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

a. Pointer

1. Int x = 4
2. Int * pX = &x => "English: integer pointer named pX is set to address of x
3. Int y = *pX => integer named y is set to the thing is pointed to by pX
4. *** = pointer**
5. **& = address of**

b. Count

```
std::unordered_map<int, int> myMap = {{1, 10}, {2, 20}, {3, 30}};
int key = 2;
int count = myMap.count(key);
// Returns 1, because the key 2 exists in the map; return 0 is not exist
```

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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();
```

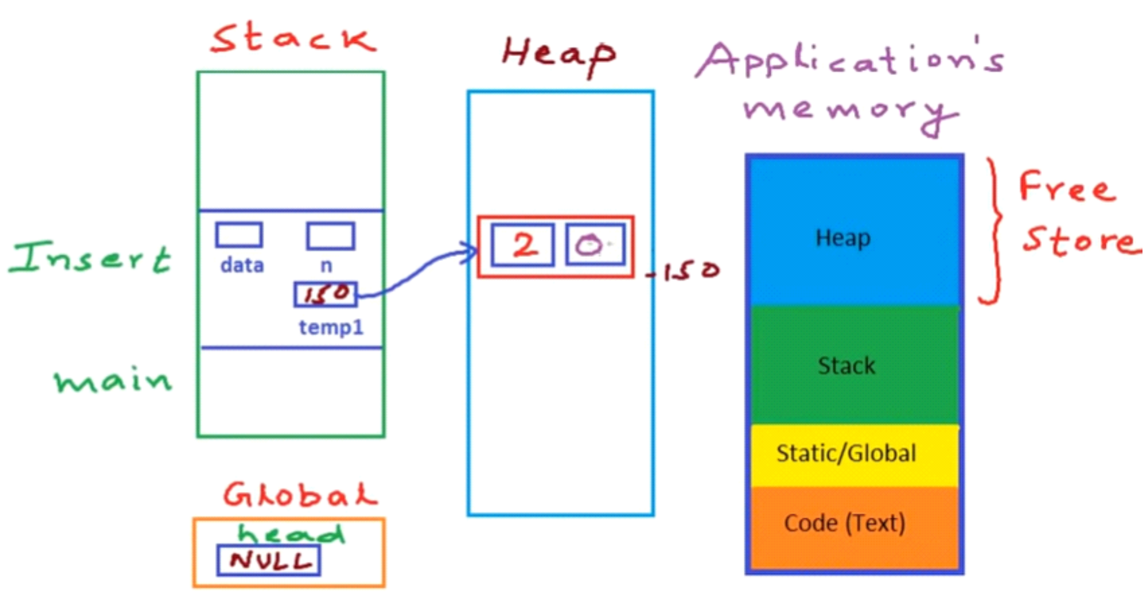
---

5. Linked List

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

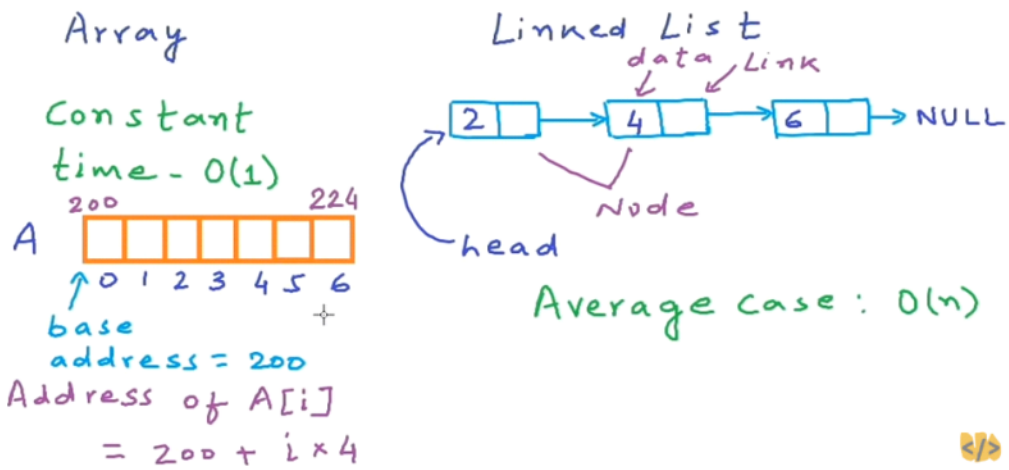
```
class Node{
    int data;
    Node next;
    Node prev;
    //contructor
    Node(int data){
        this.data = data;
    }
}

