Linked Representation of Graphs

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Introduction of Graphs

Definition

- Graphs:

A Graph **G** is a non-linear data structure defined by an ordered pair **(V, E)** where:

- **V (Vertices):** A set of nodes representing data entities.
- **E (Edges):** A set of connections between pairs of vertices.

Graphs represent pairwise relationships between objects (e.g., cities connected by roads).

Memory Representations

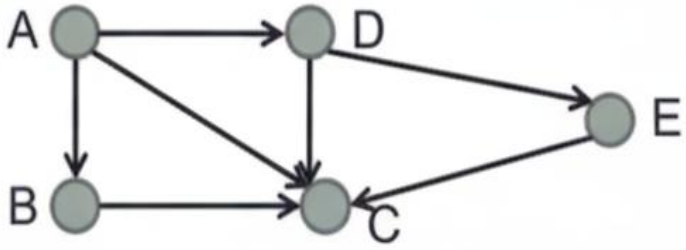
1. Sequential Representation

- Uses an **Adjacency Matrix** (2D Array). Good for dense graphs.

2. Linked Representation

- Uses **Adjacency Lists** (Linked Lists). Good for sparse graphs.

Linked Representation Overview

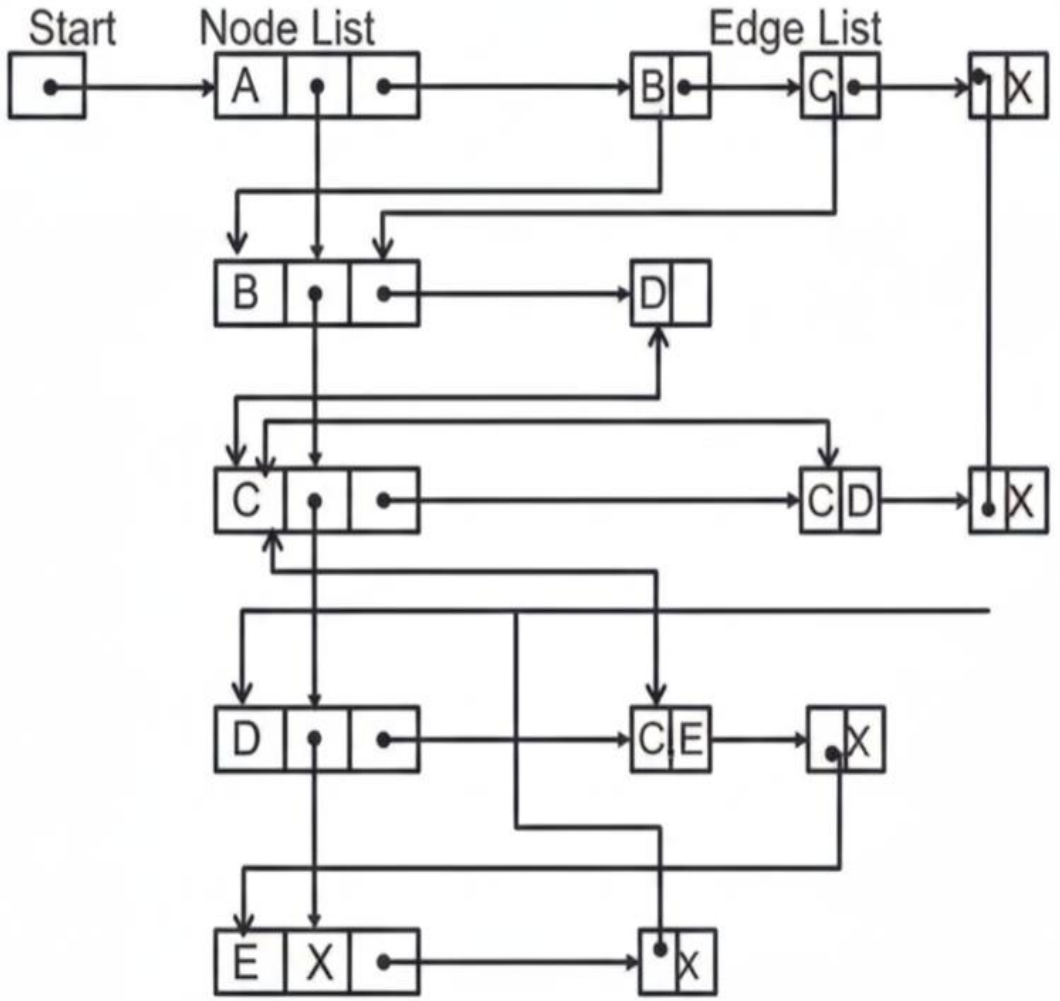


The Concept

- In linked representation, each node in G is followed by its **adjacency list**.
- This list contains all its "successors" or "neighbors".
- This representation uses two specific lists:

1. Node list (NODE)
2. Edge list (EDGE)

Node	Adjacency List
A	B, C, D
B	C
C	
D	X, E
E	C



Data Structure: The Node List, Edge List

- **Node List:** Each element in the **NODE** list corresponds to a vertex in the graph.

