Data Structure and Application (1333203) - Winter 2023 Solution

Milav Dabgar

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Question 1(a) [3 marks]

Define linked list. List different types of linked list.

Solution

Table 1. Linked List Definition and Types

Definition	Types of Linked List
A linked list is a linear data structure where elements are stored in nodes, and each node points to the next node in the sequence	1. Singly Linked List 2. Doubly Linked List 3. Circular Linked List 4. Circular Doubly Linked List

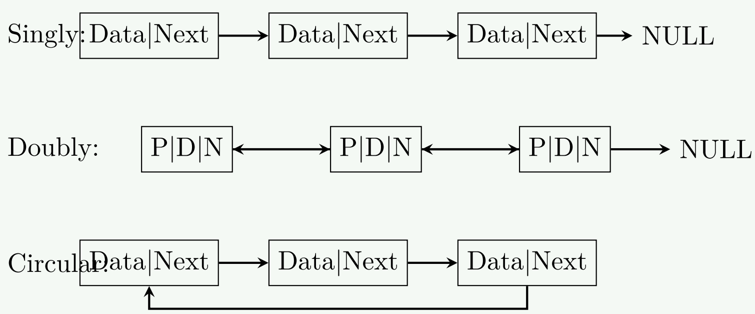


Figure 1. Types of Linked Lists

Mnemonic

"Single, Double, Circle, Double-Circle"

Question 1(b) [4 marks]

Explain Linear and Non Linear Data structure in Python with examples.

Solution

Table 2. Linear vs Non-Linear Data Structures

Data Structure	Description	Python Examples
Linear	Elements arranged in sequential order where each element has exactly one predecessor and successor (except first and last)	Lists: `[1, 2, 3]` Tuples: `(1, 2, 3)` Strings: `"abc"` Queue: `queue.Queue()`
Non-Linear	Elements not arranged sequentially; an element can connect to multiple elements	Dictionary: `{"a": 1, "b": 2}` Set: `{1, 2, 3}` Tree: Custom implementation Graph: Custom implementation

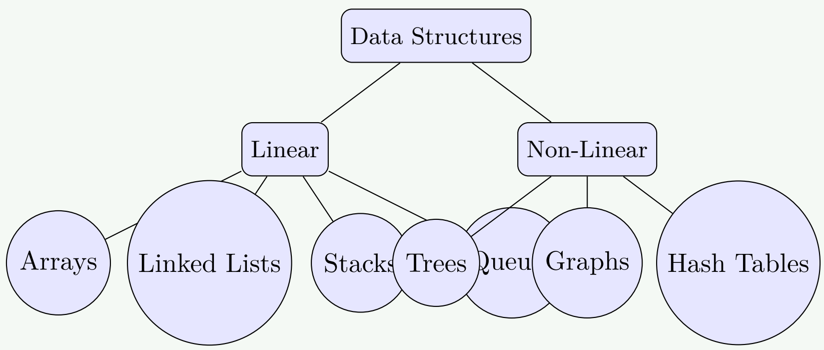


Figure 2. Classification of Data Structures

Mnemonic

"Linear Listens In Sequence, Non-linear Navigates Various Paths"

Question 1(c) [7 marks]

Explain class, attributes, object and class method in python with suitable example.

Solution

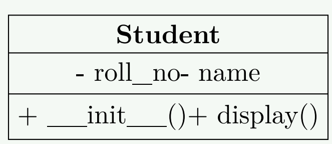


Figure 3. Class Diagram Example

Table 3. OOP Concepts

Term	Description
Class	Blueprint for creating objects with shared attributes and methods
Attributes	Variables that store data inside a class
Object	Instance of a class with specific attribute values
Class Method	Functions defined within a class that can access and modify class states

```python
class Student:
```

```python
    # Class attribute
    school = "GTU"

    # Constructor
    def __init__(self, roll_no, name):
        # Instance attributes
        self.roll_no = roll_no
        self.name = name

    # Instance method
    def display(self):
        print(f"Roll No: {self.roll_no}, Name: {self.name}")

    # Class method
    @classmethod
    def change_school(cls, new_school):
        cls.school = new_school

# Creating object
student1 = Student(101, "Raj")
student1.display()  # Output: Roll No: 101, Name: Raj
```

Mnemonic

"Class Creates, Attributes Store, Objects Use, Methods Operate"

Question 1(c) OR [7 marks]

Define Data Encapsulation & Polymorphism. Develop a Python code to explain Polymorphism.

