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Java Institute for Advanced Technology

Department of Examinations

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Abstract

This Research Document contains about the data structures such as what is a data structure, the classification of data structures, the advantages of data structures, and the fields using the data structures.

And also explains about some data structures such as arrays, linked lists, queues, stacks, graphs, and trees.

Furthermore, this research document discusses about the given exam scenario, Priority Queue, and Java code solution for the given scenario.

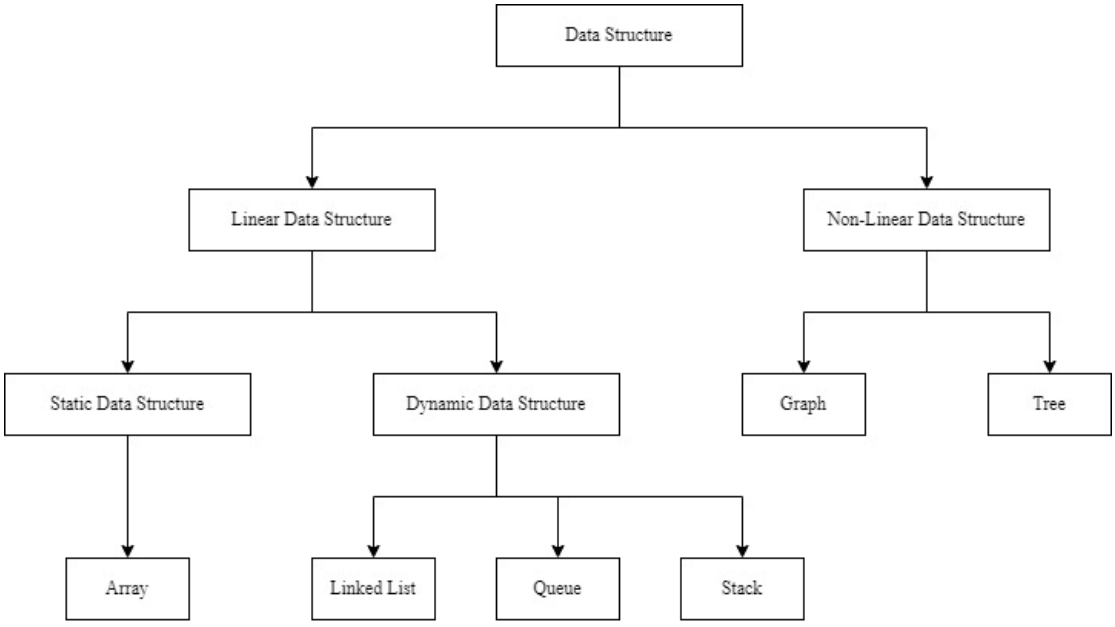
Table of Contents

1. What is a Data Structure?

“A data structure is a storage model that helps to efficiently access and update data. It is the collection of values and the format in which they are stored, the relationship between the values in the collection, as well as the operations applied to the data stored in the structure.”

A data structure is used for more than just data organization. Additionally, it is used to process, retrieve and store data. Almost all built software systems and programs use many basic and advanced data structures.

1.1 Classification of Data Structure



1. Linear Data Structure: A data structure in which the elements are ordered sequentially or linearly, and each element is connected to its immediate preceding and following neighboring elements.
    - Static Data Structure: This has a set amount of memory. A static data structure makes it easy to access elements.

- Dynamic Data Structure: The size of memory is not fixed. It can be updated randomly at runtime, which can be considered efficient given the space complexity of the code.

2. Non-Linear Data Structure: These are data structures in which the data elements are not arranged sequentially or linearly. We cannot traverse all the elements in a non-linear data structure in a single run.

Both data structure and algorithm synthesis are related to each other. The presentation of data must be simple so that the developer and the user can perform the operation efficiently.
Data structures simplify the organization, retrieval, management, and storage of data.

Advantages of Data Structures

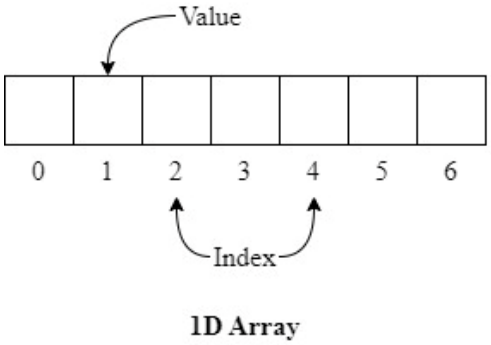
- Data representation is simple.
- Changing the data structure is simple.
- Saves memory storage space.
- Simple access to large databases.
- It takes less time.

