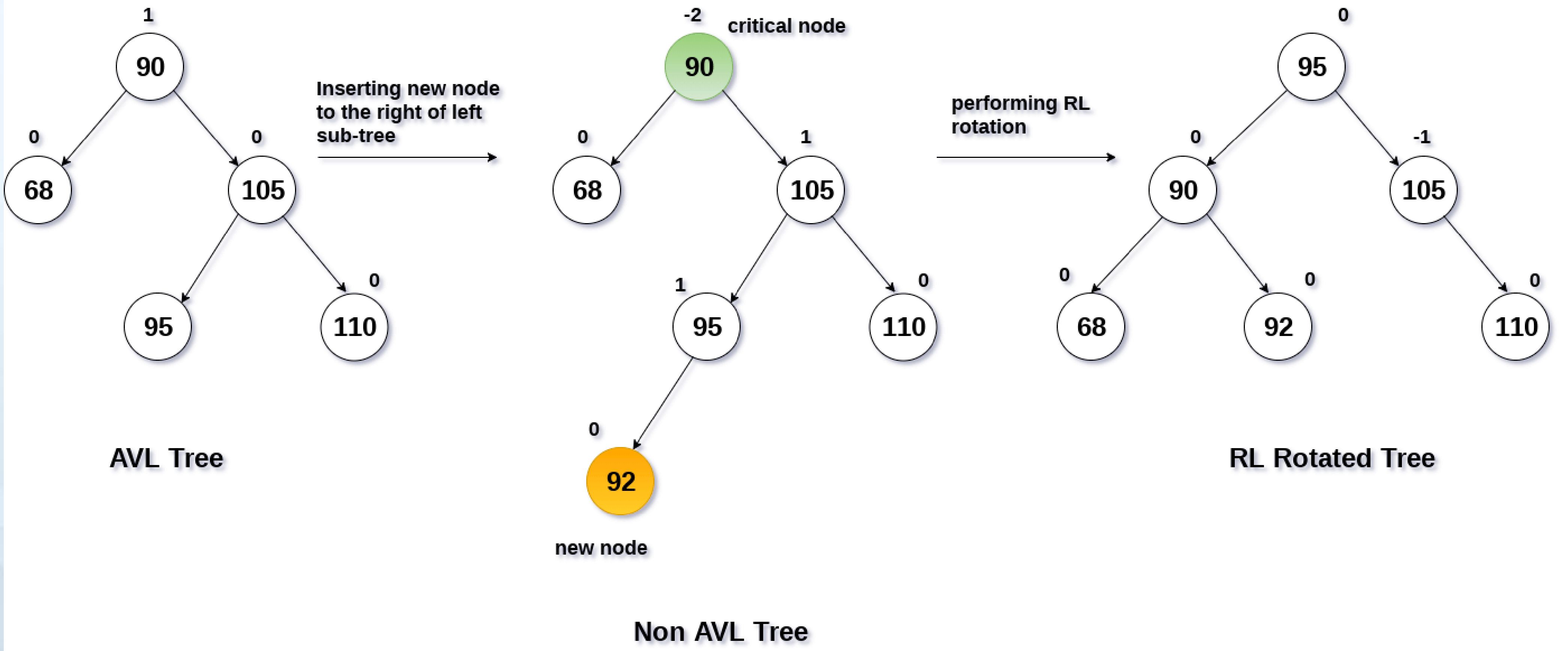
RL Rotation

- R L rotation = LL rotation + RR rotation, i.e., first LL rotation is performed on subtree and then RR rotation is performed on full tree, by full tree we mean the first node from the path of inserted node whose balance factor is other than -1, 0, or 1.



Quiz

1

What data structure can be used to check if a syntax has balanced paranthesis ?

A - queue
B - tree
C - list
D - stack

D - stack

2

Which of the following algorithm is not stable?

A - Bubble Sort
B - Quick Sort
C - Merge Sort
D - Insertion Sort

B - Quick Sort

3

Which of the following is a linear data structure?

A - queue
B - tree
C - Array
D - stack

C - Array

4

Which of the following represents the Postorder Traversal of a Binary Tree?

A - Left -> Right -> Root
B - Left -> Root -> Right
C - Right -> Left -> Root
D - Right -> Root -> Left

A - Left -> Right -> Root

5

Which of the following is not the correct statement for a stack data structure?

A - Arrays can be used to implement the stack
B - Stack follows FIFO
C - Elements are stored in a sequential manner
D - Top of the stack contains the last inserted element

B - Stack follows FIFO

6

Which one of the following techniques is not used in the Binary tree?

A. Randomized traversal
B. Preorder traversal
C. Postorder traversal
D. Inorder traversal

A - Randomized traversal

 |

7

Which of the following options is not true about the Binary Search tree?

A. The value of the left child should be less than the root node
B. The value of the right child should be greater than the root node.
C. The left and right sub trees should also be a binary search tree
D. None of the above

D - None of the above

8

How can we define a AVL tree?

A. A tree which is binary search tree and height balanced tree.
B. A tree which is a binary search tree but unbalanced tree.
C. A tree with utmost two children
D. A tree with utmost three children

A - A tree which is binary search tree and height balanced tree.

Queries

Learning material references

- Books
  - “Introduction to Algorithms”, Thomas H Cormen, Charles Leiserson, Ronald Rivest and Clifford Stein, 3rd edition, MIT, July 2009
  - “Problem Solving Using C: Structured Programming Techniques”, Yuksel Uckan , McGraw-Hill Inc.,1998
  - "Data Structures and Algorithms Made Easy in Java: Data Structure and Algorithmic Puzzles", Narasimha Karumanchi, areerMonk Publications, 2014
- Web
  - http://www.slideshare.net/dokka/program-design-and-problem-solving-techniques

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