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;
    }
}
```

```cpp
#include <iostream>
struct Node {
    int data;
    Node* next;
};
Node* head;
void Insert(int x) {
    Node* temp = new Node();
    temp->data = x;
    temp->next = head;
    head = temp;
}
void Print() {
    Node* temp = head;
    std::cout << "List is: ";
    while (temp != NULL) {
        std::cout << " " << temp->data;
        temp = temp->next;
    }
    std::cout << "\n";
}
int main() {
    head = NULL;
    std::cout << "How many numbers?\n";
    int n, x;
    std::cin >> n;
    for (int i = 0; i < n; i++) {
        std::cout << "Enter the number\n";
        std::cin >> x;
        Insert(x);
        Print();
    }
    return 0;
}
```



Array vs Linked List

1) Cost of accessing an element



Memory requirments
Array
    Fixed size
    Memory may not be available as one large blocks
Linked list
    No unused memory
    extra memory for pointer variable
    Memory may be available as multiple small blocks

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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

```python
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

```python
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

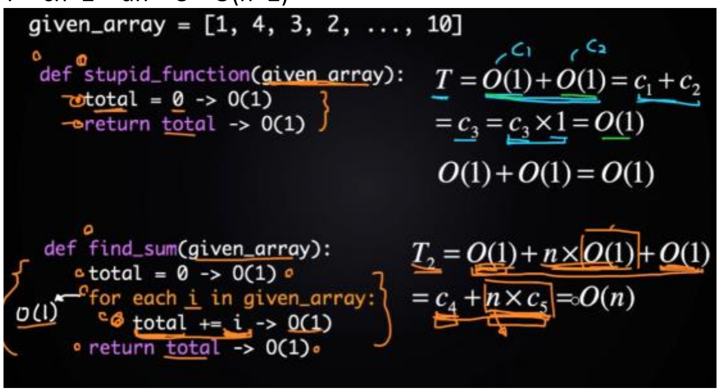
runtime = time to takes to execute a piece of code

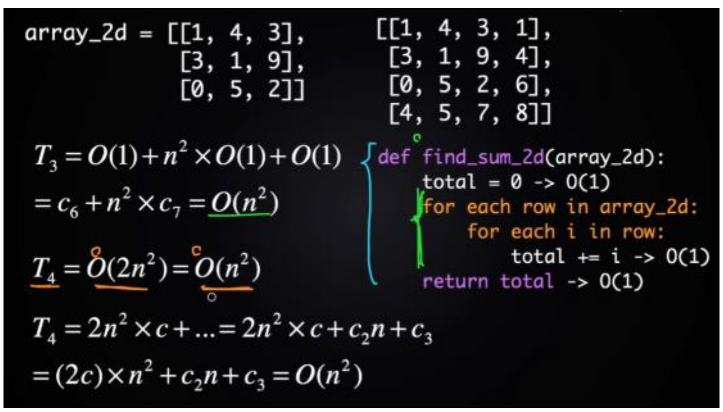
linear time = O(n)
constant time = O(1)
quadratic time = O(n^2)

Sorting = O(n log n)
Hsah Table = O(n)

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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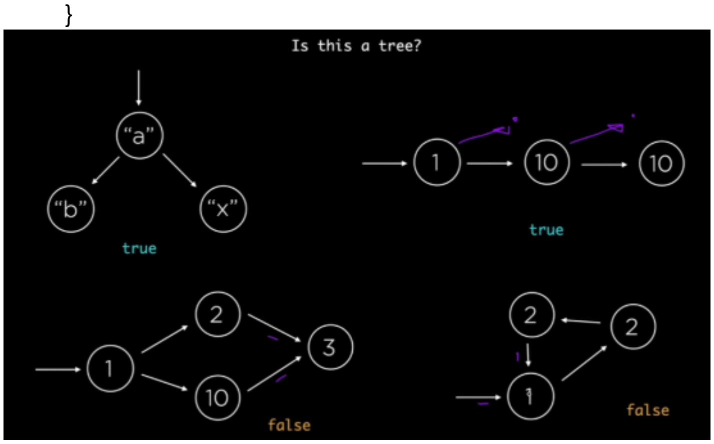
8. Tree =>

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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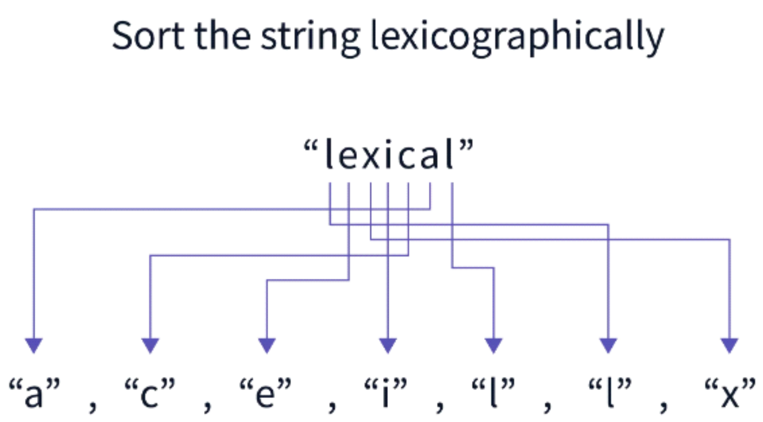
9. Sorting



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:
在一排價格已經排序好的商品中，找到所有小於某價錢的商品數量

From <https://medium.com/@lindingchi/binary-search-%E9%82%A3%E4%BA%9B%E8%97%8F%E5%9C%A8%E7%B4%B0%E7%AF%80%E8%A3%A1%E7%9A%84%E9%AD%94%E9%AC%BC-%E4%BA%8C-%E6%89%BE%E4%B8%8D%E5%88%B0%E6%80%8E%E9%BA%BC%E8%BE%A6-a308f5b9ce12>

Arr[-50 ~ 50]
Target = 20

40 -> 20 -> 10 -> … -> 1

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

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

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

