Data_structure_note

Thursday, May 30, 2024 2:42 PM

1. Data Structure => is a way of organizing data different ways of storing data on your computer
EX: is like preparing for cooking you slice up vegetables

2. Algorithm => the process that does something to data to produce the output operations on different data structure
data structure + algorithm = programming

Steps to learn:

a.. Big O notation => is the language of analyzing algorithms and data structures.

b. Data structures list:

1.Arrays
2. Linked Lists
3.Queues and Stacks
4. Trees
5. Graphs
6. Hash Maps
7. pointers
8. Memory => 1 byte = 8 bits

c. Algorithms:

1. recursion
2. sorting algorithms
3. Graph search algorithms
4. Dynamic programming
5. common problem solving patterns

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3. Memory (RAM) vs. Storage
After turning off the computer, Storage is permanent, and memory will disappear.

int a =1; => 32 bits for int
4 bytes = 32 bits = 1 integer

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4. classes and objects

```
//class
class Robot {
    string name;
    string color;
    int weight;
//constructors
    Robot(String n, String c, int w){
        this.name = n;
        this.color = c;
        this.weight = w;
    }
//function
    void introduceSelf(){
        system.out.println("My name is " + this.name);
```

```
    }
}

//to use contructors and functions
Robot r1 = new robot("Leo", "Red", "37");
r1.introduceSelf();
```

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5. Linked List

6 -> 3 -> 4 -> 2 -> 1 -> null

```
class Node{
    int data;
    Node next;
    Node prev;
    //contructor
    Node(int data){
        this.data = data;
    }
}

Node head = new Node(6);
Node nodeB = new Node(3);
Node nodec = new Node(4);
...

head.next = nodeB
nodeB.next = nodeC
...

//count how many nodes we have
int countNodes(Node head){
    //assuming head != null
    int count = 1;
    Node current = head;
    while(current.next != null){
    current = current.next;
    count += 1;
    }
}
```

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6. Recursion

//factorial

n! = n. (n-1)! if n >= 1

1 otherwise (if n = 0)

Ex: 4! = 4 x 3 x 2 x 1 = 24

```
int fact(int n){
    //assume that n is a positive integer or 0
    if (n >= 1) {
        return n * fact(n-1);
    } else {
        return 1;
```

```
    }
}
```

// Fibonacci sequence
Ex: 1, 1, 2, 3, 5, 8

```
int fib(int n){
  if (n  >= 3){
        return fib(n-1) * fib(n-2);
  } else {
      return 1;
}
```

google interview problem
Recursive staircase problem
num_way(N) = num_ways(N-1) + num_ways(N-2)
num_way(0) = 1
num_way(1) = 1

```
//python
//this won't work if n =2
def num_ways(n):
	if n == 0 or n == 1:
		return 1
	else:
		return num_ways(n-1) + num_ways(n-2)
```

//fixed

```
def num_ways_bottom_up(n):
    if n == 0 or n == 1:
        return 1
    nums = [0] * (n + 1)
    nums[0] = 1
    nums[1] = 1
    for i in range(2, n + 1):
        nums[i] = nums[i - 1] + nums[i - 2]
    return nums[n]
# Example usage
total_feet = 11
print(f"Number of ways to jump {total_feet} feet: 
{num_ways_bottom_up(total_feet)}")
```

//variation problems
X = {1,3,5}

```
//wrong
def num_ways_X(n):
	if n == 0
		return 1
	total = 0;
	for each i in {1,3,5}:
		if n -i >= 0:
```

total += num_ways_X(n-i)
return total

//fixed

```
def num_ways_bottom_up_X(n):
    if n == 0:
        return 1
    nums = [0] * (n + 1)
    nums[0] = 1
    for i in range(1, n + 1):
        total = 0
        for j in {1, 3, 5}:
            if i - j >= 0:
                total += nums[i - j]
        nums[i] = total
    return nums[n]
```