Different Fields using Data Structures

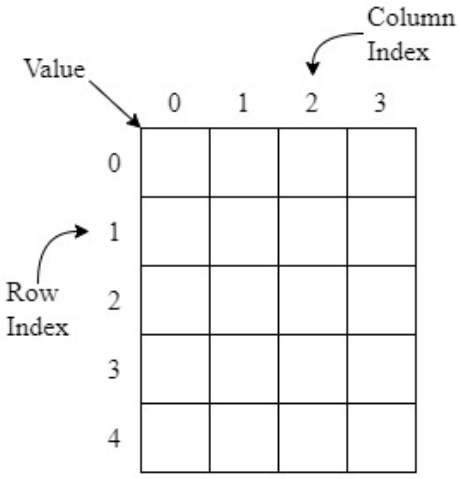
- Blockchain
- Computer Designing
- Genetics
- Graphics
- Image Processing
- Operating Systems
- Simulation

2. Array

“An array is a linear data structure that stores items in contiguous memory locations.” The concept is to keep several items of a specific type together in one location. It enables the processing of large amounts of data in a relatively short period of time. The first element of the array is indexed with a subscript of 0. On an array, you can perform various operations such as searching, sorting, inserting, traversing, reversing, and deleting.



1D Array



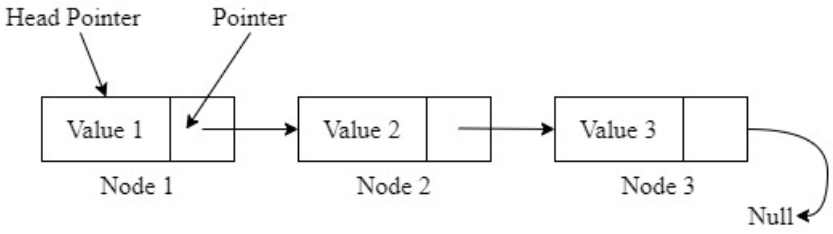
2D Array

Uses of Arrays

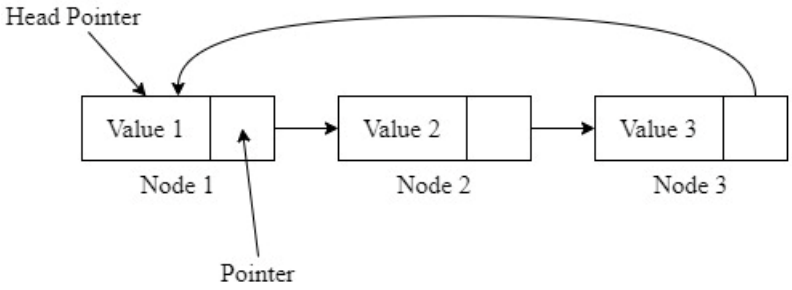
- To solve matrix problems.
- To implement database records.
- To save images in a specific dimension like 360*1200 in Android.
- In a computer screen displaying a multidimensional array.
- In many management systems such as student management systems, library management systems, and office management systems.

3. Linked Lists

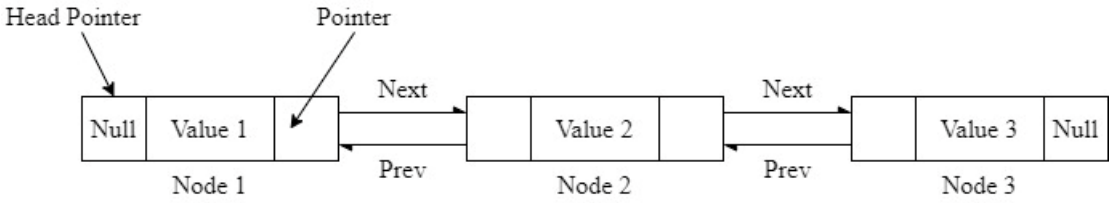
Linked lists, like arrays, are linear data structures. But, linked list elements are not stored in a contiguous location; instead, the elements are linked using pointers.