Solution

Table 4. Definitions

Concept	Definition
Data Encapsulation	Bundling data and methods into a single unit (class) and restricting direct access to some components
Polymorphism	Ability of different classes to provide their own implementation of methods with the same name

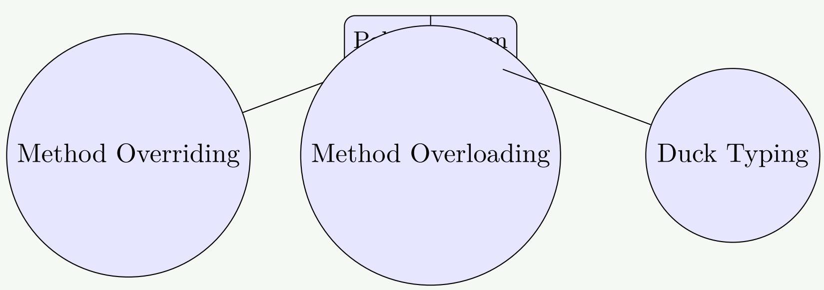


Figure 4. Types of Polymorphism

```python
# Polymorphism example
class Animal:
    def speak(self):
```

```python
        pass

class Dog(Animal):
    def speak(self):
        return "Woof!"

class Cat(Animal):
    def speak(self):
        return "Meow!"

class Duck(Animal):
    def speak(self):
        return "Quack!"

# Function demonstrating polymorphism
def animal_sound(animal):
    return animal.speak()

# Creating objects
dog = Dog()
cat = Cat()
duck = Duck()

# Same function works for different animal objects
print(animal_sound(dog))   # Output: Woof!
print(animal_sound(cat))   # Output: Meow!
print(animal_sound(duck))  # Output: Quack!
```

Mnemonic

"Encapsulate to Protect, Polymorphism for Flexibility"

Question 2(a) [3 marks]

Differentiate between Stack and Queue.

Solution

Table 5. Stack vs Queue

Feature	Stack	Queue
Principle	LIFO (Last In First Out)	FIFO (First In First Out)
Operations	Push, Pop	Enqueue, Dequeue
Access	Elements can only be added/removed from one end (top)	Elements are added at rear end and removed from front end

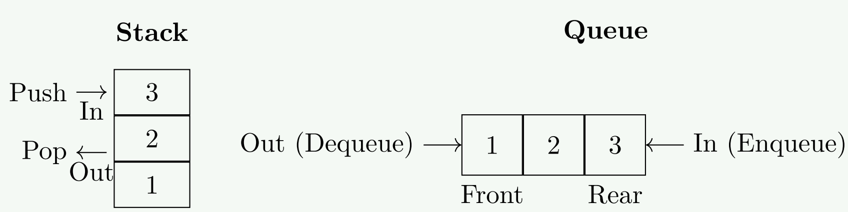


Figure 5. Stack vs Queue Visual

Mnemonic

"Stack Piles Up, Queue Lines Up"

Question 2(b) [4 marks]

Write an algorithm for PUSH and POP operation of stack in python.

Solution

PUSH Algorithm:

```
Start
  1. Check if stack is full
  2. If not full, increment top by 1
  3. Add element at position 'top'
End
```

POP Algorithm:

```
Start
  1. Check if stack is empty
  2. If not empty, retrieve element at 'top'
  3. Decrement top by 1
  4. Return retrieved element
End
```

```python
class Stack:
    def __init__(self, size):
        self.stack = []
        self.size = size
        self.top = -1

    def push(self, element):
        if self.top >= self.size - 1:
            return "Stack Overflow"
        else:
            self.top += 1
            self.stack.append(element)
            return "Pushed " + str(element)

    def pop(self):
        if self.top < 0:
            return "Stack Underflow"
        else:
            element = self.stack.pop()
            self.top -= 1
            return element
```

Mnemonic

"Push to Top, Pop from Top"

Question 2(c) [7 marks]

Convert following equation from infix to postfix using Stack.
A * (B + C) - D / (E + F)

Solution

Infix	$A * (B + C) - D/(E + F)$
Postfix	$ABC + *DEF + /-$

Table 6. Infix to Postfix Conversion Trace

Step	Symbol	Stack	Output
1	A		A
2	*	*	A
3	(	* (	A
4	B	* (	A B
5	+	* (+	A B
6	C	* (+	A B C
7	)	*	A B C +
8	-	-	A B C + *
9	D	-	A B C + * D
10	/	- /	A B C + * D
11	(	- / (	A B C + * D
12	E	- / (	A B C + * D E
13	+	- / (+	A B C + * D E
14	F	- / (+	A B C + * D E F
15	)	- /	A B C + * D E F +
16	end		A B C + * D E F + / -

Answer: `A B C + * D E F + / -`

Mnemonic

"Operators Stack, Operands Print"

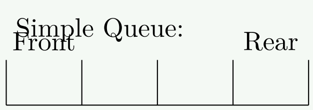
Question 2(a) OR [3 marks]

Differentiate between simple Queue and circular Queue.

Solution

Table 7. Simple vs Circular Queue

Feature	Simple Queue	Circular Queue
Structure	Linear data structure	Linear data structure with connected ends
Memory	Inefficient memory usage due to unused space after dequeue	Efficient memory usage by reusing empty spaces
Implementation	Front always at index 0, rear increases	Front and rear move in circular fashion using modulo



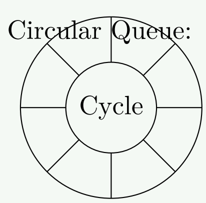


Figure 6. Simple vs Circular Queue Structure

Mnemonic

"Simple Wastes, Circular Reuses"

Question 2(b) OR [4 marks]

Explain concept of recursive function with suitable example.