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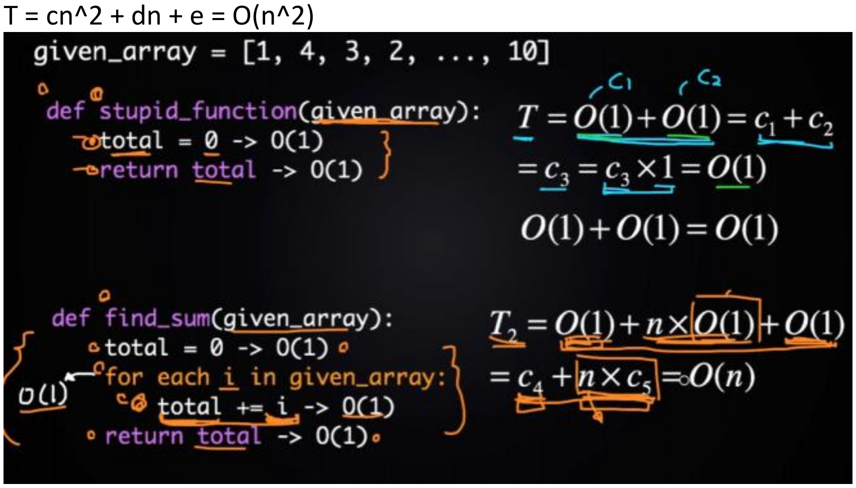
7. Big O notation

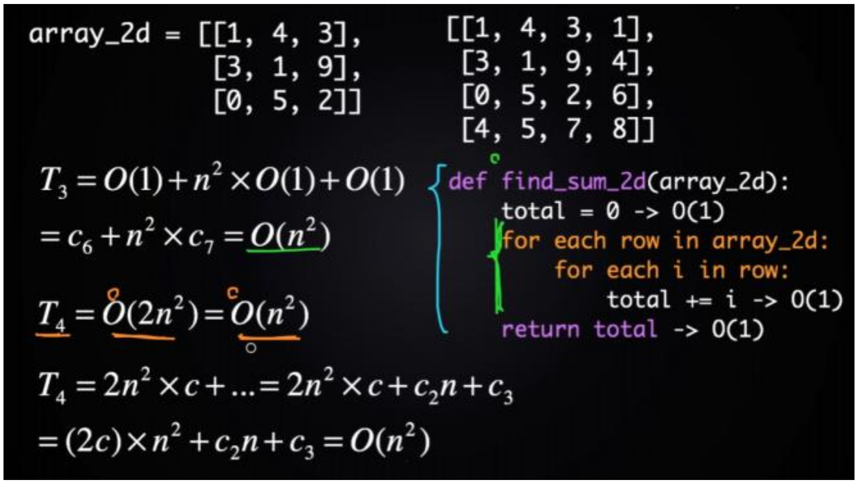
runtime = time to takes to execute a piece of code

linear time = **O(n)**
constant time = **O(1)**
quadratic time = **O(n^2)**

1. find the fastest growing term
2. take out the coefficient

T = an + b = O(n)
T = cn^2 + dn + e = O(n^2)





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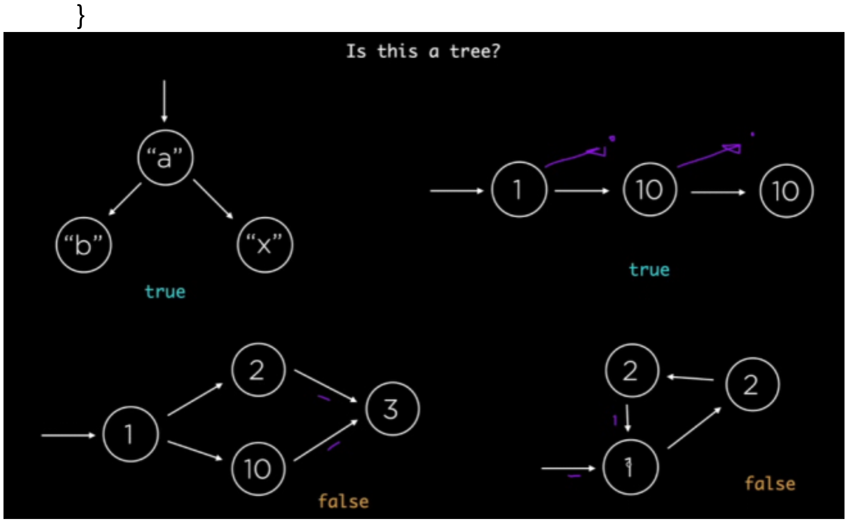
8. **Tree** =>

Class Node{
    Int data
    Node left
    Node right
}



Binary Tree =>
is a data structure in which each node has at most two children, referred to as the left child and the right child.

