Sunbeam Institute of Information Technology
Pune and Karad

Module – Data Structures

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Data Structures - Introduction

What is Data structure?

- Organising data into memory
- Processing the data efficiently

Why we need Data Structure?

To achieve

1. Efficiency
2. Reusability

Programming Language

- DS and Algorithms are language independent
- We will use **C programming** to implement Data structures

Data Structures

- **Linear Data Structures** (Basic Data Structure)
  - Array
  - Structure
  - Linked List
  - Stack
  - Queue
- **Non linear Data Structures** (Advanced Data Structure)
  - Tree
  - Heap
  - Graph

Linear Data Structures

- Data elements are arranged linearly (sequentially) into the memory.
- Data elements can be accessed linearly / Sequentially.

Non linear Data Structures

- Data elements are arranged in non linear manner (hierarchical) into the memory.
- Data elements can be accessed non linearly.

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Data Structures - Introduction

- **Algorithm**
  - is a clearly specified set of simple instructions.
  - is a solution to solve a problem.
  - is written in human understandable language.
  - Algorithm is also referred as "pseudo code".

One problem statement has multiple solutions, out of which we need to select efficient one. Hence we need to do analysis of an algorithm.

Problem Statement → Algorithm → Program → Machine

Template → Implementation

e.g. Write an algorithm to find sum of all array elements.
Algorithm:
Step 1: Initialize sum =0
Step 2: Traverse array form index 0 to N-1
Step 3: Add each element in the sum variable
Step 4: Return the final sum

```
Algorithm SumArray(array, size) {
        sum = 0;
        For(index = 0 ; index < size ; index++)
                sum += array[index];
        return sum;
}
```


Searching Algorithm : Linear Search

- Search a number in a list of given numbers (random order)

- **Algorithm**
  - Step 1: Accept key from user
  - Step 2: Traverse list from start to end
  - Step 3: Compare key with each element of the list
  - Step 4: If key is found return true else false

```
Algorithm linear_search(a, s, k)
{
        for(i = 0 ; i < s ; i++ )
        {
                if(a[i] == key)
                        return true;
        }
        return false;
}
```

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Searching Algorithm : Binary Search

- Given an integer x and integers A0, A1, …An-1, which are pre-sorted and already in memory, find i such that Ai = x or return i = -1 if x is not in the input

- **Algorithm**
  - Step 1: Accept key from user
  - Step 2: Check if x is the middle element. If so x is found at mid
  - Step 3: If x is smaller than the middle element, apply same strategy to the sorted subarray to the left of middle element.
  - Step 4: If x is larger than the middle element, apply same strategy to the sorted subarray to the right of middle element

Sorting Algorithm : Selection Sort

Algorithm:

- Find the minimum element in an array A[i -> n-1] and place it at beginning
  - where n – size of array and i – 0, 1, 2, …n-2
- Repeat the above procedure n – 1 times where n is size of array

- Select ith element (i = 0 -> n-1)
  - Compare with all elements other than ith
    - if(A[i] > A[other])
      - Swap both elements

arr	44	11	55	22	66	33
	0	1	2	3	4	5

Sorting Algorithm : Bubble Sort

Algorithm:

- Find the maximum element from two consecutive elements of an array A[i -> n-i-1] and place it at second location
  - where n – size of array and i – 0, 1, 2, …n-2
- Repeat the above procedure n – 1 times where n is size of array

- Repeat for n-1 times
  - Compare two consecutive elements
    - If left element > right element
      - Swap both elements

arr

33	22	66	55	44	11
0	1	2	3	4	5

Sorting Algorithm : Insertion Sort

Algorithm:

- Repeat from 1 to n-1
  - Select ith element in the array
    - Compare ith element with all its left neighbours
      - Insert at appropriate position

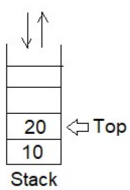
arr

55	44	22	66	11	33
0	1	2	3	4	5

Stack

Stack

- Stack is Last-In-First-Out structure.
  - Stack Operations:
    - push()
    - pop()
    - peek()
    - is_empty()
    - is_full()