```
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.")
```

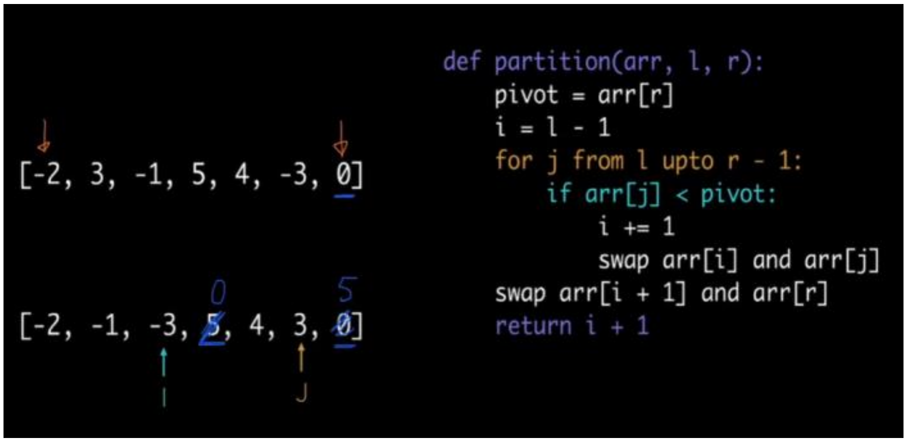
c. Quicksort:

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

Implement details:

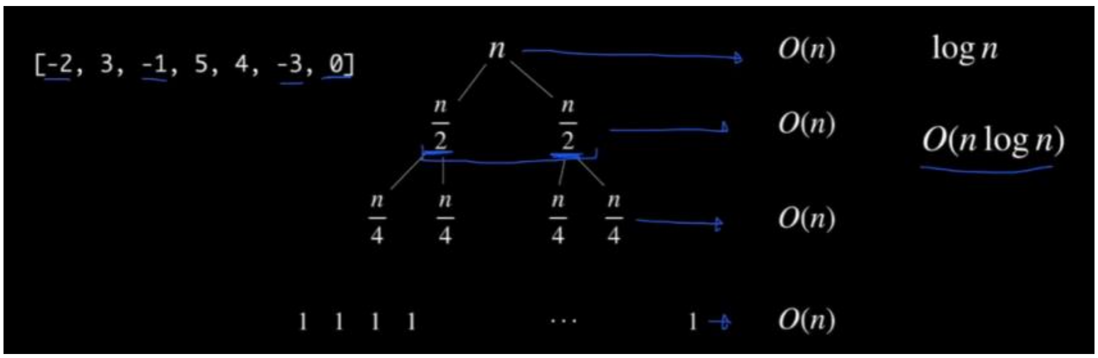
1. Choosing pivot
   Random element
   Median of three
2. Dealing with duplicates
   3-way quicksort

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

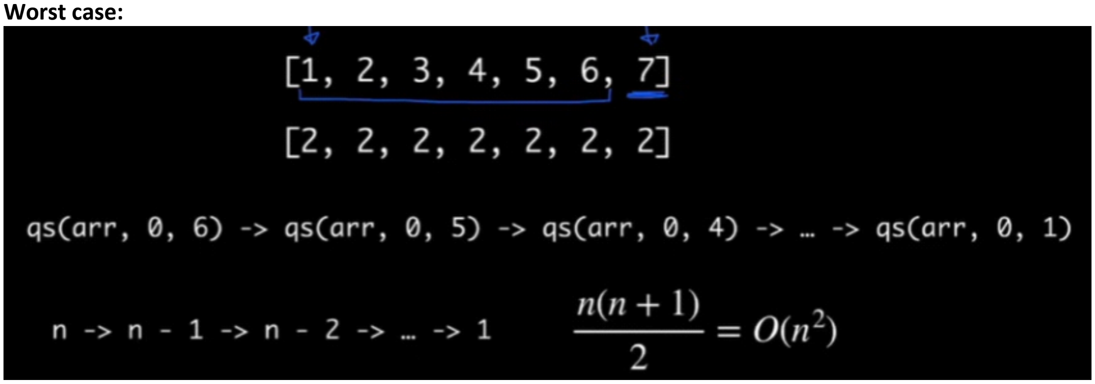


Time Complexity:

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.

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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.
   IsEmpty(): check is the stack is empy
2. **Usage:**

Undo mechanisms in text editors.
Function call management in programming languages (call stack).
Depth-first search (DFS) algorithms.