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9. **Sorting**

a.Linear search = O(n) = O(n/2) = It works by checking each element in the list, one by one, until the desired element is found or the end of the list is reached

```
def linear_search(arr, target):
    for i in range(len(arr)):
        if arr[i] == target:
            return i  # Return the index of the target element
    return -1  # Return -1 if the target is not found

# Example usage
arr = [34, 17, 23, 35, 45, 9, 1]
```

```
    target = 23
    result = linear_search(arr, target)

    if result != -1:
        print(f"Element found at index {result}")
    else:
print("Element not found")
```

b. Binary search:

Arr[-50 ~ 50]
Target = 20

40 -> 20 -> 10 -> … -> 1

N -> $\frac{n}{2} \to \frac{n}{4} \to \frac{n}{8} \to \cdots \to 1$

$$\boldsymbol{n \to \frac{n}{2} \to \frac{n}{2^2} \to \frac{n}{2^3} \to \cdots \to \frac{n}{2^x} \approx 1}$$

$$\boldsymbol{\frac{n}{2^x} \approx 1 \Rightarrow n = 2^x \Rightarrow log_2(n) = x = O(\log(n))}$$

```
def search(arr, target):
    left = 0
    right = len(arr) - 1
    while left <= right:
        mid = (left + right) // 2 # make sure to round it down
        if arr[mid] == target:
            return mid
        elif target < arr[mid]:
            right = mid - 1
        else:
            left = mid + 1
    return -1
arr1 = [-2, 3, 4, 7, 8, 9, 11, 13]
assert search(arr1, 11) == 6
assert search(arr1, 13) == 7
assert search(arr1, -2) == 0
assert search(arr1, 8) == 4
assert search(arr1, 6) == -1
assert search(arr1, 14) == -1
assert search(arr1, -4) == -1
arr2 = [3]
assert search(arr2, 6) == -1
assert search(arr2, 2) == -1
assert search(arr2, 3) == 0
print("If you didn't get an assertion error, this program has run
successfully.")
```

c. Quicksort:

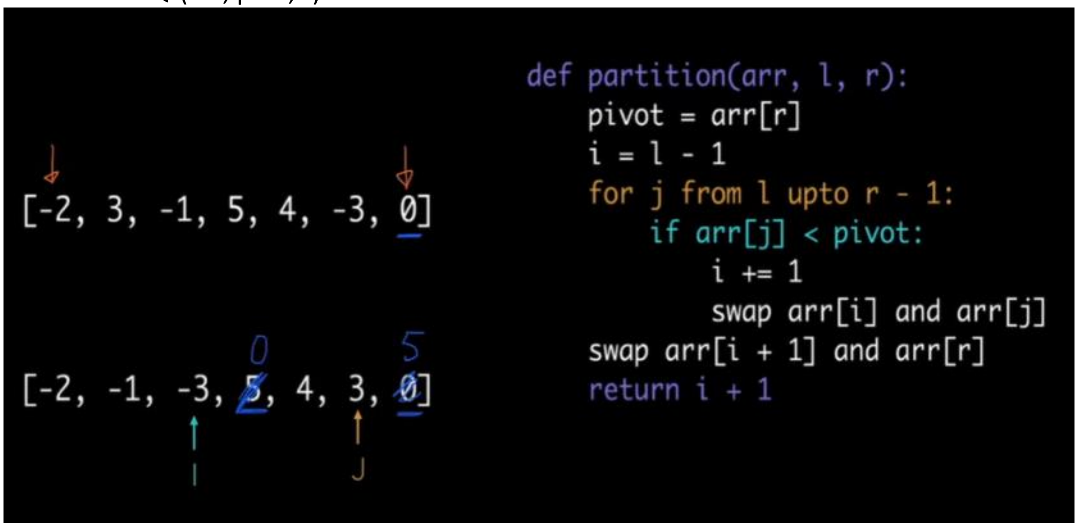
is typically the fastest for large datasets due to its low overhead and excellent average-case performance.

Implement details:

