# Unit-1
# Introduction to Data Structure

Course: MCA

Subject: Data and File Structure

# Data Structure

- A **Data Structure** is an aggregation of atomic and composite data into a set with defined relationships.

- Structure means a set of rules that holds the data together.
- Taking a combination of data and fit them into such a structure that we can define its relating rules, we create a **data structure**.

# Data structure

- A data structure in computer science is a way of storing data in a computer so that it can be used efficiently.
  - An organization of mathematical and logical concepts of data
  - Implementation using a programming language
  - A proper data structure can make the algorithm or solution more efficient in terms of time and space

# Data Structures: Properties

- **Most** of the modern programming languages **support** a number of data structures.
- In addition, modern programming languages **allow** programmers **to create new** data structures for an application.
- Data structures can be nested.
- A data structure may contain other data structures (array of arrays, array of records, record of records, record of arrays, etc.)

# What is Data Structures?

- A data structure is defined by
  - (1) the logical arrangement of data elements, combined with
  - (2) the set of operations we need to access the elements.

# What is Data Structures?

- Example:
- library is composed of elements (books)
  - Accessing a particular book requires knowledge of the arrangement of the books
  - Users access books only through the librarian

# Cont..

- An algorithm is a finite set of instructions that, if followed, accomplishes a particular task.
- All the algorithms must satisfy the following criteria:
  - Input
  - Output
  - Precision (Definiteness)
  - Effectiveness
  - Finiteness

# TYPES OF DATA STRUCURE

- **Primitive & Non Primitive Data Structures**

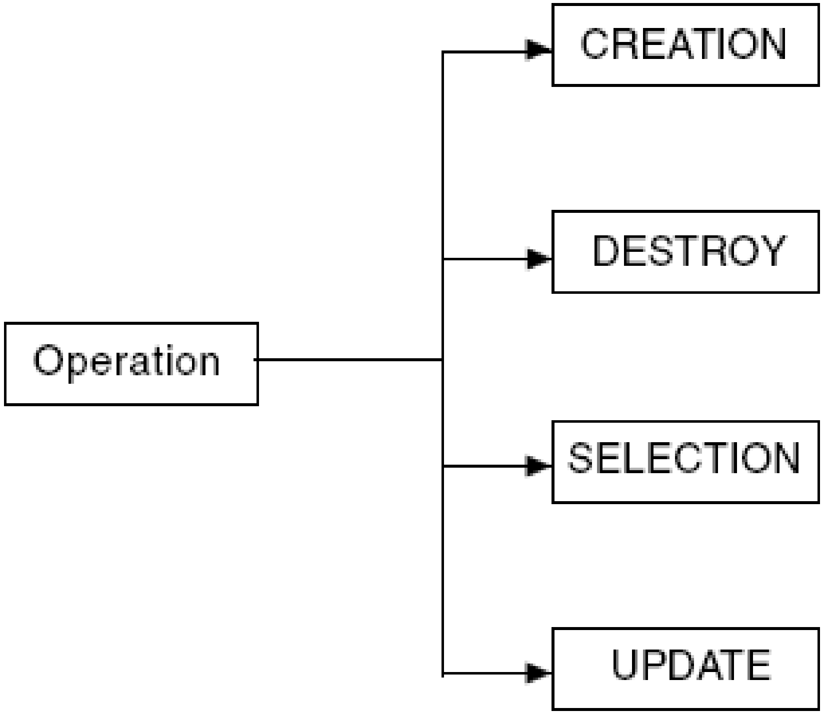
- **Primitive data Structure**
- The integers, reals, logical data, character data, pointer and reference are primitive data structures.
- Data structures that normally are directly operated upon by machine-level instructions are known as primitive data structures.

