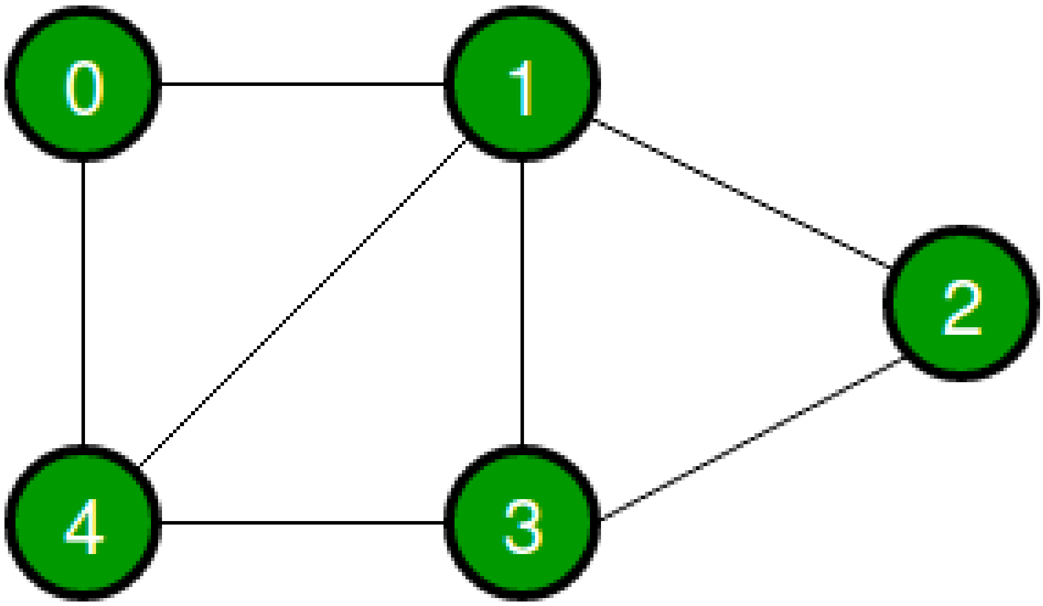
Graph and its representations

Difficulty Level : Easy • Last Updated : 07 May, 2022

A graph is a data structure that consists of the following two components:
1. A finite set of vertices also called as nodes.
2. A finite set of ordered pair of the form (u, v) called as edge. The pair is ordered because (u, v) is not the same as (v, u) in case of a directed graph(di-graph). The pair of the form (u, v) indicates that there is an edge from vertex u to vertex v. The edges may contain weight/value/cost.
Graphs are used to represent many real-life applications: Graphs are used to represent networks. The networks may include paths in a city or telephone network or circuit network. Graphs are also used in social networks like linkedIn, Facebook.

Following is an example of an undirected graph with 5 vertices.



2. Adjacency List

There are other representations also like, Incidence Matrix and Incidence List. The choice of graph representation is situation-specific. It totally depends on the type of operations to be performed and ease of use.

Adjacency Matrix:

Adjacency Matrix is a 2D array of size V x V where V is the number of vertices in a graph. Let the 2D array be adj[][], a slot adj[i][j] = 1 indicates that there is an edge from vertex i to vertex j. Adjacency matrix for undirected graph is always symmetric. Adjacency Matrix is also used to represent weighted graphs. If adj[i][j] = w, then there is an edge from vertex i to vertex j with weight w.

The adjacency matrix for the above example graph is:

	0	1	2	3	4
0	0	1	0	0	1
1	1	0	1	1	1
2	0	1	0	1	0
3	0	1	1	0	1
4	1	1	0	1	0

Pros: Representation is easier to implement and follow. Removing an edge takes O(1) time. Queries like whether there is an edge from vertex 'u' to vertex 'v' are efficient and can be done O(1).

Cons: Consumes more space O(V^2). Even if the graph is sparse(contains less number of edges), it consumes the same space. Adding a vertex is O(V^2) time. Computing all neighbors of a vertex takes O(V) time (Not efficient).