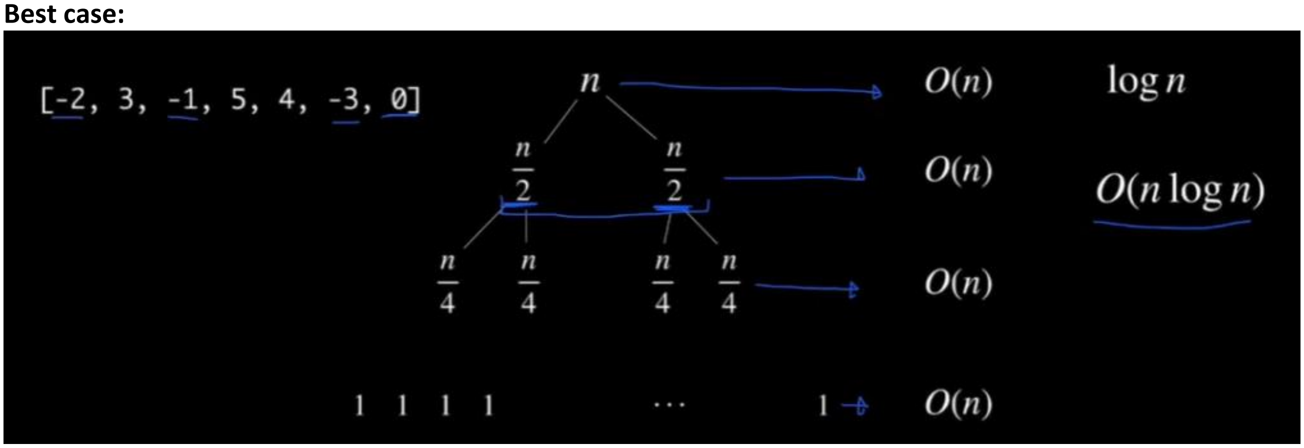
1. Choosing pivot
   Random element
   Median of three
2. Dealing with duplicates

3-way quicksort

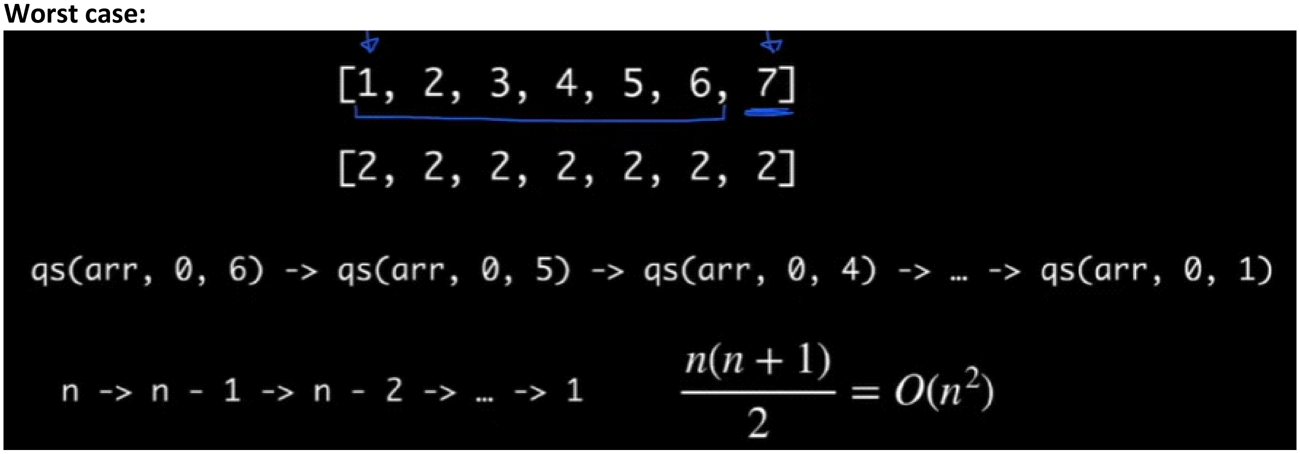
Def qs(arr, l, r):
    If l >= r:
        Return
    P = partition(arr,l,r)
    Qs(arr, l , p-1)
    Qs(arr, p +1, r)



Time Complexity:
Best case:



Worst case:



d. other sorting:

1. **Mergesort:** is a good choice when stability is required and for data that doesn't fit in memory (external sorting).

2. **Heapsort:** provides reliable O(nlogn) performance with in-place sorting but is generally outperformed by quicksort and mergesort.

3. **Timsort:** is highly efficient for real-world data and is used in many standard libraries due to its adaptive nature and stability.

10. Stacks and queues

Stacks = last in, first out.

1. **Operations:**
   Push: Add an element to the top of the stack.
   Pop: Remove the top element from the stack.
   Peek/Top: Look at the top element without removing it.
2. **Usage:**
   Undo mechanisms in text editors.
   Function call management in programming languages (call stack).
   Depth-first search (DFS) algorithms.

```
# Implementing a stack using a list
stack = []
# Push operation
stack.append(1)
stack.append(2)
stack.append(3)
# Pop operation
print(stack.pop())  # Output: 3
print(stack.pop())  # Output: 2
# Peek operation
print(stack[-1])    # Output: 1
```

Queues = first in, first out

1. **Operations:**
   Enqueue: Add an element to the end of the queue.
   Dequeue: Remove the element from the front of the queue.
   Front/Peek: Look at the front element without removing it
2. **Usages**
   Order processing systems.
   Breadth-first search (BFS) algorithms.
   Print job management.