```python
# 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

----------------------------------------------------------------
-----------
```

```cpp
#include <iostream>
#include <vector>
class Stack {
private:
    std::vector<int> items;
public:
    Stack() {}
    bool isEmpty() {
        return items.empty();
    }
    void push(int item) {
        items.push_back(item);
    }
    int pop() {
        if (!isEmpty()) {
            int topItem = items.back();
            items.pop_back();
            return topItem;
        } else {
            throw std::out_of_range("Stack is empty");
        }
    }
    int top() {
        if (!isEmpty()) {
            return items.back();
        } else {
            throw std::out_of_range("Stack is empty");
        }
    }
};
int main() {
    Stack stack;
    stack.push(1);
    stack.push(2);
    stack.push(3);
    std::cout << "Top element: " << stack.top() << std::endl; //
Output: 3
    std::cout << "Popped element: " << stack.pop() << std::endl;
// Output: 3
    std::cout << "Top element: " << stack.top() << std::endl; //
Output: 2
```

```
    std::cout << "Is stack empty: " << std::boolalpha
<< stack.isEmpty() << std::endl; // Output: false
    return 0;
}
```

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.

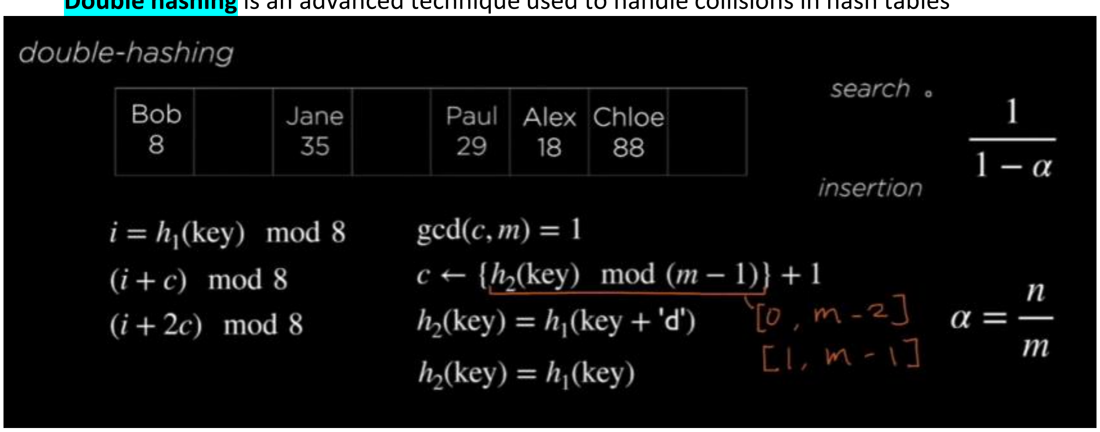
```python
from collections import deque
# Implementing a queue using deque from collections
queue = deque()
# Enqueue operation
queue.append(1)
queue.append(2)
queue.append(3)
# Dequeue operation
print(queue.popleft())  # Output: 1
print(queue.popleft())  # Output: 2
# Peek operation
print(queue[0])         # 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:$h1(44)=44 \bmod 11=0$h1(44)=44mod11=0
   Collision occurs at index 0.
   Calculate the step size using$h2(44)=1+(44 \bmod 10)=5$h2(44)=1+(44mod10)=5.
   Probe sequence:$(0+1\cdot5) \bmod 11=5$(0+1·5)mod11=5.
   No collision at index 5, so 44 is placed at index 5.
5. Insert 59:$h1(59)=59 \bmod 11=4$h1(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.

