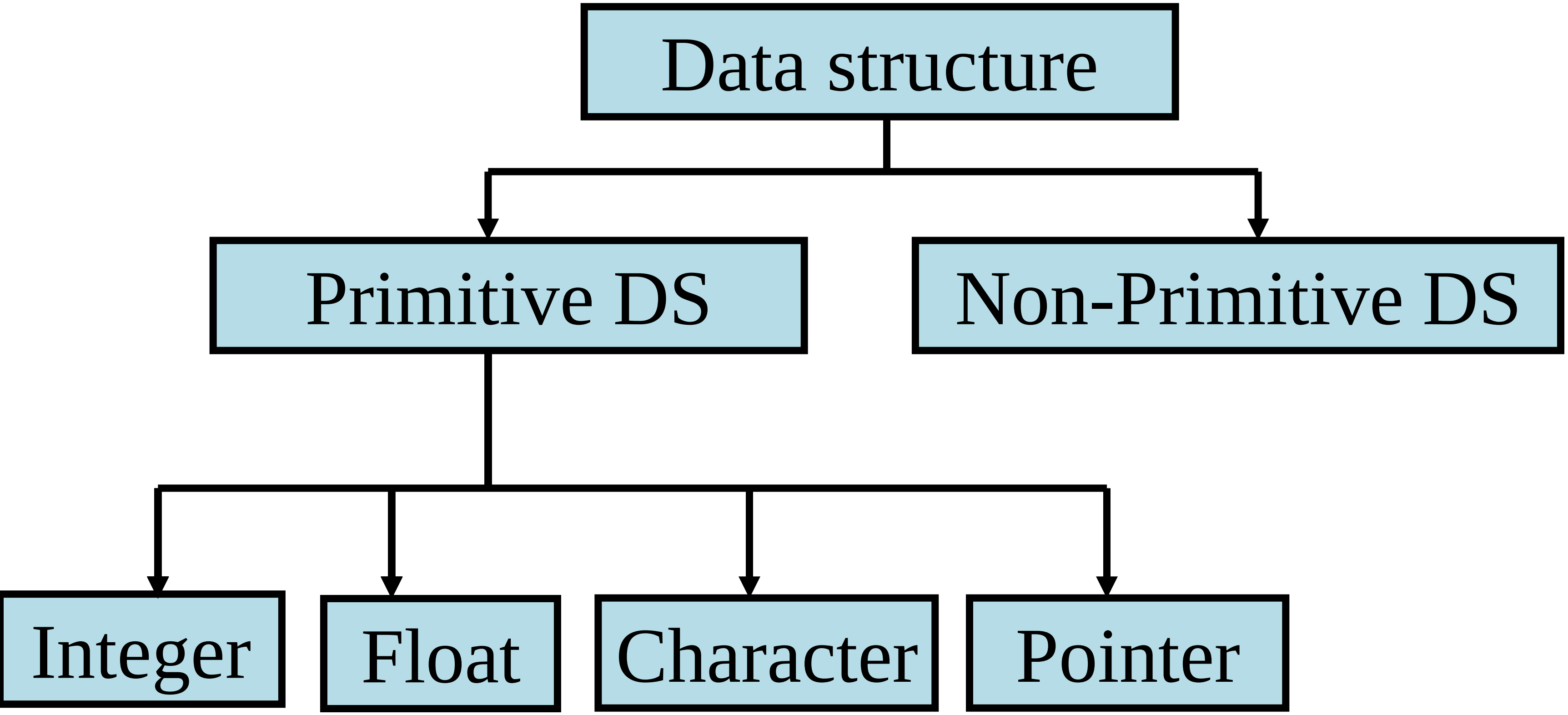
DATA STRUCTURES – TYPES AND ADT

sushmakadge@somaiya.edu

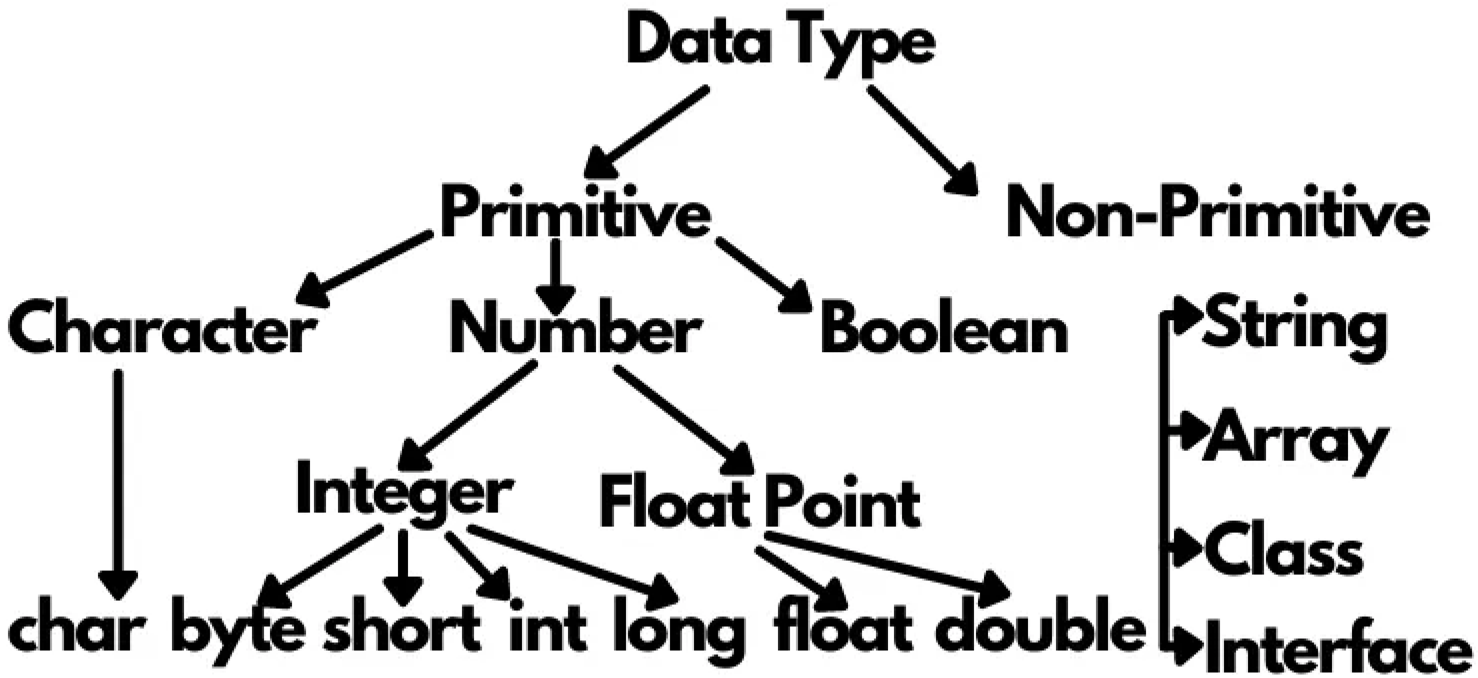
Classification of Data Structure



Primitive data structures

- are the basic DS that directly operate upon the machine instructions.
- can store the value of only one data type.
- example, a char data structure can store only characters.