Solution

Table 8. Recursive Function Concepts

Key Aspects	Description
Definition	A function that calls itself to solve a smaller instance of the same problem
Base Case	The condition where the function stops calling itself
Recursive Case	The condition where the function calls itself with a simpler version of the problem

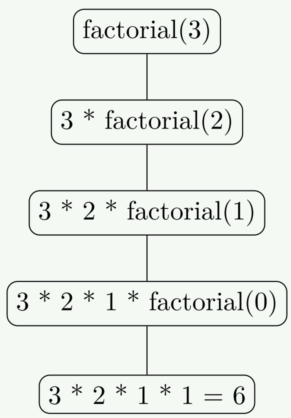


Figure 7. Recursive Calls trace for factorial(3)

```python
def factorial(n):
    # Base case
    if n == 0:
        return 1
    # Recursive case
    else:
        return n * factorial(n-1)

# Example
result = factorial(5)  # 5! = 120
```

Mnemonic

"Base Breaks, Recursion Returns"

Question 2(c) OR [7 marks]

Develop a python code to implement Enqueue and Dequeue operation in Queue.

Solution

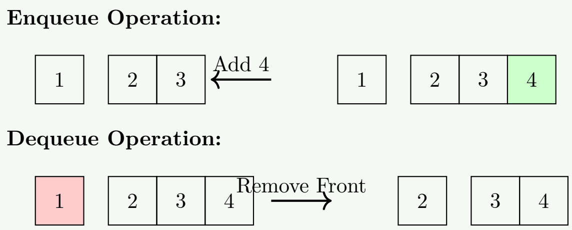


Figure 8. Enqueue and Dequeue Visualization

```python
class Queue:
    def __init__(self, size):
        self.queue = []
        self.size = size
        self.front = 0
        self.rear = -1
        self.count = 0

    def enqueue(self, item):
        if self.count >= self.size:
            return "Queue is full"
        else:
            self.rear += 1
            self.queue.append(item)
            self.count += 1
            return "Enqueued " + str(item)

    def dequeue(self):
        if self.count <= 0:
            return "Queue is empty"
        else:
            item = self.queue.pop(0)
            self.count -= 1
            return item

    def display(self):
        return self.queue

# Test
q = Queue(5)
q.enqueue(10)
q.enqueue(20)
q.enqueue(30)
print(q.display())  # [10, 20, 30]
print(q.dequeue())  # 10
print(q.display())  # [20, 30]
```

Mnemonic

"Enqueue at End, Dequeue from Start"

Question 3(a) [3 marks]

Give Difference between Singly linked list and Circular linked list.

Solution

Table 9. Singly vs Circular Linked List

Feature	Singly Linked List	Circular Linked List
Last Node	Points to NULL	Points back to the first node
Traversal	Has a definite end	Can be traversed continuously
Memory	Each node needs one pointer	Each node needs one pointer

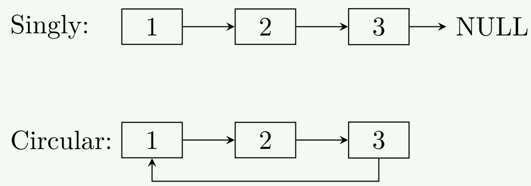


Figure 9. Singly vs Circular Structure

Mnemonic

"Singly Stops, Circular Cycles"

Question 3(b) [4 marks]

Explain concept of Doubly linked list.

Solution

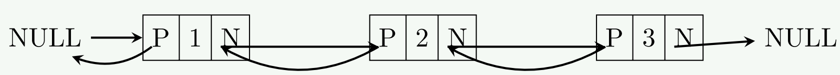


Figure 10. Doubly Linked List Structure

Table 10. Doubly Linked List Features

Feature	Description
Node Structure	Each node contains data and two pointers (previous and next)
Navigation	Can traverse in both forward and backward directions
Operations	Insertion and deletion can be performed from both ends
Memory Usage	Requires more memory than singly linked list due to extra pointer

```
class Node:
    def __init__(self, data):
        self.data = data
        self.prev = None
        self.next = None
```

Mnemonic

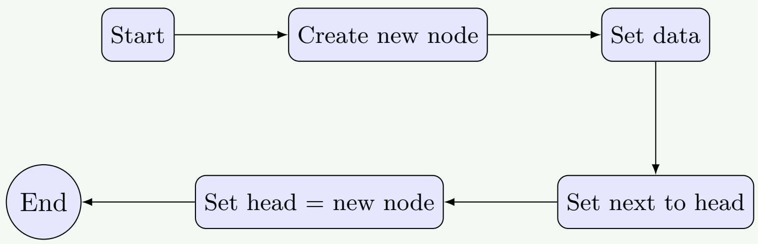
"Double Pointers, Double Directions"

Question 3(c) [7 marks]

