Data Structures and Algorithms

By

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(Lecture 2)

Introduction

- Data Structures and Algorithms
  - It is one of the classic, core topics of Computer and development of good quality computer programs
- Data Structure
  - Data Structures are the programmatic way of storing data so that data can be used efficiently.
  - Almost every enterprise application uses various types of data structures in one or the other way.

Why to Learn Data Structure and Algorithms?

- As applications are getting complex and data rich, there are three common problems that applications face now-a-days.
- **Data Search** – Consider an inventory of 1 million(10^6) items of a store. If the application is to search an item, it has to search an item in 1 million(10^6) items every time slowing down the search. As data grows, search will become slower.

Why to Learn Data Structure and Algorithms?

- **Processor speed** – Processor speed although being very high, falls limited if the data grows to billion records.
- **Multiple requests** – As thousands of users can search data simultaneously on a web server, even the fast server fails while searching the data.
- To solve the above-mentioned problems, data structures come to rescue.
- Data can be organized in such a way that all items may not be required to be searched, and the required data can be searched almost instantly.

Applications of Data Structure and Algorithms

- Algorithm is a step-by-step procedure, which defines a set of instructions to be executed in a certain order to get the desired output.
- Algorithms are generally created independent of programming languages
- An algorithm can be implemented in more than one programming language.

Applications of Data Structure and Algorithms

- From the data structure point of view, following are some important categories of algorithms –
- **Search** – Algorithm to search an item in a data structure.
- **Sort** – Algorithm to sort items in a certain order.
- **Insert** – Algorithm to insert item in a data structure.
- **Update** – Algorithm to update an existing item in a data structure.
- **Delete** – Algorithm to delete an existing item from a data structure.

Applications of Data Structure and Algorithms

- The following computer problems can be solved using Data Structures –
  - Fibonacci number series
  - Knapsack problem
  - Tower of Hanoi
  - All pair shortest path by Floyd-Warshall
  - Shortest path by Dijkstra
  - Project scheduling

Applications of Data Structure and Algorithms

- Data Structure is a systematic way to organize data in order to use it efficiently. Following terms are the foundation terms of a data structure.
  - **Interface** –
    - Each data structure has an interface. Interface represents the set of operations that a data structure supports.
    - An interface only provides the list of supported operations, type of parameters they can accept and return type of these operations.
  - **Implementation** –
    - Implementation provides the internal representation of a data structure. Implementation also provides the definition of the algorithms used in the operations of the data structure.

Characteristics of an Algorithm

- Not all procedures can be called an algorithm. An algorithm should have the following characteristics –
- **Unambiguous** – Algorithm should be clear and unambiguous. Each of its steps (or phases), and their inputs/outputs should be clear and must lead to only one meaning.
- **Input** – An algorithm should have 0 or more well-defined inputs.
- **Output** – An algorithm should have 1 or more well-defined outputs, and should match the desired output.

Execution Time Cases

- There are three cases which are usually used to compare various data structure's execution time in a relative manner.
- **Worst Case** – This is the scenario where a particular data structure operation takes maximum time it can take.
- If an operation's worst case time is $f(n)$ then this operation will not take more than $f(n)$ time where $f(n)$ represents function of n.

Execution Time Cases

- **Average Case** – This is the scenario depicting the average execution time of an operation of a data structure.
- If an operation takes $f(n)$ time in execution, then m operations will take $mf(n)$ time.
- **Best Case** – This is the scenario depicting the least possible execution time of an operation of a data structure.
- If an operation takes $f(n)$ time in execution, then the actual operation may take time as the random number which would be maximum as $f(n)$.

Basic Terminology

- **Data** – Data are values or set of values.
- **Data Item** – Data item refers to single unit of values.
- **Group Items** – Data items that are divided into sub items are called as Group Items.
- **Elementary Items** – Data items that cannot be divided are called as Elementary Items.
- **Attribute and Entity** – An entity is that which contains certain attributes or properties, which may be assigned values.

Basic Terminology

- **Entity Set** – Entities of similar attributes form an entity set.
- **Field** – Field is a single elementary unit of information representing an attribute of an entity.
- **Record** – Record is a collection of field values of a given entity.
- **File** – File is a collection of records of the entities in a given entity set.

Characteristics of a Data Structure

- **Correctness** – Data structure should implement its interface correctly.
- **Time Complexity** – Running time or the execution time of operations of data structure must be as small as possible.
- **Space Complexity** – Memory usage of a data structure operation should be as little as possible
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Characteristics of an Algorithm

- **Finiteness** – Algorithms must terminate after a finite number of steps.
- **Feasibility** – Should be feasible with the available resources.
- **Independent** – An algorithm should have step-by-step directions, which should be independent of any programming code.