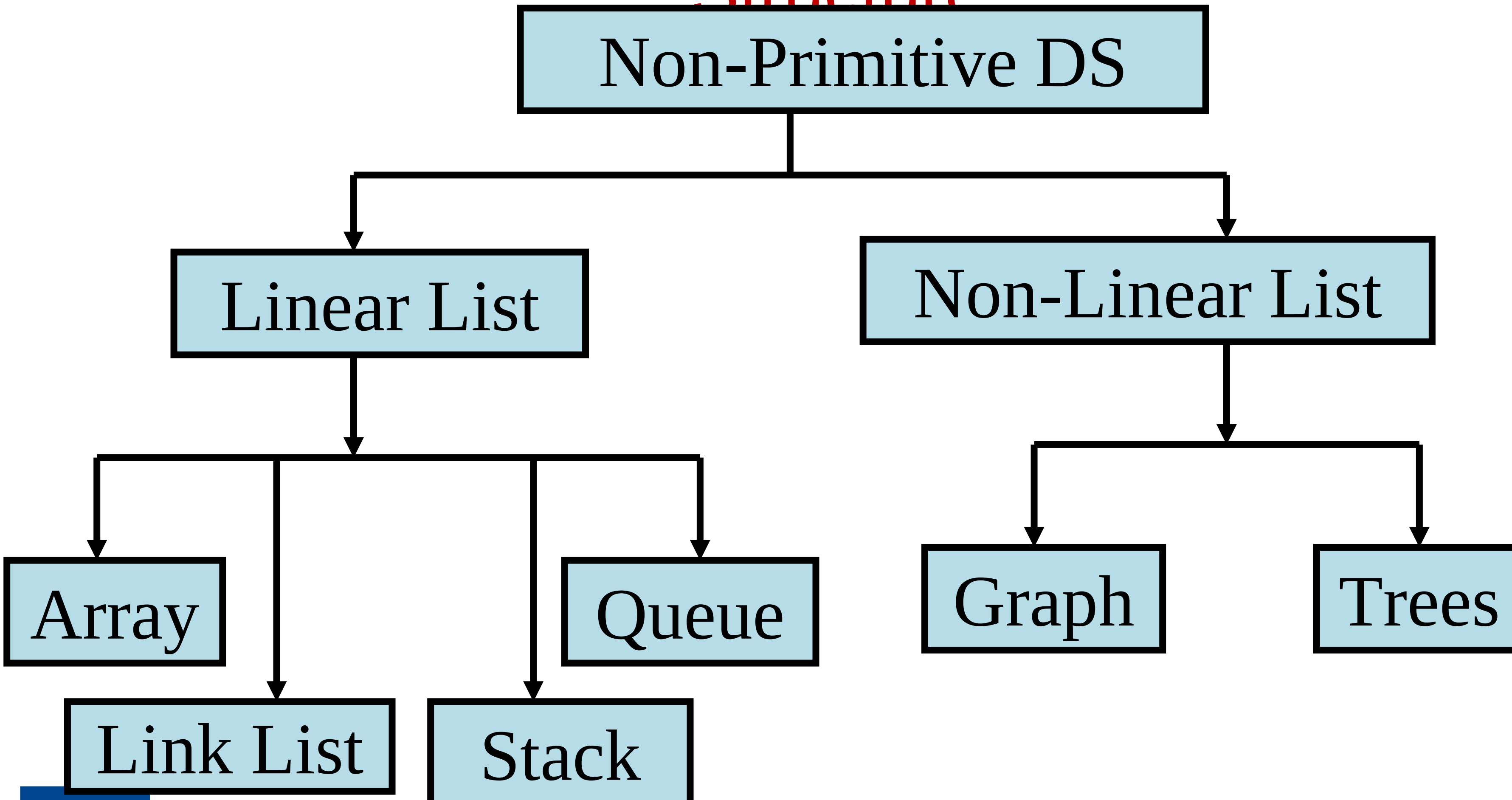
Classification of Data



Non-Primitive data structures

- are more complicated DS
- are derived from primitive DS.
- they emphasize on grouping same or different data items with relationship between each data item.
- Example: arrays, Lists and files come under this category

Classification of Data Structure



Linear data structures

- The data structure where data items are organized sequentially or linearly one after another is called Linear data structures.

- Examples : Stack and Queue

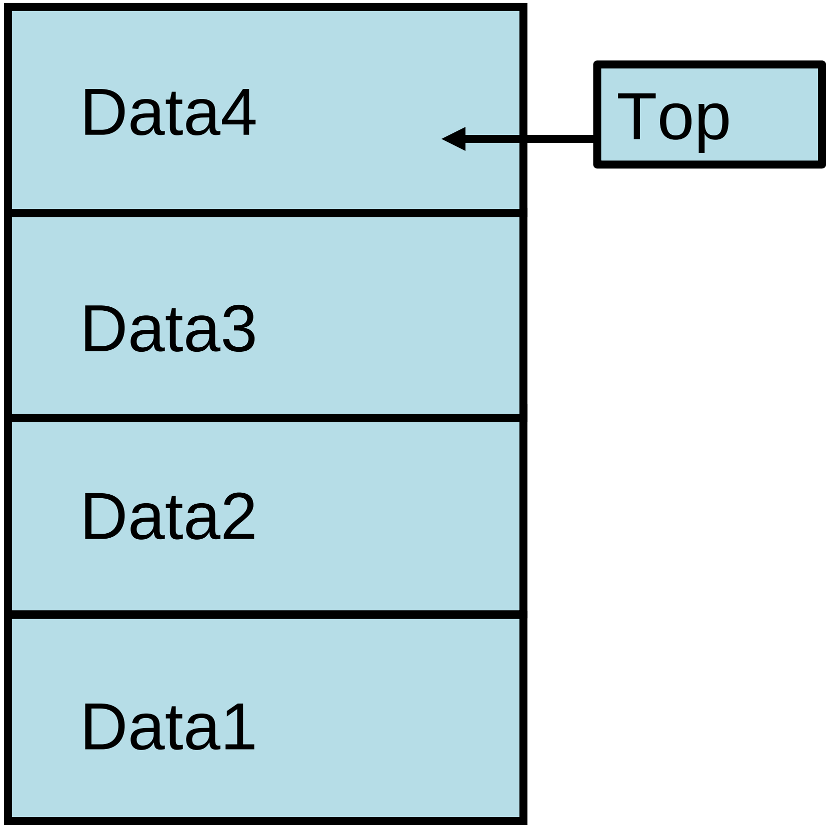
Data structures and their representations