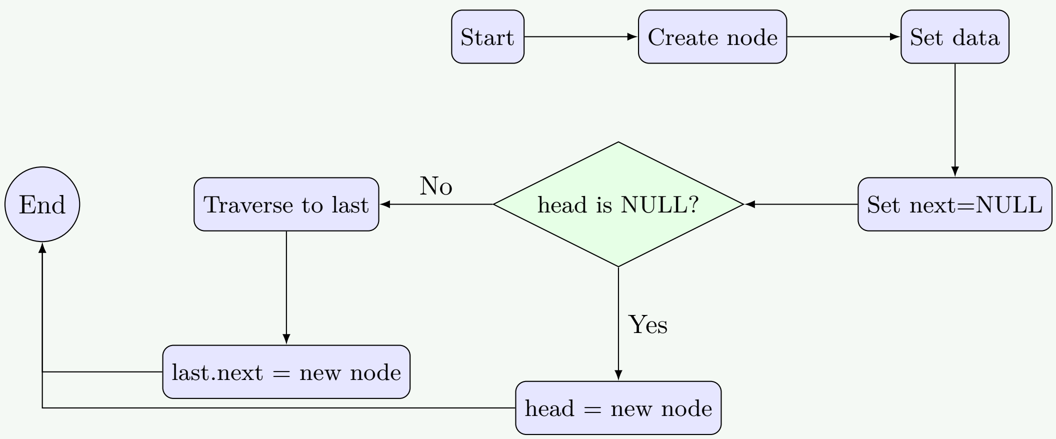
Write an algorithm for following operation on singly linked list:
1. To insert a node at the beginning of the list.
2. To insert the node at the end of the list.

Solution

1. Insert at Beginning:



2. Insert at End:




```python
def insert_at_beginning(head, data):
    new_node = Node(data)
    new_node.next = head
    return new_node  # New head

def insert_at_end(head, data):
    new_node = Node(data)
    new_node.next = None

    # If linked list is empty
    if head is None:
        return new_node

    # Traverse to the last node
    temp = head
    while temp.next:
        temp = temp.next

    # Link the last node to new node
    temp.next = new_node
    return head
```

Mnemonic

"Begin: New Leads Old, End: Old Leads New"

Question 3(a) OR [3 marks]

List different operations performed on singly linked list.

Solution

Table 11. Operations on Singly Linked List

Operations
1. Insertion (at beginning, middle, end)
2. Deletion (from beginning, middle, end)
3. Traversal (visiting each node)
4. Searching (finding a specific node)
5. Updating (modifying node data)

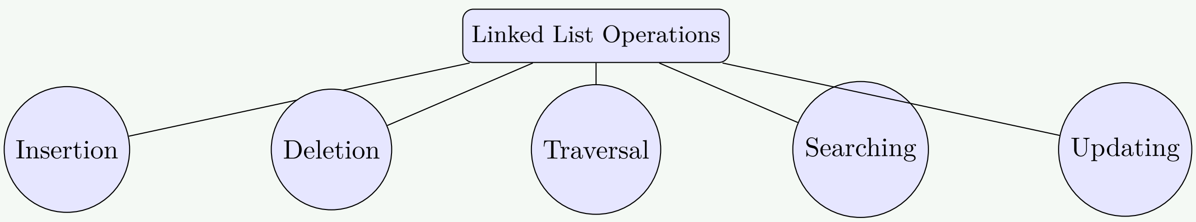


Figure 11. LL Operations

Mnemonic

"Insert Delete Traverse Search Update"

Question 3(b) OR [4 marks]

Explain concept of Circular linked list.

Solution

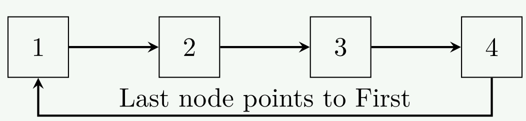


Figure 12. Circular Linked List Visualization

Table 12. Circular LL Features

Feature	Description
Structure	Last node points to the first node instead of NULL
Advantage	Allows continuous traversal through all nodes
Applications	Round robin scheduling, circular buffer implementation
Operations	Insertion and deletion similar to singly linked list with special handling for the last node

```python
class Node:
    def __init__(self, data):
        self.data = data
        self.next = None

# Creating a circular linked list with 3 nodes
head = Node(1)
node2 = Node(2)
node3 = Node(3)

head.next = node2
node2.next = node3
node3.next = head  # Makes it circular
```

Mnemonic

"Last Links to First"

Question 3(c) OR [7 marks]