# Non-primitive Data Structures

- These are more complex data structures. These data structures are derived from the primitive data structures.
- They stress on formation of sets of homogeneous and heterogeneous data elements.
- The different operations that are to be carried out on data are nothing but designing of data structures.
- CREATE
- DESTROY
- SELECT
- UPDATE

# Data structures operations

The different operations that can be performed on data structures are shown in **Fig.**



# Performance Analysis

- There are problems and algorithms to solve them.
- Problems and problem instances.
- Example: Sorting data in ascending order.
  - Problem: Sorting
  - Problem Instance: e.g. sorting data (2 3 9 5 6 8)
  - Algorithms: Bubble sort, Merge sort, Quick sort, Selection sort, etc.
- Which is the best algorithm for the problem? How do we judge?

# Performance Analysis

- Two criteria are used to judge algorithms:
  (i) time complexity (ii) space complexity.

- <u>Space Complexity</u> of an algorithm is the amount of memory it needs to run to completion.
- <u>Time Complexity</u> of an algorithm is the amount of CPU time it needs to run to completion.

# Space Complexity: Example 1

1. Algorithm abc (a, b, c)
2. {
3. return a+b+b*c+(a+b-c)/(a+b)+4.0;
4. }

For every instance 3 computer words required to store variables: a, b, and c.

Therefore $S_p()= 3$. $S(P) = 3$.

# Time Complexity

- What is a program step?
  - a+b+b*c+(a+b)/(a-b) → one step;
  - comments → zero steps;
  - while (<expr>) do → step count equal to the number of times <expr> is executed.
  - for i=<expr> to <expr1> do → step count equal to number of times <expr1> is checked.

# Performance Measurement

- Which is better?
  - $T(P1) = (n+1)$ or $T(P2) = (n^2 + 5)$.
  - $T(P1) = \log (n^2 + 1)/n!$ or $T(P2) = n^n(n\log n)/n^2$.
- Complex step count functions are difficult to compare.
- For comparing, ‘rate of growth’ of time and space complexity functions is easy and sufficient.