Stack

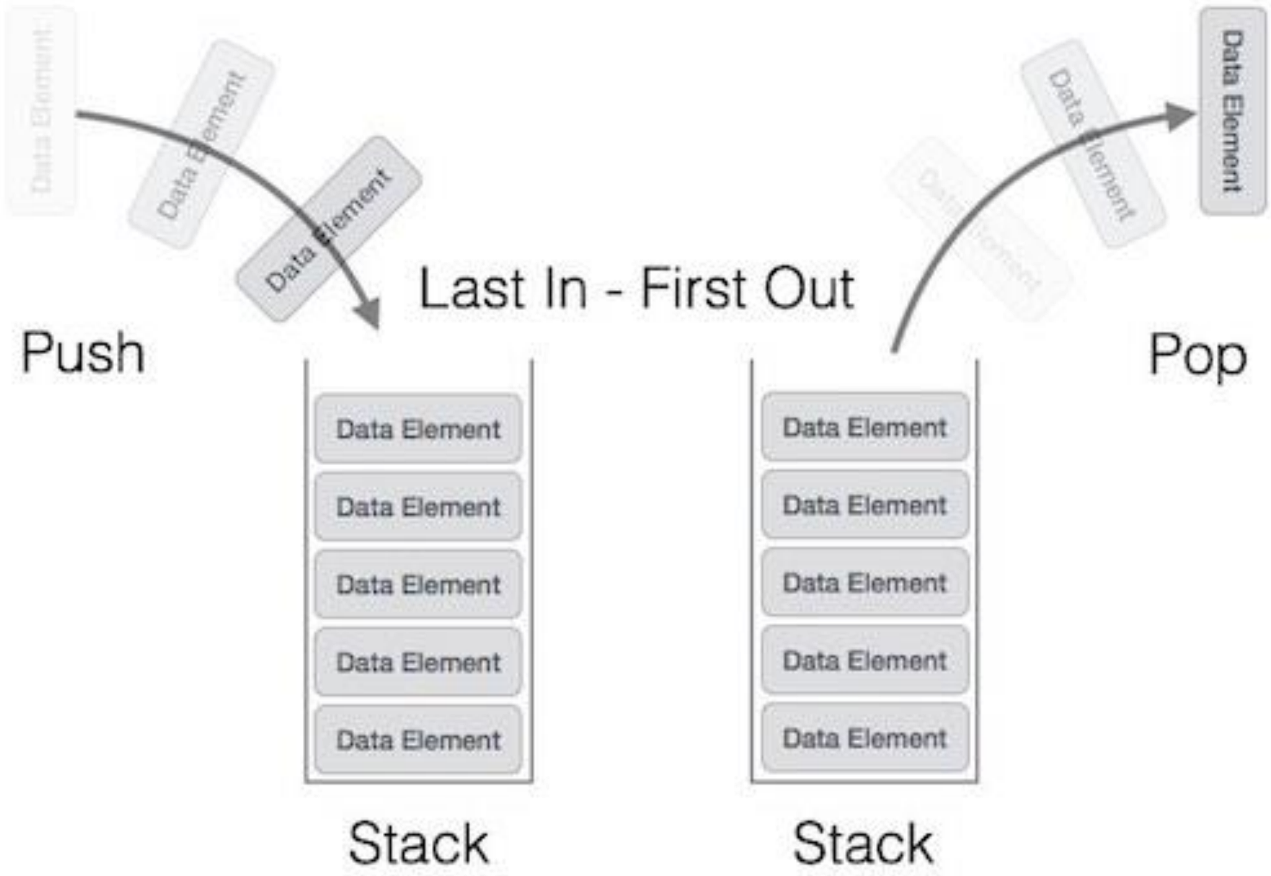
- Stack is a DS in which addition and deletion of element is allowed at the same end called as TOP of the stack.

- A Stack is LIFO(Last In First Out) DS where element that added last will be retrieved first.

Stack



Stack

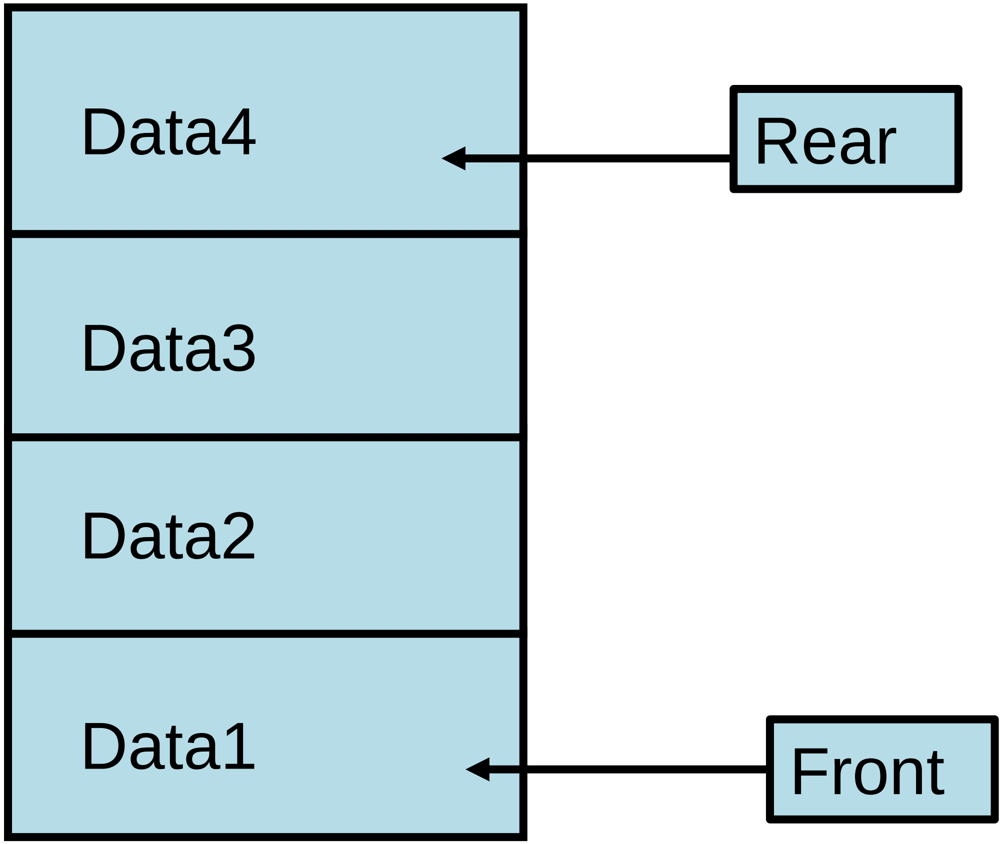

Push
Last In - First Out
Pop
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Data Element
Stack
Stack