Ditionary

- Create a dictionary by using empty brackets {}.
- dictionary_name[key] = value adds items to a dictionary.
- len(dictionary_name) returns the number of keys in a dictionary.
- print(dictionary_name[key]) prints the value associated with the key.
- Keys in a dictionary are unique. When a key is added multiple times, the old value is overwritten by the new one.

----

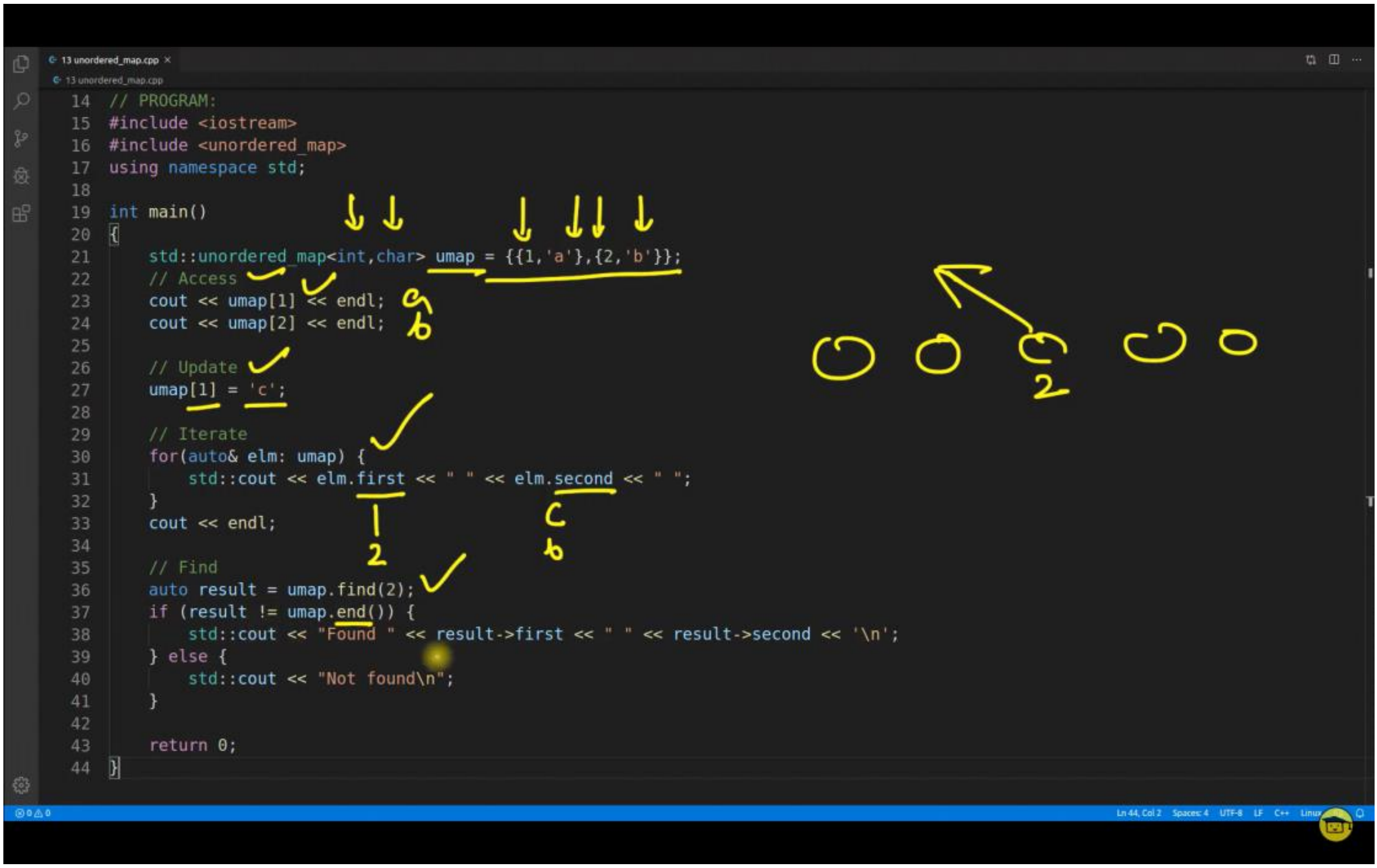
12. Unordered Map

NOTES:

0. std: :unordered map is an associative container that contains key-value pairs with unique keys.
1. Search, insertion, and removal have average constant-time complexity.
2. Internally, the elements are organized into buckets.
3. It uses hashing to insert elements into buckets.
4. This allows fast access to individual elements, because after computing the hash of the value it refers to the exact bucket the element is placed into.