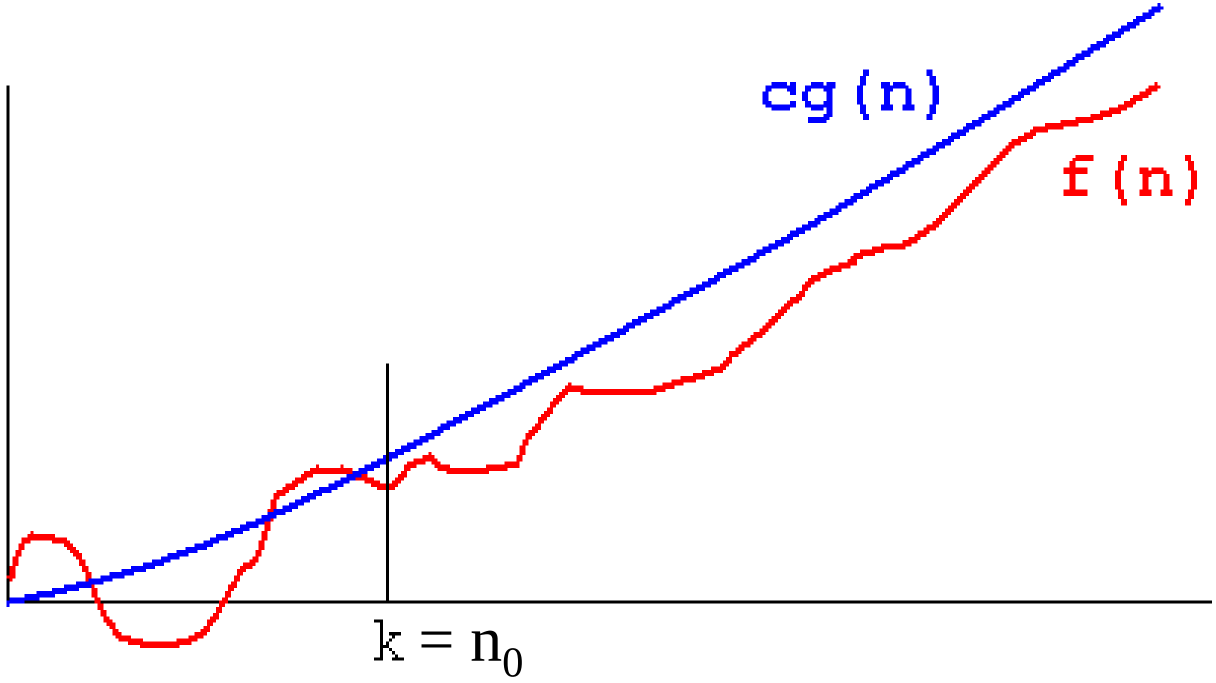
# Big O Notation

- Big O of a function gives us 'rate of growth' of the step count function *f(n)*, in terms of a simple function *g(n)*, which is easy to compare.
- Definition:

  [Big O] The function $f(n) = O(g(n))$ (big 'oh' of g of n) if

  there exist positive constants c and $n_0$ such that $f(n) <= c*g(n)$ for all $n$, $n>=n_0$. See graph on next slide.
- Example: f(n) = 3n+2 is O(n) because 3n+2 <= 4n for all n >= 2. c = 4, $n_0$ = 2. Here g(n) = n.

# Big O Notation[1]



# Big O Notation

- Example: $f(n) = 10n^2+4n+2$ is $O(n^2)$

  because $10n^2+4n+2 <= 11n^2$ for all $n >=5$.
- Example: $f(n) = 6*2^n+n^2$ is $O(2^n)$

  because $6*2^n+n^2 <=7*2^n$ for all $n>=4$.
- Algorithms can be:
- $O(1)$ → constant; $O(\log n)$ → logrithmic; $O(n\log n)$; $O(n)$→ linear; $O(n^2)$ → quadratic; $O(n^3)$ → cubic; $O(2^n)$ → exponential.

# Big O Notation

- Now it is easy to compare time or space complexities of algorithms.
- Which algorithm complexity is better?
  - $T(P1) = O(n)$ or $T(P2) = O(n^2)$
  - $T(P1) = O(1)$ or $T(P2) = O(\log n)$
  - $T(P1) = O(2^n)$ or $T(P2) = O(n^{10})$

# Linear & Non Linear Data Structures

- **Linear data structures**:- in which insertion and deletion is possible in linear fashion .
- example:- arrays, linked lists.

- **Non linear data structures**:-in which it is not possible. example:- trees ,stacks

# LINEAR DATA STRUCTURE Array

- Array is linear, homogeneous data structures whose elements are stored in contiguous memory locations.

# Arrays

- Array: a set of pairs, <index, value>
- Data structure
  - For each index, there is a value associated with that index.
- Representation (possible)
  - Implemented by using consecutive memory.
  - In mathematical terms, we call this a *correspondence* or a *mapping*.

# Initializing Arrays

- Using a loop:
- for (int i = 0; i < myList.length; i++)
- myList[i] = i;

- Declaring, creating, initializing in one step:
- double[] myList = {1.9, 2.9, 3.4, 3.5};
- This shorthand syntax must be in one statement.

# Declaring and Creating in One Step

- datatype[] arrayname = new
- datatype[arraySize];
- double[] myList = new double[10];

- datatype arrayname[] = new datatype[arraySize];
- double myList[] = new double[10];

# Sparse Matrix[2]

- A sparse matrix is a matrix that has many zero entries.

$$\begin{bmatrix} 15 & 0 & 0 & 22 & 0 & -15 \\ 0 & 11 & 3 & 0 & 0 & 0 \\ 0 & 0 & 0 & -6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 91 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 28 & 0 & 0 & 0 \end{bmatrix}$$

- This is a ___×___ matrix.
- There are _____ entries.
- There are _____ nonzero entries.
- There are _____ zero entries.