Queue

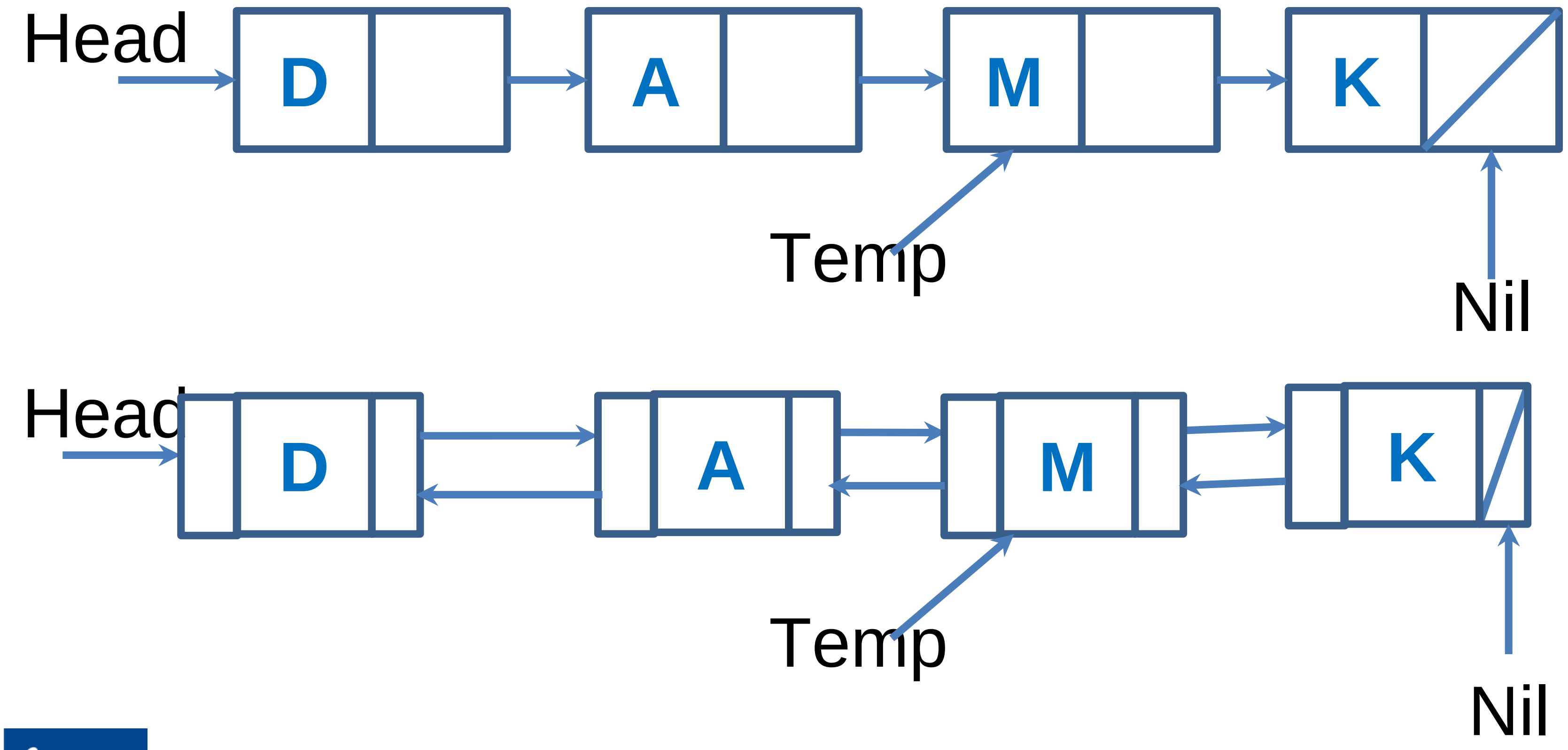
- A Queue is a DS in which addition of element is allowed at the one end called as REAR and deletion is allowed at another end called as FRONT.

- A Queue is FIFO(First In First Out) DS where element that added first will be retrieved first.

Queue



List- A ***Flexible*** structure that can grow and shrink on demand



Non Linear data structures

- The data structure in which the data items are not organized sequentially or in linear fashion is called Non Linear data structures.

- Examples : Tree and Graph

Tree

- Tree is collection of nodes where these nodes are arranged hierarchically and form a parent child relationship