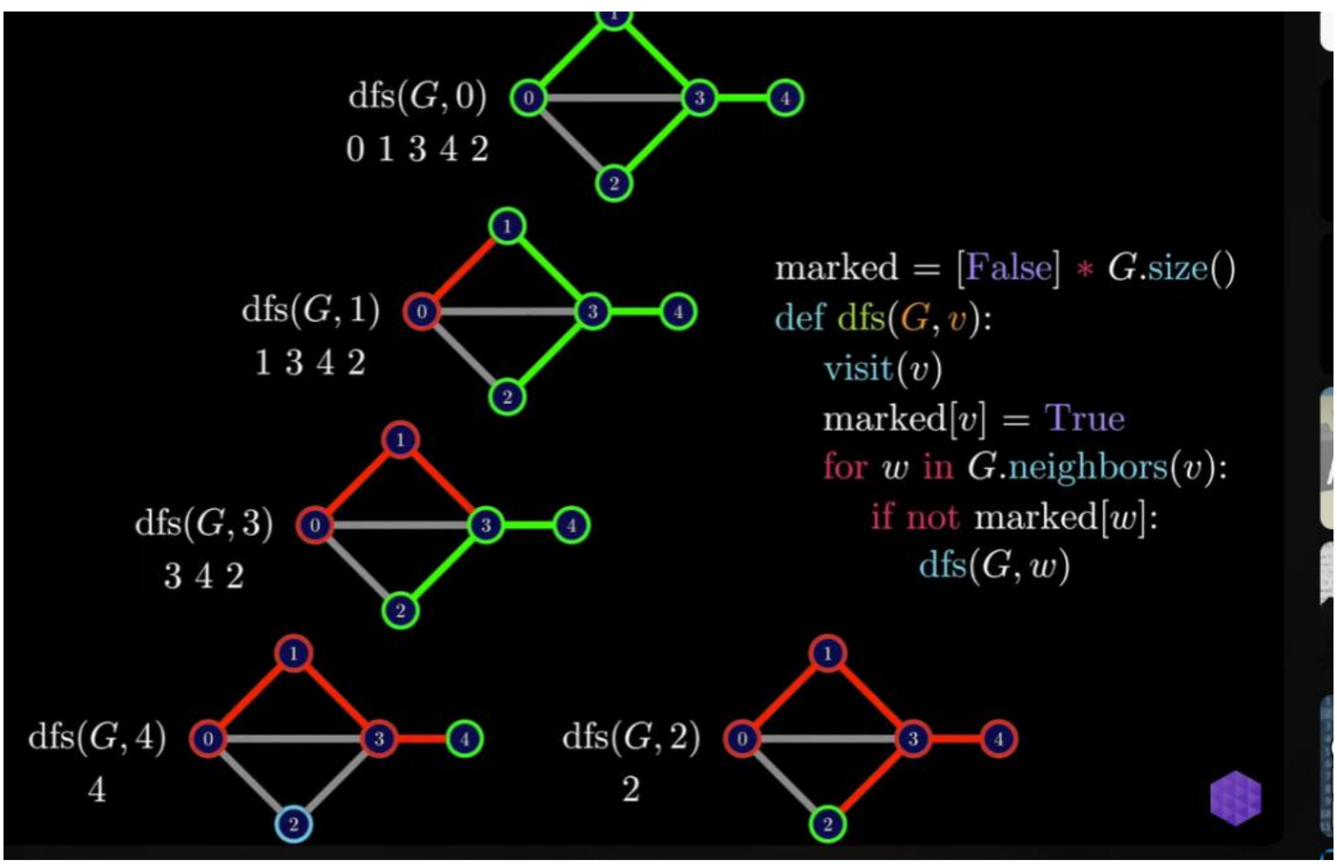
WHY UNORDERED MAP

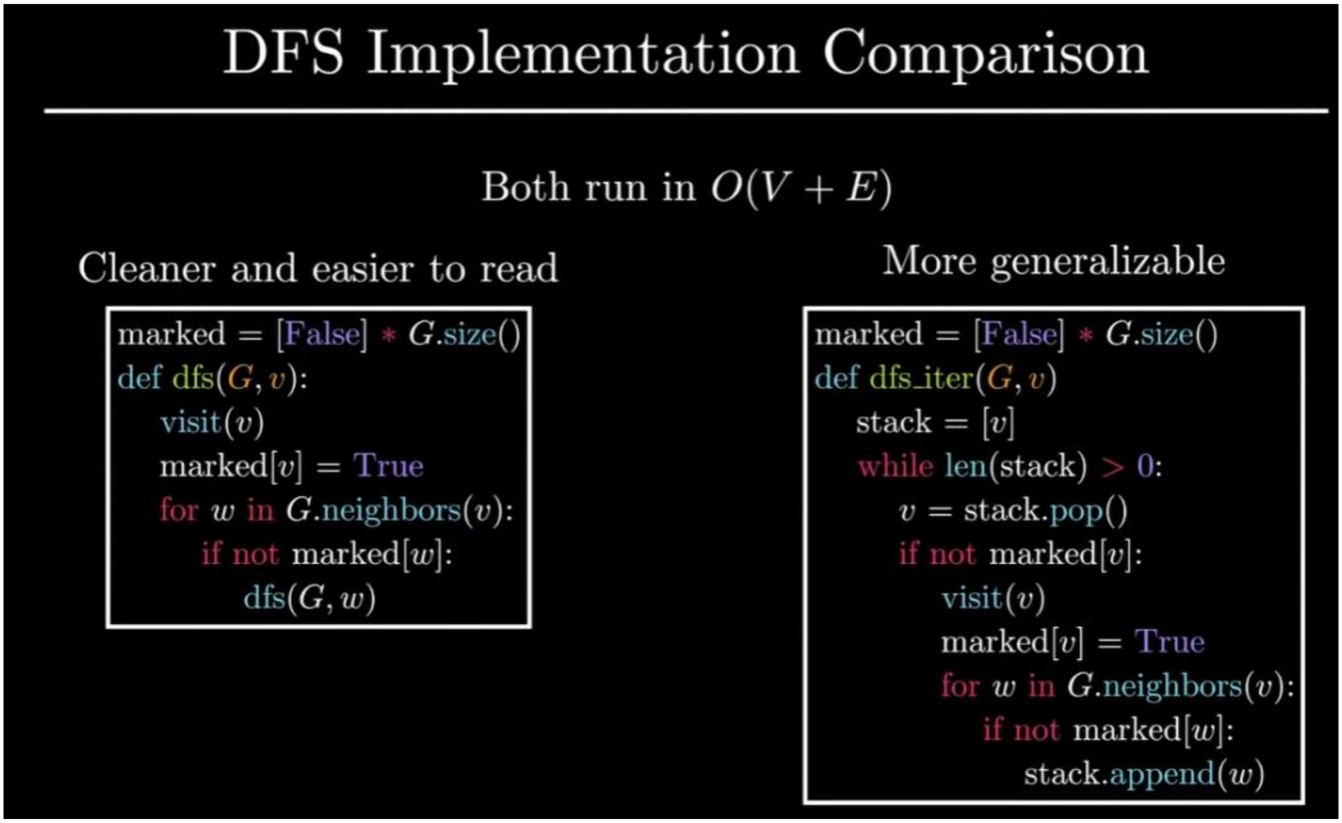
maintain a collection of unique {key:value) pairs with fast insertion and removal.