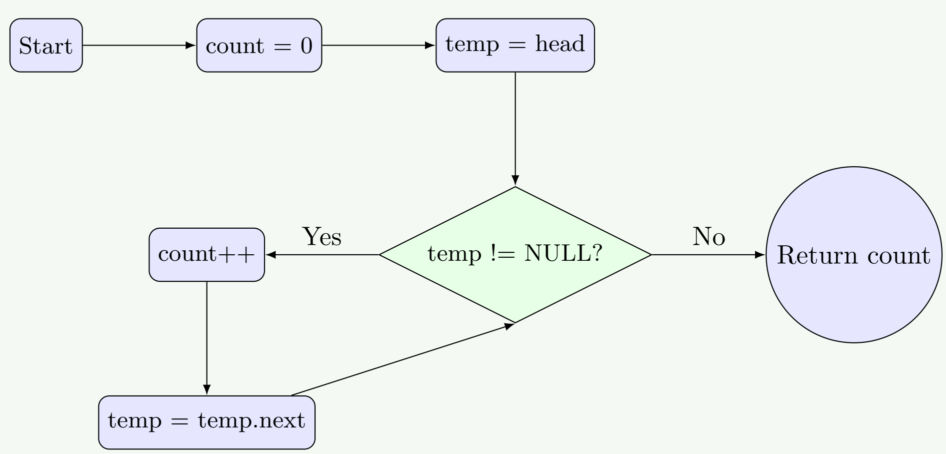
List application of linked list. Write an algorithm to count the number of nodes in singly linked list.

Solution

Table 13. Applications

Applications of Linked List
1. Implementation of stacks and queues
2. Dynamic memory allocation
3. Undo functionality in applications
4. Hash tables (chaining)
5. Adjacency lists for graphs

Algorithm to Count Nodes:




```python
def count_nodes(head):
    count = 0
    temp = head

```

```python
    while temp:
        count += 1
        temp = temp.next

    return count

# Example usage
# Assuming head points to the first node of a linked list
total_nodes = count_nodes(head)
print(f"Total nodes: {total_nodes}")
```

Mnemonic

"Count While Moving"

Question 4(a) [3 marks]

Compare Linear search with Binary search.

Solution

Table 14. Linear vs Binary Search

Feature	Linear Search	Binary Search
Data Arrangement	Works on both sorted and unsorted data	Works only on sorted data
Time Complexity	O(n)	O(log n)
Implementation	Simpler	More complex
Best For	Small datasets or unsorted data	Large sorted datasets

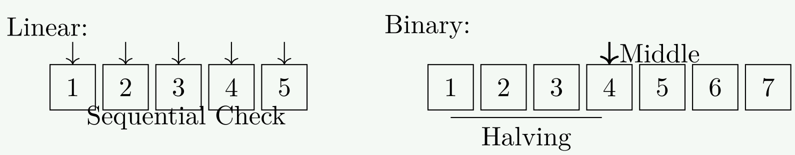


Figure 13. Search Comparison

Mnemonic

"Linear Looks at All, Binary Breaks in Half"

Question 4(b) [4 marks]

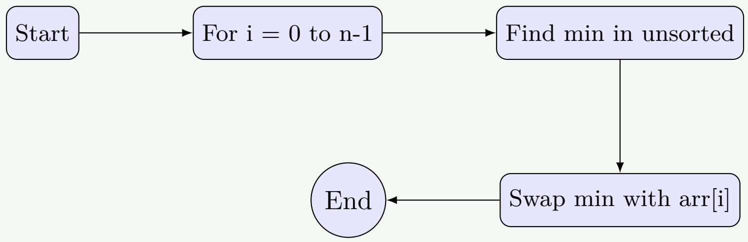
Write an algorithm for selection sort method.

Solution

Visualization:

5	3	8	1	2	Initial
1	3	8	5	2	Pass 1 (Swap 1 & 5)
1	2	8	5	3	Pass 2 (Swap 2 & 3)

Algorithm:




```python
def selection_sort(arr):
    n = len(arr)

    for i in range(n):
        min_idx = i

        # Find the minimum element in unsorted array
        for j in range(i+1, n):
            if arr[j] < arr[min_idx]:
                min_idx = j

        # Swap the found minimum element with the first element
        arr[i], arr[min_idx] = arr[min_idx], arr[i]
```

Mnemonic

"Find Minimum, Swap Position"

Question 4(c) [7 marks]

Develop a python code to sort following list in ascending order using Bubble sort method. list1=[5,4,3,2,1,0]

Solution

Initial:	5	4	3	2	1	0	
Pass 1:	4	3	2	1	0	5	(5 bubbles to end)
Pass 2:	3	2	1	0	4	5	(4 bubbles up)

... continues until sorted ...

Figure 14. Bubble Sort Trace

```python
def bubble_sort(arr):
    n = len(arr)

    # Traverse through all array elements
```

```python
    for i in range(n):
        # Last i elements are already in place
        for j in range(0, n-i-1):
            # Swap if current element is greater than next element
            if arr[j] > arr[j+1]:
                arr[j], arr[j+1] = arr[j+1], arr[j]

    return arr

# Input list
list1 = [5, 4, 3, 2, 1, 0]

# Sorting the list
sorted_list = bubble_sort(list1)

# Displaying the result
print("Sorted list:", sorted_list)
# Output: Sorted list: [0, 1, 2, 3, 4, 5]
```

Mnemonic

"Bubble Biggest Upward"

Question 4(a) OR [3 marks]

Define sorting. List different sorting methods.