It is a record containing three fields:

1. **NODE:** Name or key value of the node.
2. **NEXT:** Pointer to the next node in the list.
3. **ADJ:** Pointer to the first element in the adjacency list (maintained in EDGE list).

Node record structure below:

NODE	NEXT	ADJ	…

* Note: Records may also store INDEG, OUTDEG, or STATUS.

- **Edge List:** Each element in the **EDGE** list corresponds to an edge of G.

It is a record containing two main fields:

1. **DEST:** Points to the location of the destination node in the NODE list.
2. **LINK:** Links together edges with the same initial node (the next neighbor).

Edge record structure below:

DEST	LINK	…

* Records may also store edge weights or labels.

Graph Traversal & Node States

There are two ways:

1. **Breadth First Search (BFS):** Uses a queue as an auxiliary structure to hold nodes for future processing.
2. **Depth First Search (DFS):** Uses a stack as an auxiliary structure.

❖ During algorithms (BFS/DFS), each node N will be in one of three states:

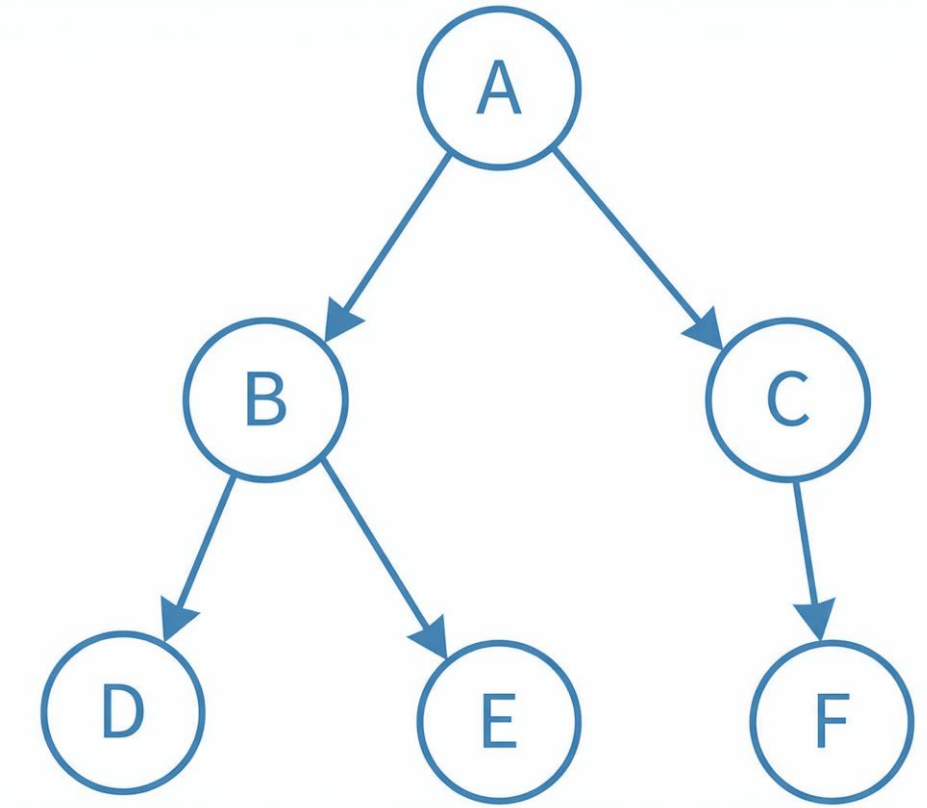
1	2	3
Ready State	**Waiting State**	**Processed State**
The initial state of Node N. (STATUS=1)	Node N is in the Queue or Stack, waiting to be processed. (STATUS=2)	Node N has been fully processed. (STATUS=3)

Breadth-First Search (BFS)

❖ Algorithm Logic:

1. Initialize all nodes to **Ready (1)**
2. Put start node A in **Queue** and set to **Waiting (2)**.
3. Repeat until Queue is empty:

   (i) Remove front node N. Process it. Set to **Processed (3)**.
   (ii) Add all neighbors of N that are **Ready (1)** to Queue and set them to **Waiting (2)**.



Breadth-First Search

BFS Simulation Steps:

Initialization

• **Queue :** Empty initially.
• **Visited Nodes :** Start with only the source node marked as visited.

Step 1 : Enqueue the starting node

• Enqueue node **A**.
• **Queue :** [A]
• **Visited :** {A}

Step 2: Dequeue and process node A

• Dequeue **A** and process it.
• Enqueue its unvisited neighbors : **B** and **C**.
• **Queue :** [B, C]
• **Visited :** {A, B, C}

Step 3 : Dequeue and process node B

• Dequeue **B** and process it.
• Enqueue its unvisited neighbors: **D** and **E**.
• **Queue :** [C, D, E]
• **Visited :** {A, B, C, D, E}

Step 4 : Dequeue and process node C

• Dequeue **C** and process it.
• Enqueue its unvisited neighbor : **F**.
• **Queue :** [D, E, F]
• **Visited :** {A, B, C, D, E, F}

Step 5 : Process the remaining nodes

• Continue dequeuing and processing nodes (**D, E, F**) until the queue is empty.