Stack

- Parenthesis balancing
- Expression conversion and evaluation
- Function calls
- Used in advanced data structures for traversing

- **Expression conversion and evaluation:**
  - Infix to postfix
  - Infix to prefix
  - Postfix evaluation
  - Prefix evaluation
  - Prefix to postfix
  - Postfix to infix

Sorting Algorithms : Merge and Quick Sort

- **Merge sort**
  - Divide array in two equal partitions
  - Sort two partitions individually
  - Merge these sorted partitions into a temp array
  - Over write temp array back to original array

- **Quick sort**
  - Select pivot element from your array.
  - Arrange smaller elements than pivot to the left side of pivot.
  - Arrange greater elements than pivot to the right side of pivot.
  - Further sort the elements on both sides of pivot separately.

Algorithm Analysis

- Analysis is done to determine how much resources it require.
- Resources such as time or space
- There are two measures of doing analysis of any algorithm
  - Space Complexity
    - Unit space to store the data into the memory (Input space) and additional space to process the data (Auxiliary space)

    e.g. Algorithm to find sum of all array elements.

    int arr[n] – n units of input space
    sum, index, size – 3 units of auxiliary space
    Total space required = input space + auxiliary space = n + 3 = n units
  - Time Complexity
    - Unit time required to complete any algorithm
    - Approximate measure of time required to complete algorithm
    - Depends on loops in the algorithm
    - Also depends on some external factors like type of machine, no of processed running on machine.
    - That's why we can not find exact time complexity.
  - Method used to calculate complexities, is "**Asymptotic Analysis**"

Asymptotic Analysis

- It is a mathematical way to calculate complexities of an algorithm.
- It is a study of change in performance of the algorithm, with the change in the order of inputs.
- It is not exact analysis
- Few mathematical notations are used to denote complexities.
- These notations are called as "Asymptotic notations" and are
  - Omega notation (Ω)
    - Represents lower bound of the running algorithm
    - It is used to indicate the best case complexity of an algorithm
  - Big – Oh notation (O)
    - Represents upper bound of the running algorithm
    - It is used to indicate the worst case complexity of an algorithm
  - Theta notation (ϴ)
    - Represents upper and lower bound of the running time of an algorithm (tight bound)
    - It is used to indicate the average case complexity of an algorithm

Time Complexity

```
Statement;
```

constant

```
for(i=0; i< n; i++)
{
        statements;
}
```

Linear

```
for(i=0; i< n; i++)
{
        for(j=0; j< n; j++)
        {
                statements;
        }

}
```

Quadratic

```
for(i=n; i>0; i/=2)
{
        statement
}
```

Logarithmic

Searching Algorithms : Time Complexity

Linear Search :

	No of Comparisons		Running Time	Time Complexity
Best Case	1	Key found at very first position	O(1)	O(1)
Average Case	n/2	Key found at in between position	O(n/2) = O(n)	O(n)
Worst Case	n	Key found at last position or not found	O(n)	O(n)

Binary Search :

	No of Comparisons		Running Time	Time Complexity
Best Case	1	Key found in very first iteration	O(1)	O(1)
Average Case	log n	Key found at non-leaf position	O(log n)	O(log n)
Worst Case	log n	if either key is not found or key is found at leaf position	O(log n)	O(log n)

Sorting Algorithms : Comparisons

- Selection sort algorithm is too simple, but performs poor and no optimization possible.
- Bubble sort can be improved to reduce number of iterations.
- Insertion sort performs well if number of elements are too less. Good if adding elements and resorting.
- Quick sort is stable if number of elements increased. However worst case performance is poor.
- Merge sort also perform good, but need extra auxiliary space.

Algorithm	Best Case	Average Case	Worst Case
Selection sort	O(n^2)	O(n^2)	O(n^2)
Bubble sort	O(n)	O(n^2)	O(n^2)
Insertion sort	O(n)	O(n^2)	O(n^2)
Merge sort	O(n log n)	O(n log n)	O(n log n)
Quick sort	O(n log n)	O(n log n)	O(n^2)

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Thank you!

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