Singly Linked List



Circular Linked List



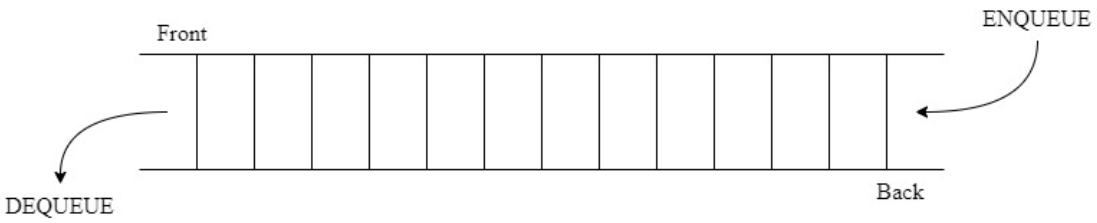
Doubly Linked List

Uses of Linked Lists

- To perform arithmetic operations on long integers.
- To implement stacks, queues, graphs, and other data structures.
- To save the history of the page visited.
- To perform undo operations.
- To display image containers. By that, users can view images from the past, present, and next.

4. Queue

“A queue is a linear data structure that performs operations in a specified order. The order is FIFO (First In First Out) which means that the data item stored first will be accessed first.” In this case, data is entered and retrieved from different ends. It can reverse a queue with or without using recursion or reverse the first K elements of a queue. Enqueue, dequeue, front, rear, and other basic operations are performed on the queue.

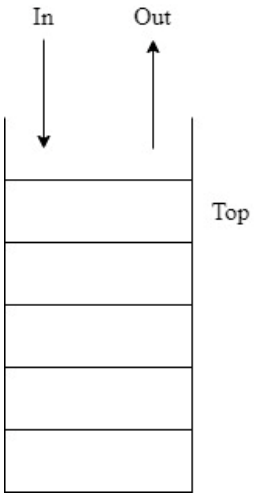


Uses of Queues

- To manage website traffic.
- To post multiple images or videos in social media.
- To manage interrupts in the operating systems.
- To switch between different applications in Windows.
- To serve requests on a single shared resource, such as a printer.

5. Stack

“A stack is a linear data structure that performs operations in a specific order. The format is FILO (First In Last out). Data can be entered and retrieved from one end only.” In a stack, inserting and retrieving data is called push and pop operation. There are various operations on a stack like sorting, reversing a stack using iteration, deleting the middle element of a stack, etc.



Uses of Stacks

- In repetitive operations.
- In virtual machines such as JVM.
- In word processors, the stack is used to perform undo and redo operations.
- To play the next song and the previous song in media players.
- To evaluate and convert the arithmetic expressions.

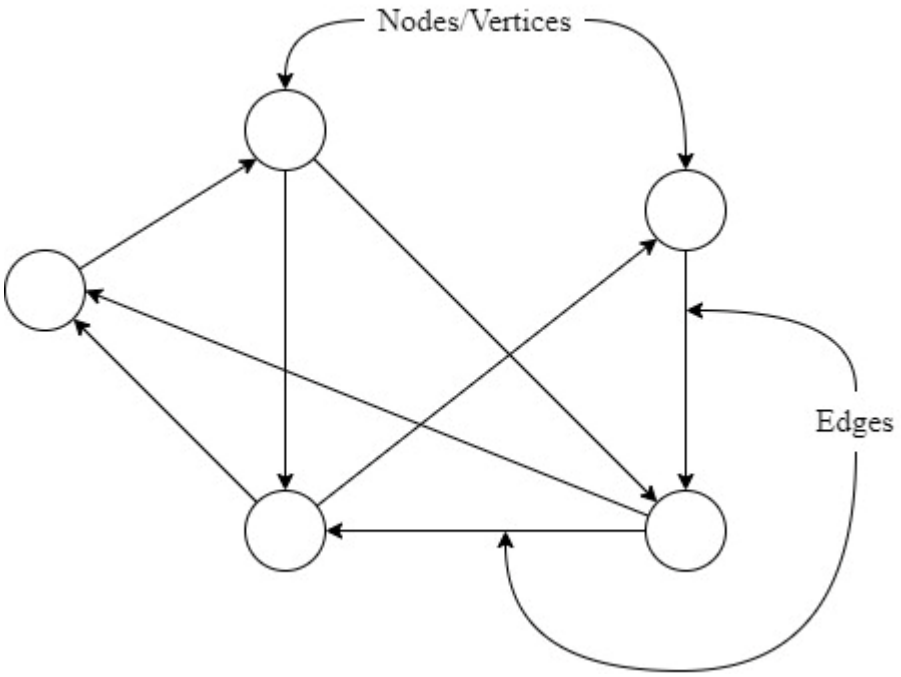
Basic operations performed in a stack

- Initialize: Empty a stack.
- Push: Inserts an item into the stack. When the stack is full, this is called an overflow condition.
- Pop: This method removes an item from the stack. The Items are popped in the reverse manner that they were pushed. When the stack is empty, this is called an underflow condition.