Solution

Table 15. Sorting Definition

Definition	**Sorting Methods**
Sorting is the process of arranging data in a specified order (ascending or descending)	1. Bubble Sort 2. Selection Sort 3. Insertion Sort 4. Merge Sort 5. Quick Sort 6. Heap Sort 7. Radix Sort

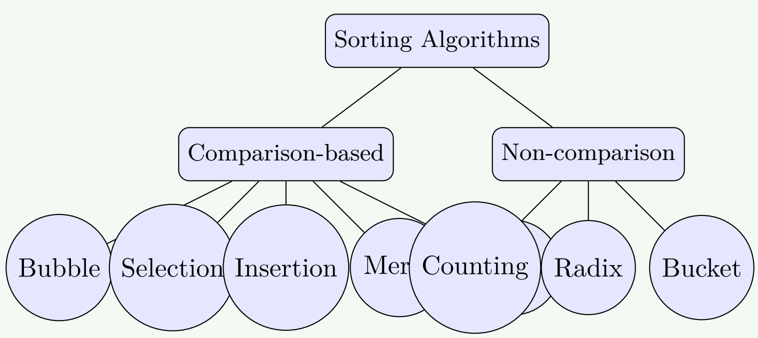


Figure 15. Hierarchy of Sorting Algorithms

Mnemonic

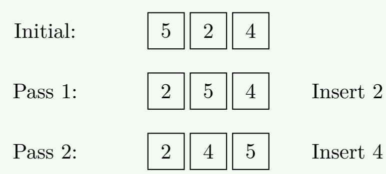
"Better Sort Improves Many Query Results"

Question 4(b) OR [4 marks]

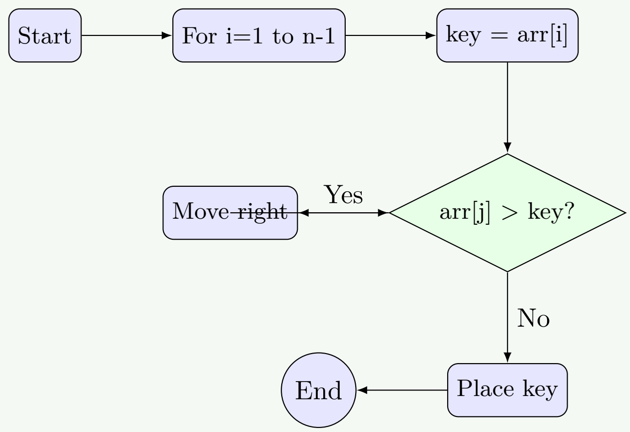
Write an algorithm for Insertion sort method.

Solution

Visualization:



Algorithm Flow:




```python
def insertion_sort(arr):
    for i in range(1, len(arr)):
        key = arr[i]
        j = i - 1

        # Move elements that are greater than key
        # to one position ahead of their current position
        while j >= 0 and arr[j] > key:
            arr[j + 1] = arr[j]
            j -= 1

        arr[j + 1] = key
```

Mnemonic

"Take Card, Insert In Order"

Question 4(c) OR [7 marks]

Develop a python code to sort following list in ascending order using selection sort method. list1=[6,3,25,8,-1,55,0]

Solution

Initial:	6	3	25	8	-1	55	0	
Pass 1:	-1	3	25	8	6	55	0	Swap -1 & 6
Pass 2:	-1	0	25	8	6	55	3	Swap 0 & 3

... continues ...

Figure 16. Selection Sort Trace

```python
def selection_sort(arr):
    n = len(arr)

    for i in range(n):
        # Find the minimum element in remaining unsorted array
        min_idx = i
        for j in range(i+1, n):
            if arr[j] < arr[min_idx]:
                min_idx = j

        # Swap the found minimum element with the first element
        arr[i], arr[min_idx] = arr[min_idx], arr[i]

    return arr

# Input list
list1 = [6, 3, 25, 8, -1, 55, 0]

# Sorting the list
sorted_list = selection_sort(list1)

# Displaying the result
print("Sorted list:", sorted_list)
# Output: Sorted list: [-1, 0, 3, 6, 8, 25, 55]
```

Mnemonic

"Select Smallest, Shift to Start"

Question 5(a) [3 marks]

Define following terms regarding Tree data structure:
1. Forest
2. Root node
3. Leaf node

Solution

Table 16. Tree Terminology

Term	Definition
Forest	Collection of disjoint trees (multiple trees without connections between them)
Root Node	Topmost node of a tree with no parent, from which all other nodes are descended
Leaf Node	Node with no children (terminal node at the bottom of the tree)

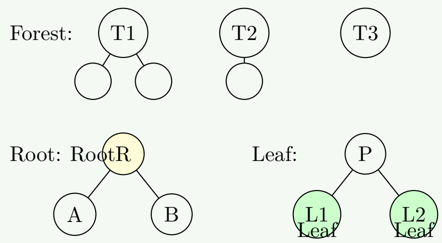


Figure 17. Tree Terms Visualization

Mnemonic

"Forest has Many Roots, Roots Lead All, Leaves End All"

Question 5(b) [4 marks]

Draw Binary search tree for 78, 58, 82, 15, 66, 80, 99 and write In-order traversal for the tree.