Consider we use a 2D array to represent a $n \times n$ sparse matrix. How many entries are required? _____ entries. The space complexity is O( ).

# Sparse Matrix

- If *n* is large, say *n* = 5000, we need 25 million elements to store the matrix.
- 25 million units of time for operation such as addition and transposition.
- Using a representation that stores only the nonzero entries can reduce the space and time requirements considerably.

# Sparse Matrix Representation

- The information we need to know
  - The number of rows
  - The number of columns
  - The number of nonzero entries
  - All the nonzero entries are stored in an array. Therefore, we also have to know
    - The capacity of the array
    - Each element contains a triple <*row*, *col*, *value*> to store.
      - The triples are ordered by rows and within rows by columns.

# Sparse Matrix Representation

```
class SparseMatrix;
class MatrixEntry {
friend class SparseMatrix;
private:
        int row, col, value;
};

class SparseMatrix {
private:
        int rows, cols, terms, capacity;
        MatrixEntry *smArray;
};
```

# The array as an ADT

- When considering an ADT we are more concerned with the operations that can be performed on an array.
  - Aside from <u>creating</u> a new array, most languages provide only two standard operations for arrays, one that <u>retrieves</u> a value, and a second that <u>stores</u> a value.
  - The advantage of this ADT definition is that it clearly points out the fact that the array is a more general structure than "a consecutive set of memory locations."