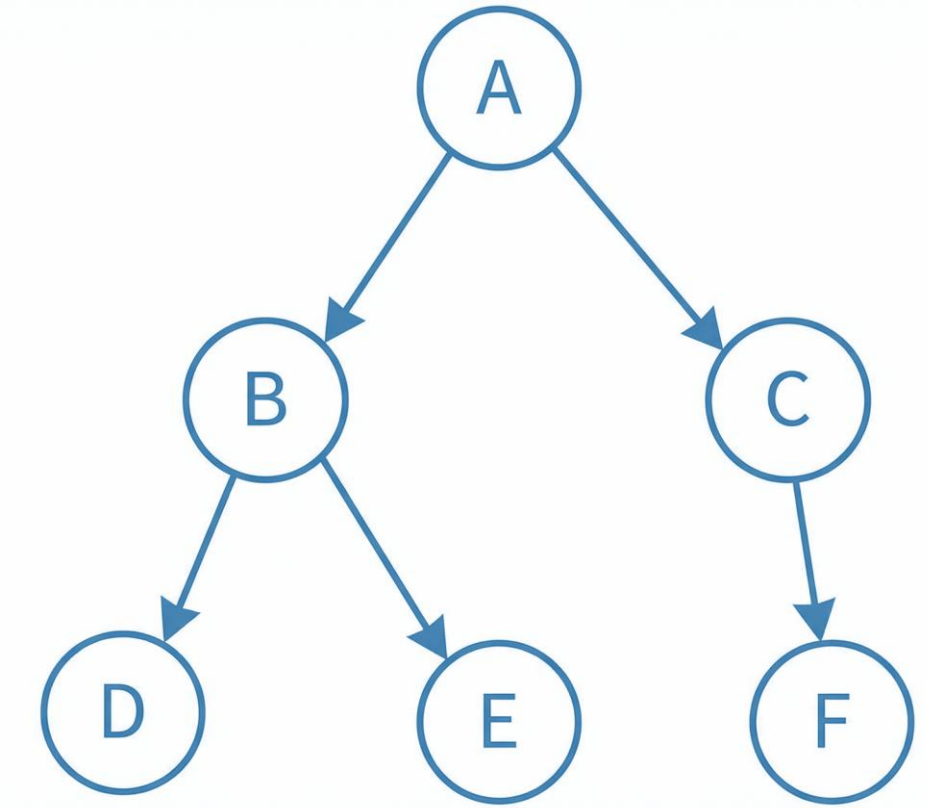
Final Traversal Order : A → B → C → D → E → F

Depth-First Search (DFS)

❖Algorithm Logic:

Similar to BFS, but uses a **Stack** instead of a Queue.

1. Initialize all nodes to **Ready (1)**
2. Push start node A to Stack, set to **Waiting (2)**.
3. Repeat until Stack is empty:
    a) Pop top node N. Process it. Set to **Processed (3)**.
    b) Push neighbors of N that are **Ready (1)** to Stack, set to **Waiting (2)**.



Depth-First Search

Here's the simulated Depth-First Search (DFS) on the provided graph:

DFS Simulation Steps:

- **Initialization**: Stack: [], Visited: {}.

1. Start at A: Push A.
❖ Stack: [A], Visited: {A}.

2. Process A, Move to B: Pop A. Push A's unvisited neighbors (e.g., C, then B). Pop B. Push B's unvisited neighbors (e.g., E, then D).
❖ Stack: [C, D, E], Visited: {A, B, C, D, E}.

3. Process D: Pop D. D has no unvisited neighbors.
❖ Stack: [C, E].

4. Process E: Pop E. E has no unvisited neighbors
❖ Stack: [C].

5. Process C, Move to F: Pop C. Push C's unvisited neighbor (F).
❖ Stack: [F], Visited: {A, B, C, D, E, F}.

6. Process F: Pop F. F has no unvisited neighbors.
❖ Stack: [] (Empty).

Final DFS Traversal Order: A → B → D → E → C → F

Differences Between BFS and DFS

Feature	BFS (Breadth First Search)	DFS (Depth First Search)
Traversal Method	Level-by-level (horizontal movement	Depth-wise (vertical movement)
Data Structure	Queue	Stack / Recursion
Starting Node	Start from a source and explores neighbors first	Starts form a source and goes deep before backtracking
Uses	Shortest Path Finding, Cycle Detection, Connected Components, Network Routing	Detect cycles, path checking, topological sorting
Memory Usage	High (stores many nodes in queue)	Low (stores only path nodes)
Time Complexity	O(V + E)	O(V + E)
Space Complexity	O(V)	O(V)
Tree Produced	BFS Tree	DFS Tree
Nature or Search	Complete Search	Backtracking-based search

Thank You

For your patience