Solution

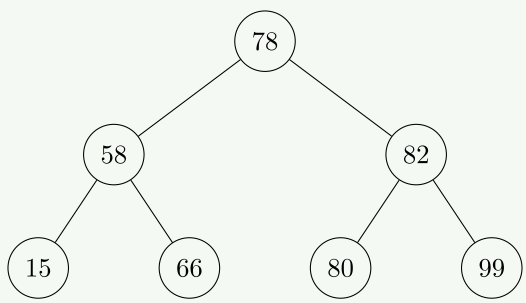


Figure 18. Binary Search Tree for Given Data

In-order Traversal:

Step	Visit Order
1	Visit left subtree of 78
2	Visit left subtree of 58
3	Visit 15
4	Visit 58
5	Visit 66
6	Visit 78
7	Visit left subtree of 82
8	Visit 80
9	Visit 82
10	Visit 99

In-order Traversal Result: 15, 58, 66, 78, 80, 82, 99

Mnemonic

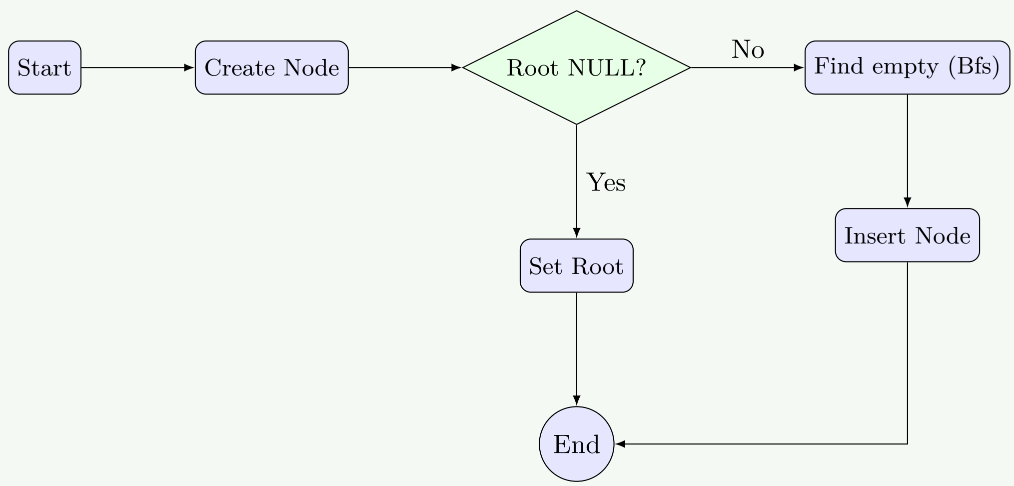
"Left, Root, Right"

Question 5(c) [7 marks]

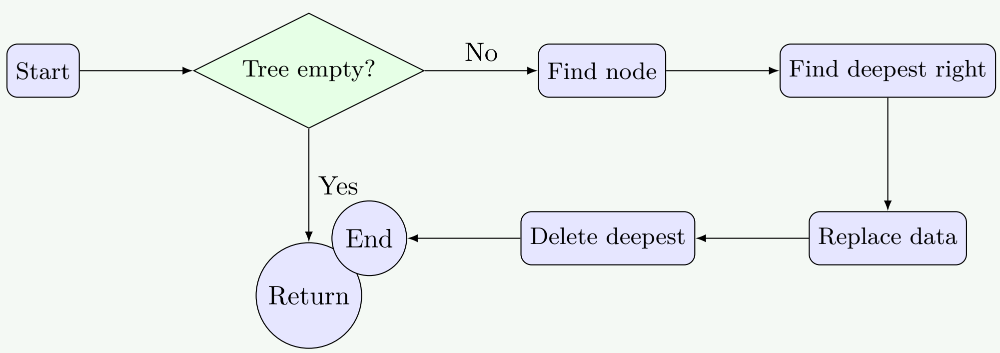
Write an algorithm for following operation:
1. Insertion of Node in Binary Tree
2. Deletion of Node in Binary Tree

Solution

Insertion Algorithm:



Deletion Algorithm:




```python
class Node:
    def __init__(self, data):
        self.data = data
        self.left = None
        self.right = None

# Insertion in Binary Tree
def insert(root, data):
    if root is None:
        return Node(data)

    # Level order traversal to find vacant position
    queue = []
    queue.append(root)

    while queue:
        temp = queue.pop(0)

        if temp.left is None:
            temp.left = Node(data)
```

```
                break
            else:
                queue.append(temp.left)

            if temp.right is None:
                temp.right = Node(data)
                break
            else:
                queue.append(temp.right)

    return root

# Deletion in Binary Tree
def delete_node(root, key):
    if root is None:
        return None

    if root.left is None and root.right is None:
        if root.data == key:
            return None
        else:
            return root

    # Find the node to delete and deepest node
    key_node = None
    last = None
    parent = None
    queue = []
    queue.append(root)

    while queue:
        temp = queue.pop(0)
        if temp.data == key:
            key_node = temp
        if temp.left:
            parent = temp
            queue.append(temp.left)
            last = temp.left
        if temp.right:
            parent = temp
            queue.append(temp.right)
            last = temp.right

    if key_node:
        key_node.data = last.data
        if parent.right == last:
            parent.right = None
        else:
            parent.left = None

    return root
```