# Exercise : Bubble Sort

int[] myList = {2, 9, 5, 4, 8, 1, 6}; // Unsorted

Pass 1: 2, 5, 4, 8, 1, 6, 9

Pass 2: 2, 4, 5, 1, 6, 8, 9

Pass 3: 2, 4, 1, 5, 6, 8, 9

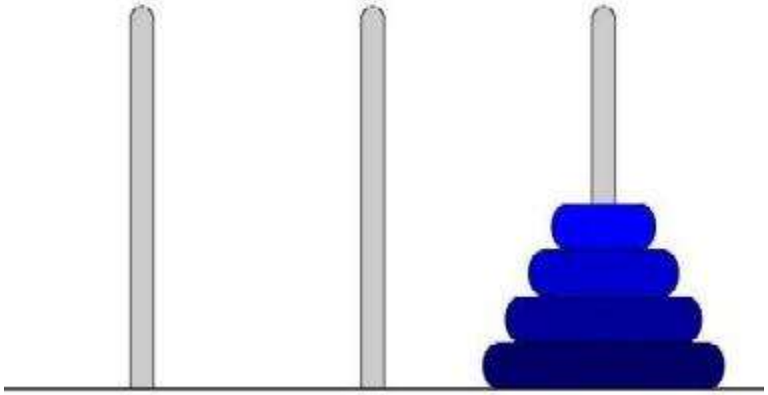
Pass 4: 2, 1, 4, 5, 6, 8, 9

Pass 5: 1, 2, 4, 5, 6, 8, 9

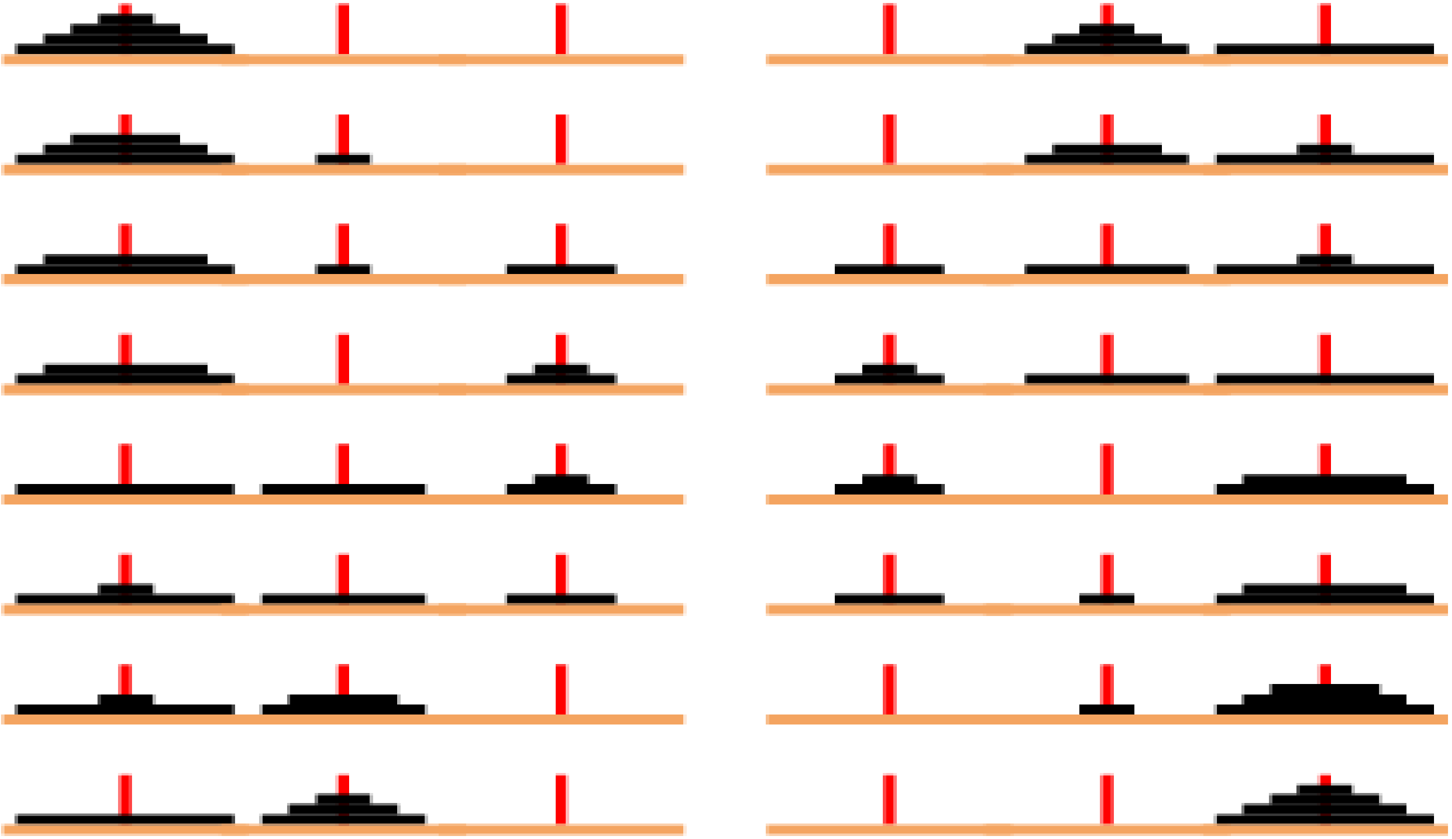
Pass 6: 1, 2, 4, 5, 6, 8, 9

# Tower of Hanoi[3]

- The Objective is to transfer the entire tower to one of the other pegs.
- However you can only move one disk at a time and you can never stack a larger disk onto a smaller disk. Try to solve it in fewest possible moves.



# Tower of Hanoi[4]



# References


1) An introduction to Datastructure with application by jean Trembley and sorrenson
2) Data structures by schaums and series –seymour lipschutz
3) http://en.wikipedia.org/wiki/Book:Data_structures
4) http://www.amazon.com/Data-Structures-Algorithms
5) http://www.amazon.in/Data-Structures-Algorithms-Made-Easy/dp/0615459811/
6) http://www.amazon.in/Data-Structures-SIE-Seymour-Lipschutz/dp


**List of Images**


1. Data structures by schaums and series –seymour lipschutz
2. http://en.wikipedia.org/wiki/Book:Data_structures
3. http://en.wikipedia.org/wiki/tower of hanoi
4. http://en.wikipedia.org/wiki/tower of hanoi