Tree

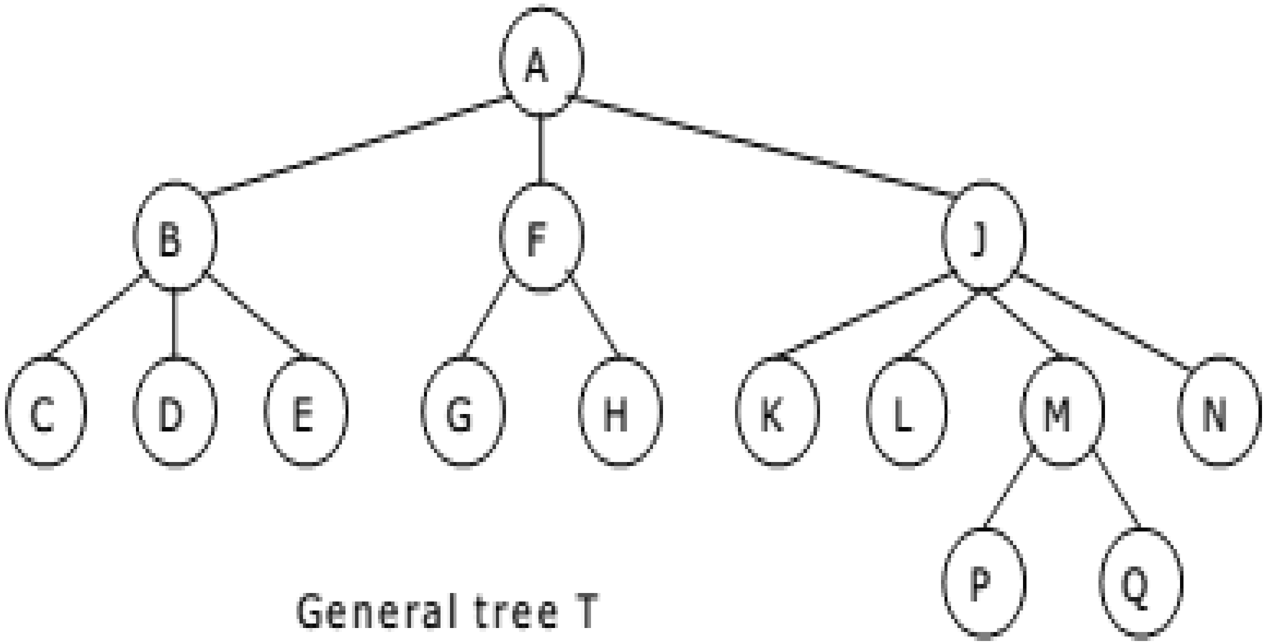


Image courtesy: ExamRadar.com

Graph

- A Graph is a collection of a finite number of vertices and edges which connect these vertices.
- Edges represent relationships among vertices that stores data elements.

Binary Tree, Binary search tree and Heaps

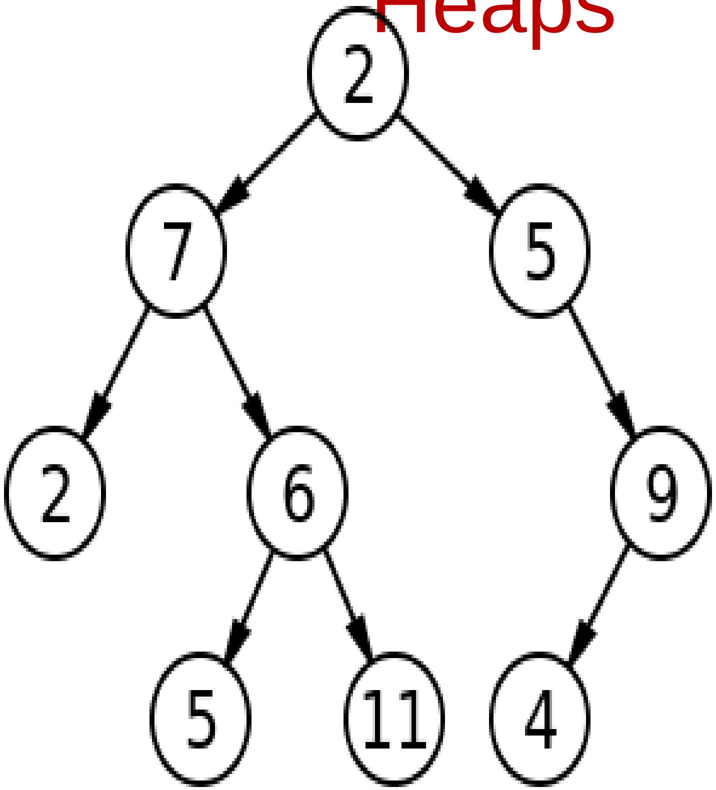


Image courtesy: ExamRadar.com

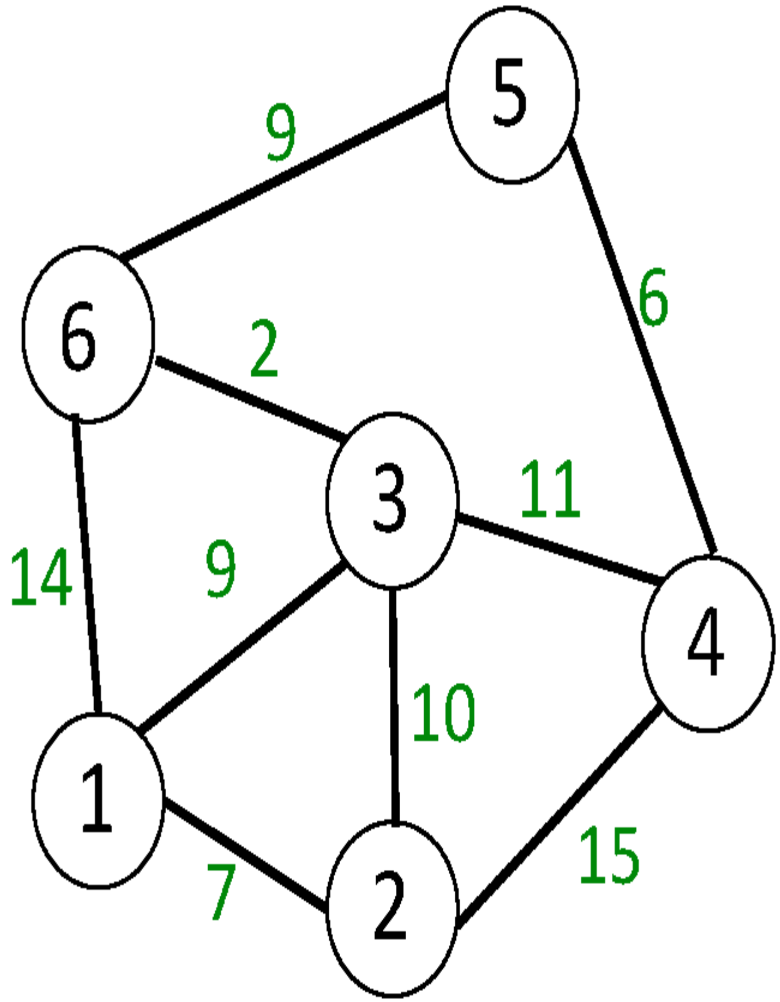


Image courtesy: Medium.com

Difference Linear and Non-linear Data Structures:

S.NO	Linear Data Structure	Non-linear Data Structure
1.	In a linear data structure, data elements are arranged in a linear order where each and every element is attached to its previous and next adjacent.	In a non-linear data structure, data elements are attached in hierarchically manner.
2.	In linear data structure, single level is involved.	Whereas in non-linear data structure, multiple levels are involved.
3.	Its implementation is easy in comparison to non-linear data structure.	While its implementation is complex in comparison to linear data structure.
4.	In linear data structure, data elements can be traversed in a single run only.	While in non-linear data structure, data elements can't be traversed in a single run only.
5.	In a linear data structure, memory is not utilized in an efficient way.	While in a non-linear data structure, memory is utilized in an efficient way.
6.	Its examples are: array, stack, queue, linked list, etc.	While its examples are: trees and graphs.
7.	Applications of linear data structures are mainly in application software development.	Applications of non-linear data structures are in Artificial Intelligence and image processing.