How to Write an Algorithm?

- There are no well-defined standards for writing algorithms.
- Rather, it is problem and resource dependent.
- Algorithms are never written to support a particular programming code.
- As we know that all programming languages share basic code constructs like loops (do, for, while), flow-control (if-else), etc.
- These common constructs can be used to write an algorithm.

How to Write an Algorithm?

- We write algorithms in a step-by-step manner, but it is not always the case.
- Algorithm writing is a process and is executed after the problem domain is well-defined.
- That is, we should know the problem domain, for which we are designing a solution.

Example

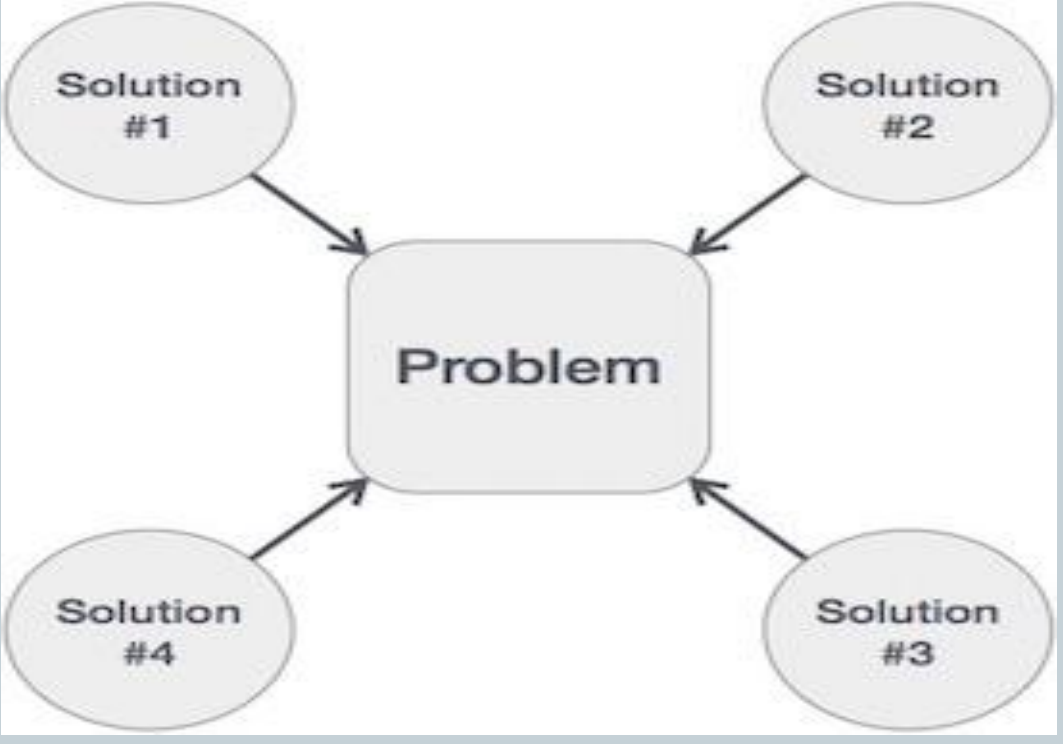
- Let's try to learn algorithm-writing by using an example.

```
Step 1 - START
Step 2 - declare three integers a, b & c
Step 3 - define values of a & b
Step 4 - add values of a & b
Step 5 - store output of step 4 to c
Step 6 - print c
Step 7 - STOP
```

```
Step 1 - START ADD
Step 2 - get values of a & b
Step 3 - c ← a + b
Step 4 - display c
Step 5 - STOP
```

- Usually the second method is easy for the analyst to analyze the algorithm ignoring all unwanted definitions

- We design an algorithm to get a solution of a given problem. A problem can be solved in more than one ways.



Algorithm Analysis

- Efficiency of an algorithm can be analyzed at two different stages, before implementation and after implementation. They are the following –
- ***A Priori* Analysis** – This is a theoretical analysis of an algorithm. Efficiency of an algorithm is measured by assuming that all other factors, for example, processor speed, are constant and have no effect on the implementation.
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- ***A Posterior* Analysis** – This is an empirical analysis of an algorithm. The selected algorithm is implemented using programming language. This is then executed on target computer machine. In this analysis, actual statistics like running time and space required, are collected.

Algorithm Complexity

- **Time Factor** – Time is measured by counting the number of key operations such as comparisons in the sorting algorithm.
- **Space Factor** – Space is measured by counting the maximum memory space required by the algorithm.