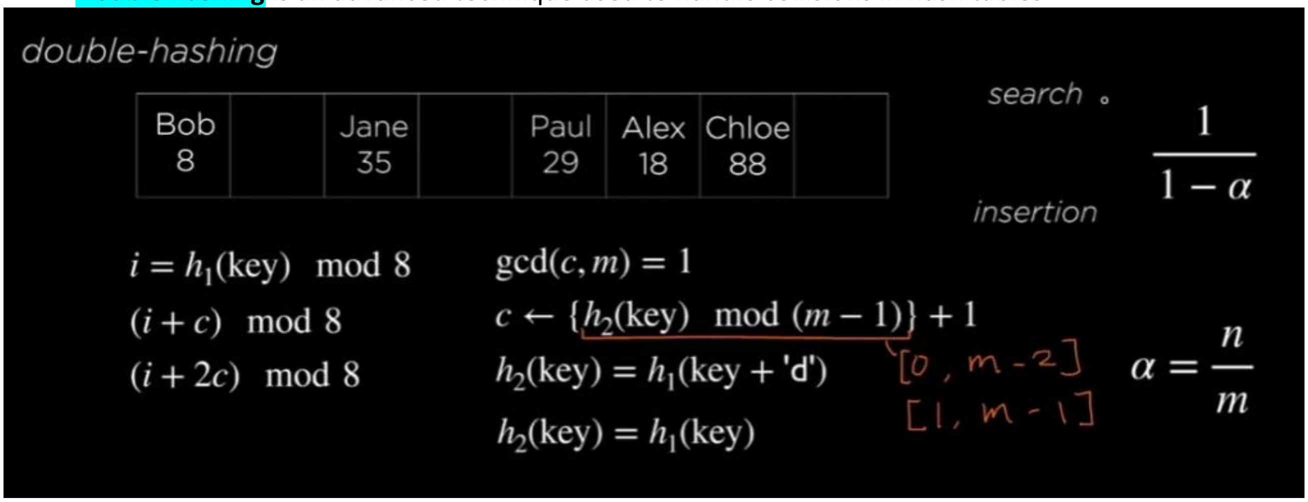
```
from collections import deque
# Implementing a queue using deque from collections
queue = deque()
# Enqueue operation
queue.append(1)
queue.append(2)
queue.append(3)
# Dequeue operation
print(queue.popleft())  # Output: 1
print(queue.popleft())  # Output: 2
# Peek operation
print(queue[0])         # Output: 3
```

11. Hash Tables and Dictionaries

is a data structure that implements an associative array abstract data type, a structure that

can map keys to values. It uses a hash function to compute an index into an array of buckets or slots, from which the desired value can be found.
Fast to compute
Avoid collision

Double hashing is an advanced technique used to handle collisions in hash tables



Suppose we want to insert the keys 10, 22, 31, 44, 59 into the hash table:

1. Insert 10:h1(10)=10mod11=10h1(10)=10mod11=10
   No collision, so 10 is placed at index 10.
2. Insert 22:h1(22)=22mod11=0h1(22)=22mod11=0
   No collision, so 22 is placed at index 0.
3. Insert 31:h1(31)=31mod11=9h1(31)=31mod11=9
   No collision, so 31 is placed at index 9.
4. Insert 44:h1(44)=44mod11=0h1(44)=44mod11=0
   Collision occurs at index 0.
   Calculate the step size using$h$2(44)=1+(44mod10)=5h2(44)=1+(44mod10)=5.
   Probe sequence:(0+1·5)mod11=5(0+1·5)mod11=5.
   No collision at index 5, so 44 is placed at index 5.
5. Insert 59:h1(59)=59mod11=4h1(59)=59mod11=4
   No collision, so 59 is placed at index 4.

Advantages of Double Hashing

1. Reduced Clustering: It minimizes both primary and secondary clustering compared to linear and quadratic probing.
2. Efficiency: Provides good performance in terms of average search, insert, and delete operations.

Resources: [Resources for Learning Data Structures and Algorithms (Data Structures & Algorithms # 8)]