Analysis of Algorithms

- Understanding the analysis of algorithms is crucial for designing efficient algorithms and making informed decisions about algorithm selection based on the specific requirements of a problem. It helps in comparing algorithms and choosing the most suitable one for a given task.
- By analyzing algorithms, developers and researchers can make informed decisions about algorithm selection, understand trade-offs between time and space efficiency, and design algorithms that meet specific performance requirements for different applications.

Analysis of Algorithms

- "Analysis of Algorithms" involves evaluating algorithms' efficiency in terms of their time complexity and space complexity. Here's a brief overview
- Time Complexity Analysis
- Space Complexity Analysis
- ~~Best, Worst, and Average Case Analysis~~
- ~~Asymptotic Analysis~~
- ~~Amortized Analysis~~

Time Complexity Analysis:

- **Definition:** Time complexity is a measure of the amount of time an algorithm takes to complete based on the input size.
- **Big O Notation (O):** It is a common way to express time complexity. Big O notation is a commonly used metric used in computer science to classify algorithms based on their time and space complexity. It represents the upper bound of an algorithm's growth rate in terms of the input size. It provides an asymptotic (worst-case) upper limit on the growth rate of the algorithm's running time concerning the input size.

Time Complexity Analysis:

Types:

- **O(1):** Constant time complexity.
- **O(log n):** Logarithmic time complexity (common in binary search).
- **O(n):** Linear time complexity.
- **O(n log n):** logLinear time complexity (common in many efficient sorting algorithms).
- **O(n^2):** Quadratic time complexity (common in some nested loop algorithms).
- **O(2^n):** Exponential time complexity (common in brute-force algorithms).

Space Complexity Analysis:

- **Definition:** Space complexity is a measure of the amount of memory an algorithm uses based on the input size.
- **Big O Notation for Space (O):** Similar to time complexity, but it measures the space requirements of an algorithm.

Abstract Data Type and Data Structure

- An abstract data type (ADT) is the way we look at a data structure, focusing on **what it does and ignoring how it does its job**.
- For example, stacks and queues are perfect examples of an ADT.
- We can implement both these ADTs using an array or a linked list. This demonstrates the ‘abstract’ nature of stacks and queues.

Abstract Data Type and Data Structure

- To further understand the meaning of an abstract data type, we will break the term into ‘data type’ and ‘abstract’, and then discuss their meanings.
- Data type of a variable is the set of values that the variable can take.
- The basic data types in C include int, char, float, and double.

Abstract Data Type and Data Structure

- When we talk about a primitive type (built-in data type), we actually consider two things: a data item with certain characteristics and the permissible operations on that data.
- For ex, an int variable can contain any whole-number value from –32768 to 32767 and can be operated with the operators +, –, *, and /.
- In other words, the operations that can be performed on a data type are an inseparable part of its identity.
- Therefore, when we declare a variable of an abstract data type (e.g., stack or a queue), we also need to specify the operations that can be performed on it.

Abstract Data Type and Data Structure

- In C, an abstract data type can be a structure considered without regard to its implementation.
- It can be thought of as a ‘description’ of the data in the structure with a list of operations that can be performed on the data within that structure.
- The end-user is not concerned about the details of how the methods carry out their tasks.
- They are only aware of the methods that are available to them and are only concerned about calling those methods and getting the results.
- They are not concerned about how they work

Abstract Data Type and Data Structure

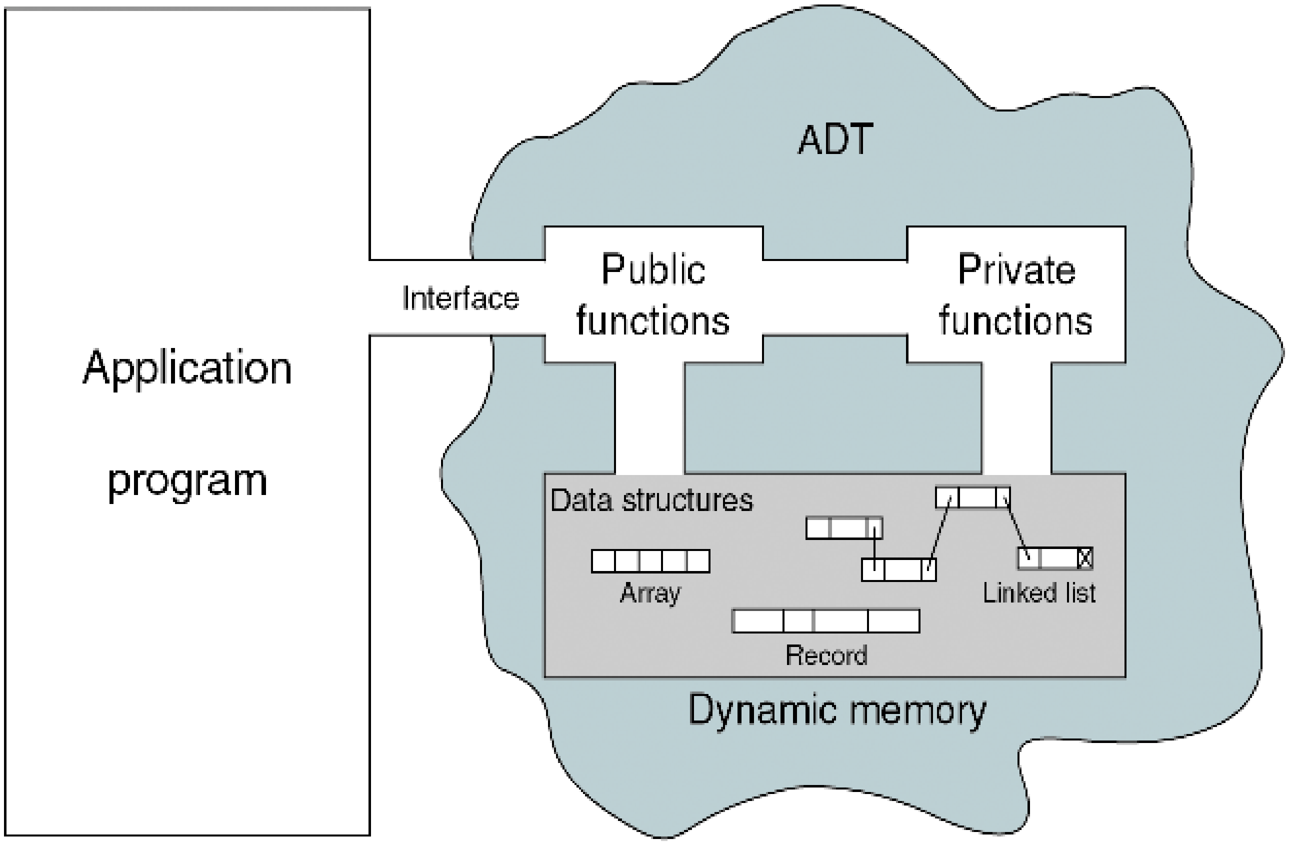


FIGURE 1-2 Abstract Data Type Model

The Abstract Data Type (ADT)

The Abstract Data Type (ADT) is:

- A data declaration packaged together with the operations that are meaningful for the data type.
- In other words, we encapsulate the data and the operations on the data, and then we hide them from the user.