- Peek or Top: Returns the top element of the stack.
- isEmpty: True if the stack is empty, false otherwise.

6. Graph

“A graph is a non-linear data structure made up of vertices (or nodes) and edges. It consists of a limited number of vertices and edges connecting two nodes.” The graph is used to solve some of the most difficult and complex programming problems. It has various terminologies like path, degree, adjacent vertices, connected components, etc.

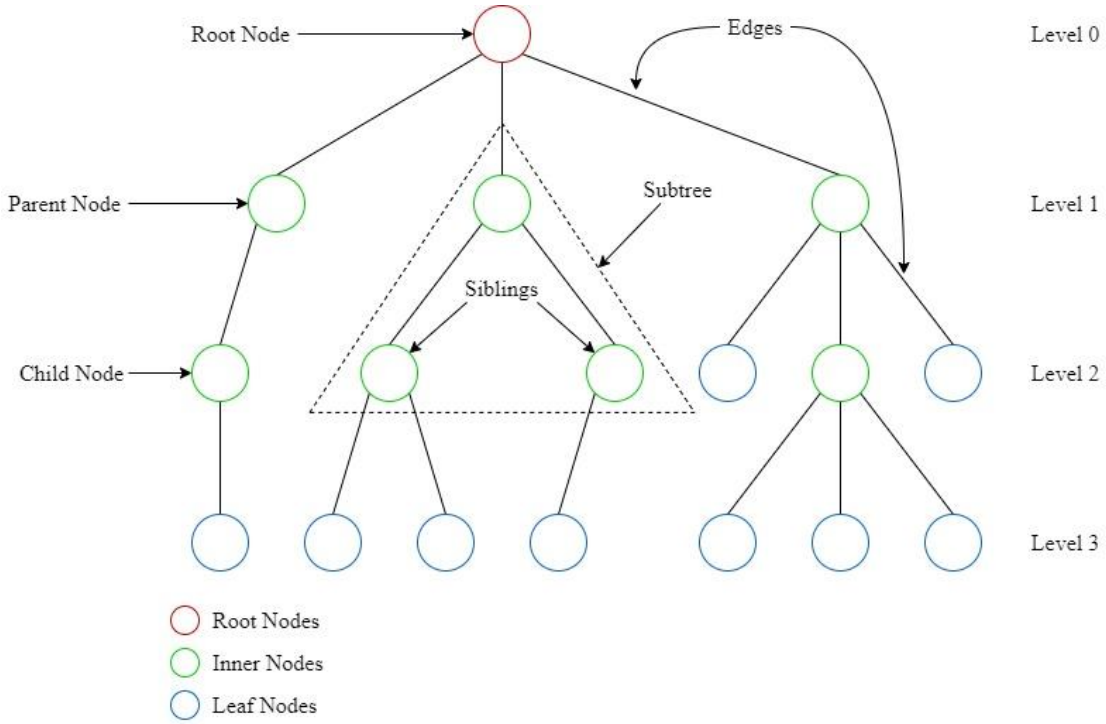


Uses of Graphs

- To represent the computation flow.
- In the World Wide Web, where web pages serve as nodes.
- The operating system uses resource allocation graphs.

7. Tree

A tree is a non-linear, hierarchical data structure with elements organized in a tree-like structure. The root node is the topmost node of a tree. Each node has some data, which can be of any type. It is made up of a central node, structural nodes, and sub-nodes that are linked together by edges. Because it is a non-linear data structure, different tree data structures provide fast and easy access to data. A tree has different terminologies like Node, Root, Edge, Tree Height, Tree Degree, etc.



Different Types of Tree-Like Structures

- AVL Tree
- Binary Tree
- Binary Search Tree
- B-Tree
- etc.

Uses of Trees

- Indexing in databases is implemented using B- Tree and B+ Tree.
- Spanning trees are used in routers.
- Heap is a tree data structure used to implement priority queues implemented using arrays.
- A K-D Tree is a space partitioning tree that can be used to arrange points in K-dimensional space.
- Syntax Tree helps in scanning, code generation, parsing, and evaluating arithmetic expressions in compiler design.