Mnemonic

"Insert at Empty, Delete by Swap and Remove"

Question 5(a) OR [3 marks]

Define following terms regarding Tree data structure:

1. In-degree
2. Out-degree
3. Depth

Solution

Table 17. Definitions

Term	Definition
In-degree	Number of edges coming into a node (always 1 for each node except root node in a tree)
Out-degree	Number of edges going out from a node (number of children)
Depth	Length of the path from root to the node (number of edges in path)

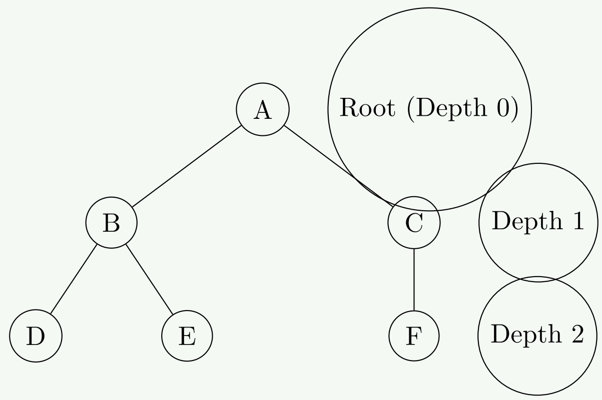


Figure 19. Tree Depth and Degrees

Table 18. Degree Analysis

Node	In-degree	Out-degree
A	0	2
B	1	2
C	1	1
D	1	0
E	1	0
F	1	0

Mnemonic

"In Counts Parents, Out Counts Children, Depth Counts Edges from Root"

Question 5(b) OR [4 marks]

Write Preorder and postorder traversal of following Binary tree.
100 -> (20 -> (10, 30), 200 -> (150, 300))

Solution

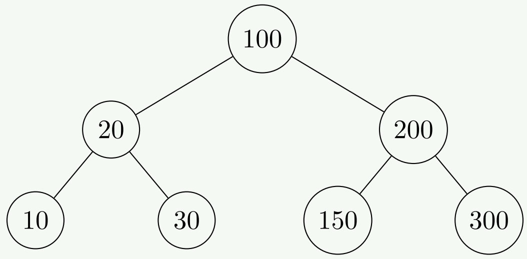


Figure 20. Given Binary Tree

Table 19. Traversals

Traversal	Order	Result
Preorder	Root, Left, Right	100, 20, 10, 30, 200, 150, 300
Postorder	Left, Right, Root	10, 30, 20, 150, 300, 200, 100

Mnemonic

"Preorder: Root First, Postorder: Children First"

Question 5(c) OR [7 marks]

Develop a program to implement construction of Binary Search Tree.

Solution

Construction Visualization:

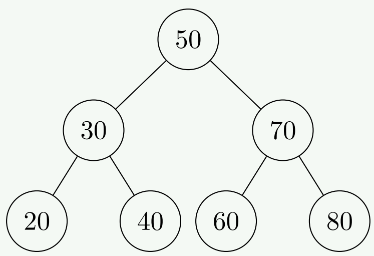


Figure 21. BST Constructed from [50, 30, 20, 40, 70, 60, 80]

```
class Node:
    def __init__(self, key):
        self.key = key
        self.left = None
        self.right = None

def insert(root, key):
    # If the tree is empty, return a new node
    if root is None:
        return Node(key)

    # Otherwise, recur down the tree
    if key < root.key:
        root.left = insert(root.left, key)
    else:
        root.right = insert(root.right, key)

```

```python
    # Return the unchanged node pointer
    return root

def inorder(root):
    if root:
        inorder(root.left)
        print(root.key, end=" ")
        inorder(root.right)

def preorder(root):
    if root:
        print(root.key, end=" ")
        preorder(root.left)
        preorder(root.right)

def postorder(root):
    if root:
        postorder(root.left)
        postorder(root.right)
        print(root.key, end=" ")

# Driver program to test the above functions
def main():
    # Create BST with these elements: 50, 30, 20, 40, 70, 60, 80
    root = None
    elements = [50, 30, 20, 40, 70, 60, 80]

    for element in elements:
        root = insert(root, element)

    # Print traversals
    print("Inorder traversal: ", end="")
    inorder(root)
    print("\nPreorder traversal: ", end="")
    preorder(root)
    print("\nPostorder traversal: ", end="")
    postorder(root)

# Run the program
main()
```

Example Output:

```
Inorder traversal: 20 30 40 50 60 70 80
Preorder traversal: 50 30 20 40 70 60 80
Postorder traversal: 20 40 30 60 80 70 50
```

Mnemonic

"Insert Smaller Left, Larger Right"