- ➢Declaration of data
- ➢Declaration of operations
- ➢Encapsulation of data and operations

Typical Abstract Data Types

- Lists
- Stacks
- Queues
- Trees
- Heaps
- Graphs

Important Properties of ADT

- Specification: The supported operations of the ADT
- Implementation: Data structures and actual coding to meet the specification

Courtsey:
https://www.comp.nus.edu.sg/~stevenha/cs1020e/lectures/L5%20-%20ADT.pdf

ADT : Specification and Implementation

- Specification and implementation are disjointed:
  - One specification
  - One or more implementations
    - Using different data structure
    - Using different algorithm
- Users of ADT:
  - Aware of the specification only
    - Usage only base on the specified operations
  - Do not care / need not know about the actual implementation
    - i.e. Different implementation do not affect the

Example ADT : String

- Definition: String is a sequence of characters
- Operations:
  - StringLength
  - StringCompare
  - StringConcat
  - StringCopy

ADT Syntax : Value Definition

Abstract typedef < *ParameterType Parameter1, ParameterType Parameter2……, ParameterType ParameterN* > ADTType

condition:

Example ADT : String

- Value Definition

Abstract Typedef StringType<<Chars>>

Condition: None (A string may contain n characters where n=>0)

ADT Syntax : Operator definition

Abstract ReturnType OperationName (ParameterType Parameter1, ParameterType Parameter2……, ParameterType ParameterN)

Precondition:

Postcondition:

OR

Abstract ReturnType OperationName (Parameter1, Parameter2……, ParameterN)

ParameterType Parameter1, ParameterType Parameter2……, ParameterType ParameterN

Precondition:

Postcondition:

Example ADT : String Operator Definition

1. abstract Integer StringLength (StringType String)

Precondition: None (A string may contain n characters where n=>0)

Postcondition:

Stringlength= NumberOfCharacters(String)

Example ADT : String Operator Definition

2. abstract StringType StringConcat(StringType String1, StringType String2)

Precondition: None

Postcondition: StringConcat= String1+String2 / All the characters in Strings1 immediately followed by all the characters in String2 are returned as result.

Example ADT : String Operator Definition

3. abstract Boolean StringCompare(StringType String1, StringType String2)

Precondition: None

Postcondition:

StringCompare= True if strings are equal, StringCompare= False if they are unequal . (Function returns 1 if strings are same, otherwise zero)

Example ADT : String Operator Definition

4. abstract StringType StringCopy(StringType String1, StringType String2)

Precondition: None

Postcondition: StringCopy: String1= String2 / All the characters in Strings2 are copied/overwritten into String1.

Example ADT : Rational Number

- Definition:
- expressed as the quotient or fraction of two integers,
- Operations:
  - IsEqualRational()
  - MultiplyRational()
  - AddRational()

Example ADT : Rational Number

- Value Definition

abstract TypeDef<integer, integer>
RATIONALType;

Condition: RATIONALType [1]!=0;

Example ADT : Rational Number Operator Definition

- abstract RATIONALType makerational<a,b>

integer a,b;

Preconditon: b!=0;

postcondition :

makerational [0] =a;

makerational [1] =b;

- abstract RATIONALtype add<a,b>

RATIONALType a,b;

Precondition: none

postcondition :

add[0] = a[0]*b[1]+b[0]*a[1]

add[1] = a[1] * b[1]

Example ADT : Rational Number Operator Definition

- abstract RATIONALType mult<a, b>

RATIONALType a,b;

Precondition: none

postcondition

mult[0] = = a[0]*b[0]

mult[1] = = a[1]*b[1]

- abstract ReturnType? Equal<a,b>

RATIONALType a,b;

Precondition: none

postcondition equal = =

|a[0] * b[1] = = b[0] * a[1];

Typical Rational ADT code:

```
struct rational {
int numerator;
int denominator;
};
```

Typical Rational ADT code:

```
struct rational sum ( struct rational a, struct rational b)
{
rational c;
c.numerator = a.numerator * b.denominator +
b.numerator * a.denominator;
c.denominator = a.denominator * b.denominator;
return c;
}
```

Typical Complex number operation ADT code:

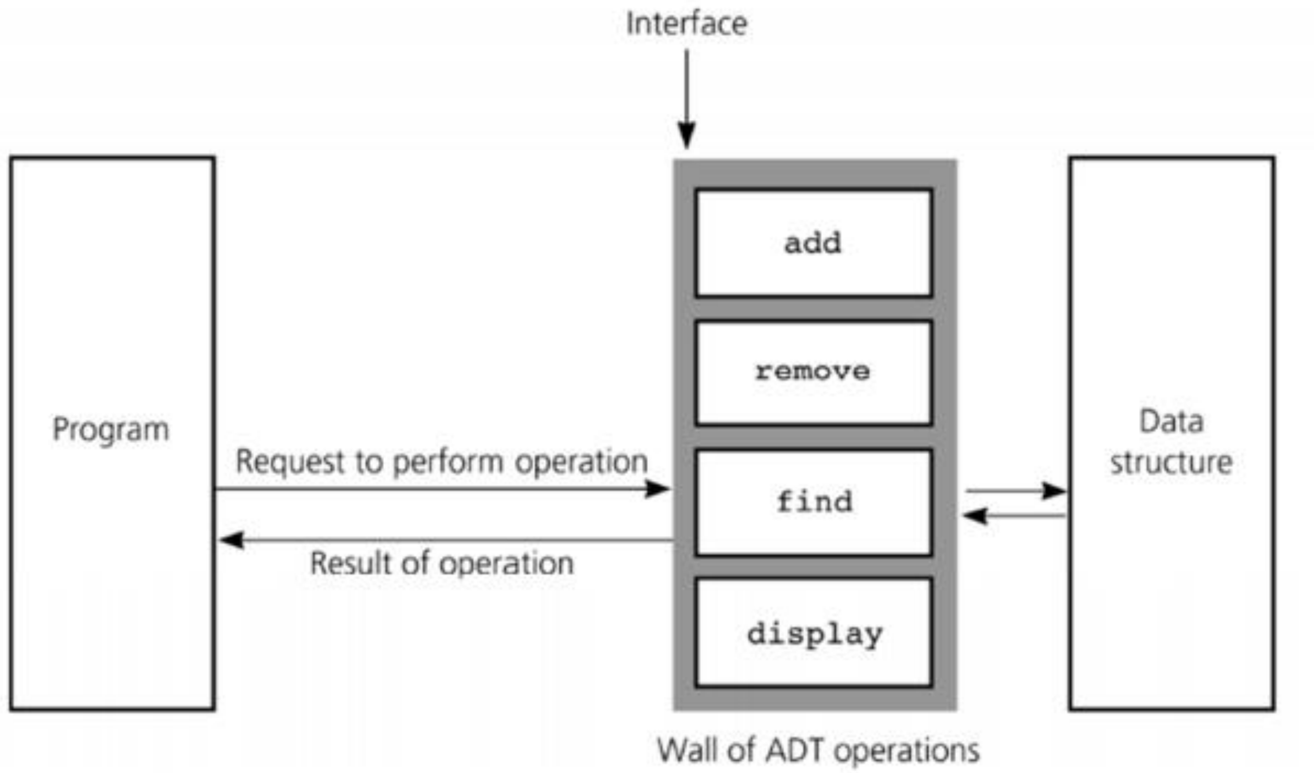
```
include<iostream>
using namespace std;
class comp{
    public:
    int real,img;
};
```