8. Scenario

1. Supermarket Stack

New West is a chain of supermarket stores in Sri Lanka. This chain of stores operates with the aim of providing the best products and services to the customers, thereby achieving the development of the company. Instead of keeping most of the products until they expire, the company intends to provide them to the customer before they expire. Here, every expired product needs to be placed on the shelves from the beginning to the end. By doing so, their expectation is to reduce the amount of goods that must be removed if the customer gets the goods in the order they expire. In order to achieve this, the following data structure is provided.

Item ID	Item Name	Expire Date
1	Signal Tooth Paste	2023/02/02
2	Mixed Fruit Jam	2023/02/12
3	Dried Sparts 1KG Pack	2023/04/05
4	Fresh Milk 1L	2023/01/07

The most appropriate data structure for this scenario is the Priority Query.

A Priority Queue is an abstract data type that behaves similarly to a regular queue except that each element has a priority, in a Priority Queue the element with the highest priority comes first. The order in which elements are removed from a Priority Queue is determined by the priority of the elements in the Priority Queue. The Priority Queue supports only comparable elements, which are sorted in ascending or descending order.

In this case, the priority is the expiration date, with the element (product) expiring soonest having the highest priority. This data structure allows for easy insertion and retrieval of products based on their expiration date, ensuring that products with the soonest expiration date are always at the front of the queue, making them easily accessible to customers. Additionally, a binary heap or a self-balancing binary search tree can be used.

Features of a Priority Queue

- Each element in a priority queue is assigned a priority.
- If two elements in a priority queue share the same priority, they are processed on a FIFO (First In First Out) principle.
- The higher-priority element is deleted before the lower-priority element.

The Four Ways of Implementing a Priority Queue

1. Arrays
2. Binary Search Tree
3. Heap Data Structure
4. Linked List

Usages of Priority Queues

- In heap sorting.
- In prim algorithms.
- In the shortest path algorithm of Dijkstra.
- In data compression techniques such as Huffman code.
- In operating systems to perform tasks such as load balancing, interrupt handling, and priority

8.1 Java Code Solution for the Given Scenario

```
/*
 * To change this license header, choose License Headers in Project
Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package model;

import java.util.Comparator;
import java.util.PriorityQueue;

/**
 *
 * @author NUWAA
 */
class Item {
    int itemId;
    String itemName;
    String itemExpireDate;

    public Item(int itemId, String itemName, String itemExpireDate) {
        this.itemId = itemId;
        this.itemName = itemName;
        this.itemExpireDate = itemExpireDate;
    }
}

class ItemComparator implements Comparator<Item> {
    public int compare(Item item1, Item item2) {
        return item1.itemExpireDate.compareTo(item2.itemExpireDate);
    }
}

public class Main {
    public static void main(String[] args) {
        PriorityQueue<Item> priorityQueue = new PriorityQueue<>(new
ItemComparator());

        priorityQueue.add(new Item(1, "Signal Tooth Paste",
"2023/02/02"));
        priorityQueue.add(new Item(2, "MD Mixed Fruit Jam",
"2023/02/12"));
        priorityQueue.add(new Item(3, "Dried Sparts 1KG Pack",
"2023/04/05"));
        priorityQueue.add(new Item(4, "Fresh Milk 1L", "2023/01/07"));
```

```
        while (!priorityQueue.isEmpty()) {
            Item item = priorityQueue.poll();
            System.out.println("Item ID: " + item.itemId + ", Item
Name: " + item.itemName + ", Expire Date: " + item.itemExpireDate);
        }
    }
}
```

Here, I have used a linked list to develop this program. The time complexity of priority queuing when using a linked list:

- Insert - O(1)
- Remove - O(n)
- Peek - O(n)

The main class of products and expiration dates are added to the Priority Queue. The ItemComparator class, which implements the Comparator function, compares the expiration dates of products and rearranges them. Then the poll() method returns the first element until the queue is empty.

Output:

Item ID: 4, Item Name: Fresh Milk 1L, Expire Date: 2023/01/07

Item ID: 1, Item Name: Signal Tooth Paste, Expire Date: 2023/02/02

Item ID: 2, Item Name: MD Mixed Fruit Jam, Expire Date: 2023/02/12

Item ID: 3, Item Name: Dried Sparts 1KG Pack, Expire Date: 2023/04/05

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