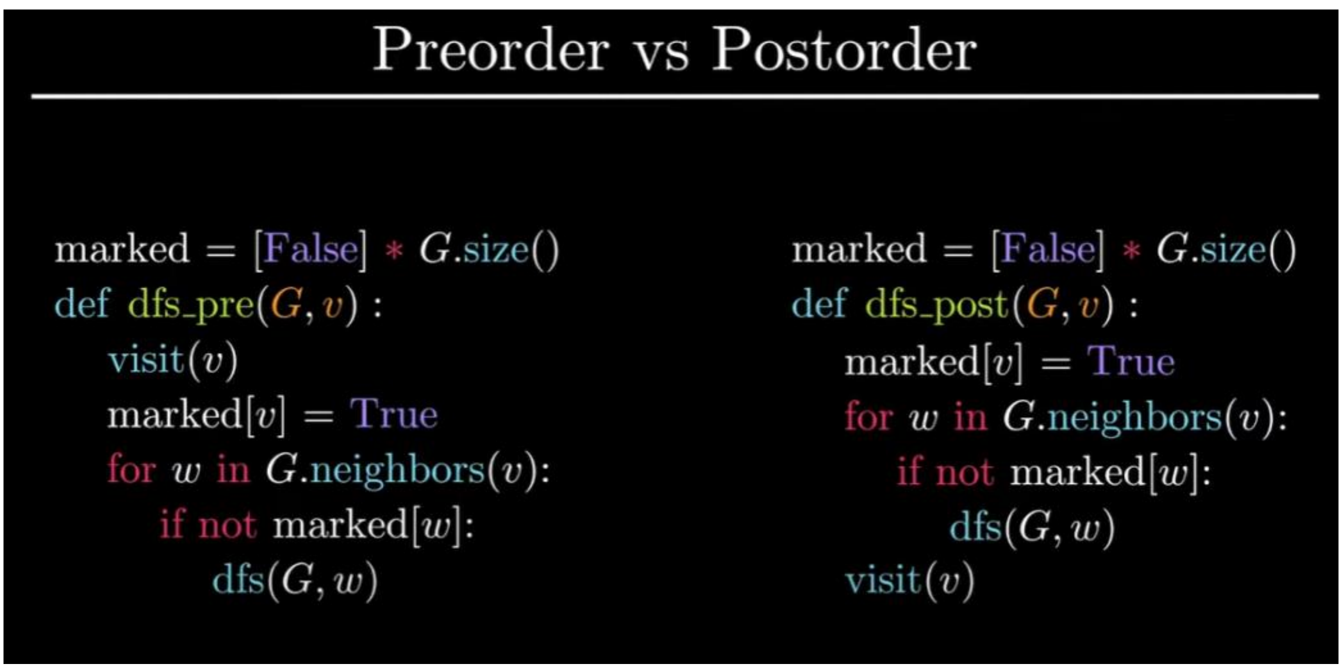


```cpp
// PROGRAM:
#include <iostream>
#include <unordered_map>
using namespace std;

int main()
{
    std::unordered_map<int,char> umap = {{1,'a'},{2,'b'}};
    // Access
    cout << umap[1] << endl;
    cout << umap[2] << endl;

    // Update
    umap[1] = 'c';

    // Iterate
    for(auto& elm: umap) {
        std::cout << elm.first << " " << elm.second << " ";
    }
    cout << endl;

    // Find
    auto result = umap.find(2);
    if (result != umap.end()) {
        std::cout << "Found " << result->first << " " << result->second << '\n';
    } else {
        std::cout << "Not found\n";
    }

    return 0;
}
```


13.Depth First Search(DFS)







Recursive

```
#include <iostream>
#include <vector>
#include <stack>
using namespace std;
// Function to visit a node (you can modify this as per your
requirements)
void visit(int node) {
    cout << node << " ";
}
// Function to perform DFS
```

```cpp
void dfs(vector<vector<int>>& graph, int start, vector<bool>&
marked) {
    // Mark the starting node as visited
    marked[start] = true;

    // Visit the starting node
    visit(start);

    // Visit all the unvisited neighbors of the starting node
    for (int neighbor : graph[start]) {
        if (!marked[neighbor]) {
            dfs(graph, neighbor, marked);
        }
    }
}
int main() {
    // Create a sample graph
    vector<vector<int>> graph = {
        {1, 2},
        {0, 2, 3},
        {0, 1, 3},
        {1, 2}
    };

    // Perform DFS starting from node 0
    vector<bool> marked(graph.size(), false);
    dfs(graph, 0, marked);

    return 0;
}
```


14.Breath First search

```cpp
#include <iostream>
#include <vector>
#include <queue>
using namespace std;
class Graph {
public:
    Graph(int vertices);
    void addEdge(int v, int w);
    vector<int> neighbors(int v);
    int size();
private:
    int V;
    vector<vector<int>> adj;
};
Graph::Graph(int vertices) : V(vertices), adj(vertices) {}
void Graph::addEdge(int v, int w) {
    adj[v].push_back(w);
    adj[w].push_back(v); // Assuming an undirected graph
}
vector<int> Graph::neighbors(int v) {
    return adj[v];
}
int Graph::size() {
    return V;
```

```
}
void visit(int v) {
    cout << "Visited vertex: " << v << endl;
}
void bfs(Graph& G, int v) {
    vector<bool> marked(G.size(), false);
    queue<int> q;
    q.push(v);
    while (!q.empty()) {
        int v = q.front();
        q.pop();
        if (!marked[v]) {
            visit(v);
            marked[v] = true;
            for (int w : G.neighbors(v)) {
                if (!marked[w]) {
                    q.push(w);
                }
            }
        }
    }
}
int main() {
    Graph g(5); // Example with 5 vertices
    g.addEdge(0, 1);
    g.addEdge(0, 2);
    g.addEdge(1, 2);
    g.addEdge(1, 3);
    g.addEdge(2, 4);
    cout << "BFS starting from vertex 0:" << endl;
    bfs(g, 0);
    return 0;
}
```

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