Typical Complex number operation ADT code:

```
void addComplex(int c1real,int c1img,int c2real,int c2img){
    int real_sum = c1real+ c2real;
    int img_sum = c1img + c2img;
    cout<<"\nThe addition of the 2 complex number is:- " <<real_sum<<" + "<<img_sum<<"i";
}
```

A wall of ADT operations

- ADT operations provides:
  - Interface to data structure
  - Secure access



Courtsey:
https://www.comp.nus.edu.sg/~stevenha/cs1020e/lectures/L5%20-

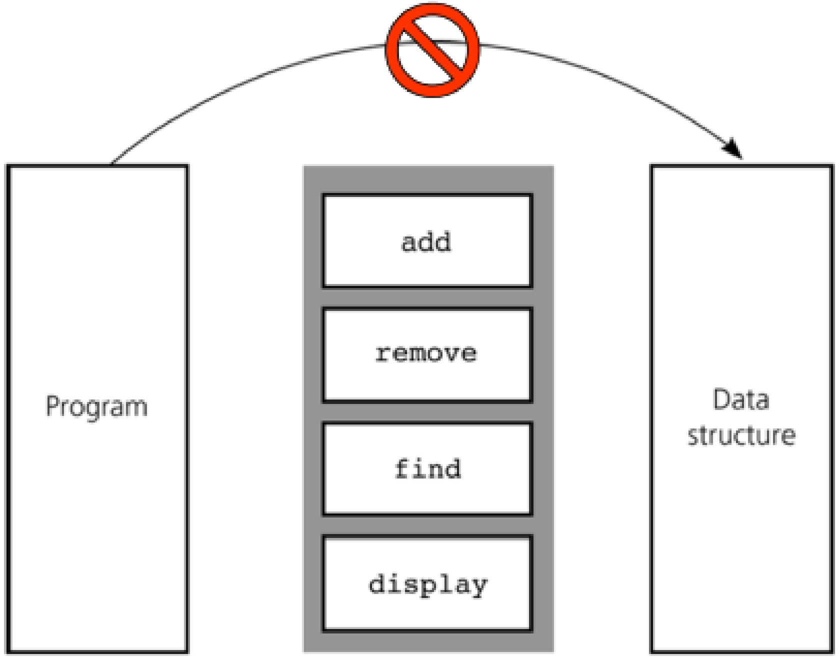
Abstract Data Types: Advantages

- Hide the unnecessary details by building walls around the data and operations
  - o that changes in either will not affect other program components that use them
- Functionalities are less likely to change
- Localize rather than globalize changes
- Help manage software complexity
- Easier software maintenance

Courtsey: https://www.comp.nus.edu.sg/~stevenha/cs1020e/lectures/L5%20-%20ADT.pdf

Violating the Abstraction

- User programs **should not**:
  - Use the underlying data structure directly
  - Depend on implementation details



Wall of ADT operations

Courtsey:
https://www.comp.nus.edu.sg/~stevenha/cs1020e/lectures/L5%20-%20ADT.pdf

SOMAIYA VIDYAVIHAR UNIVERSITY
K J Somaiya College of Engineering

ADT Implementation

- Computer languages do not provide complex ADT packages.
- To create a complex ADT, it is first implemented and kept in a library.

TRUST

Abstract Data Type and Data Structure

- Definition:-
  - *Abstract Data Types (ADTs)* stores data and allow various operations on the data to access and change it.
  - A mathematical model, together with various operations defined on the model
  - An ADT is a collection of data and associated operations for manipulating that data

Abstract Data Type

- ADTs support *abstraction*, *encapsulation*, and *information hiding*.
- *Abstraction* is the structuring of a problem into well-defined entities by defining their data and operations.
- The principle of hiding the used data structure and to only provide a well-defined interface is known as *encapsulation.*

ADT Operations

Every Collection ADT should provide a way to:

- Create data structure
- add an item
- remove an item
- find, retrieve, or access an item

No single data structure works well for all purposes, and so it is important to know the strengths and limitations of several of them

Abstract Data Structure

- Logical Definition
- Mathematical definition

- ADTs represent concepts
- Free from hardware or software dependency
- Operation name is assumed as the return variable name

Abstraction

- The process of isolating implementation details and extracting only essential property from an entity
- Hence, abstractions in a program:
  - Data abstraction :What operations are needed by the data
  - Functional abstraction : What is the purpose of a function (algorithm)

Program = data + algorithms

Courtsey: https://www.comp.nus.edu.sg/~stevenha/cs1020e/lectures/L5%20-%20ADT.pdf

ADTs

- Abstract Data Type (ADT):
  - End result of data abstraction
  - A collection of data together with a set of operations on that data
  - ADT = Data + Operations
- ADT is a language independent concept
  - Different language supports ADT in different ways
  - In C++, the class construct is the best match

Courtsey:
https://www.comp.nus.edu.sg/~stevenha/cs1020e/lectures/L5%20-%20ADT.pdf

Thank you