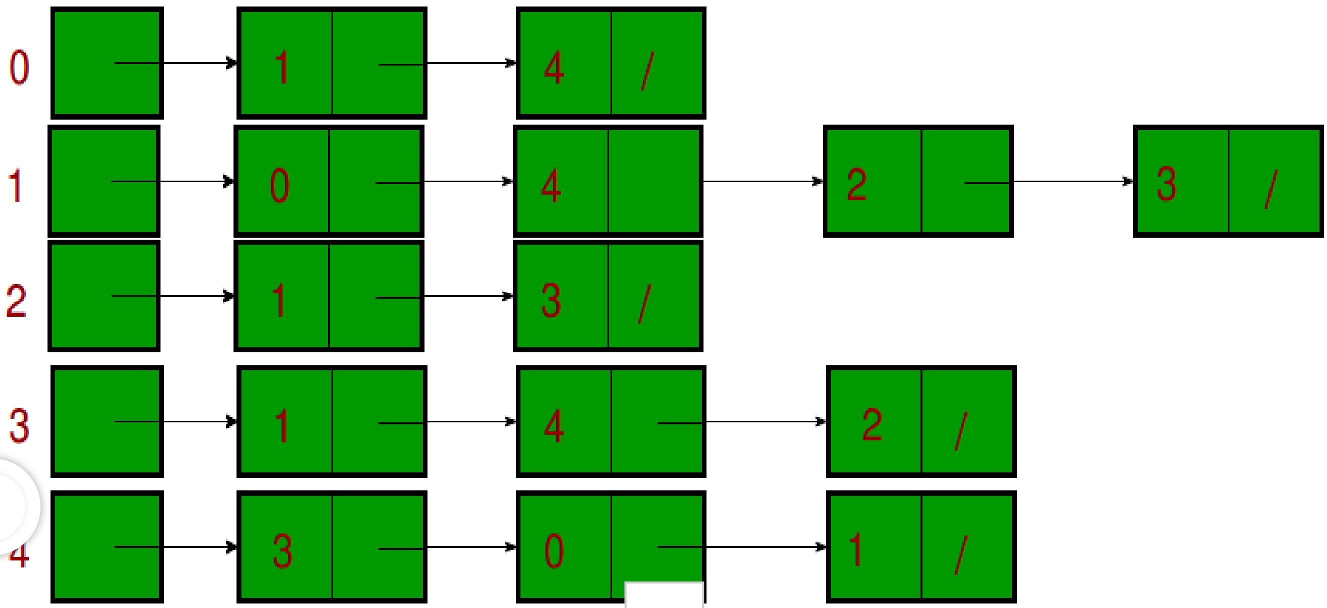
Please see this for a sample Python implementation of adjacency matrix.

plementation of taking input for adjacency matrix

```
#include <iostream>
using namespace std;

int main()
{
    // n is the number of vertices
    // m is the number of edges
    int n, m;
    cin >> n >> m ;
    int adjMat[n + 1][n + 1];
    for(int i = 0; i < m; i++){
        int u , v ;
        cin >> u >> v ;
        adjMat[u][v] = 1 ;
          adjMat[v][u] = 1 ;
    }


    return 0;
}
```

Adjacency List:

An array of lists is used. The size of the array is equal to the number of vertices. Let the array be an array[]. An entry array[i] represents the list of vertices adjacent to the *i*th vertex. This representation can also be used to represent a weighted graph. The weights of edges can be represented as lists of pairs. Following is the adjacency list representation of the above graph.



Note that in the below implementation, we use dynamic arrays (vector in C++/ArrayList in Java) to represent adjacency lists instead of the linked list. The vector implementation has advantages of cache friendliness.

C++

```
// A simple representation of graph using STL
#include <bits/stdc++.h>
using namespace std;

// A utility function to add an edge in an
// undirected graph.
void addEdge(vector<int> adj[], int u, int v)
{
    adj[u].push_back(v);
    adj[v].push_back(u);
}

// A utility function to print the adjacency list
// representation of graph
void printGraph(vector<int> adj[], int V)
{
    for (int v = 0; v < V; ++v) {
        cout << "\n Adjacency list of vertex " << v
             << "\n head ";
        for (auto x : adj[v])
            cout << "-> " << x;
        printf("\n");
    }
}

// Driver code
int main()
{
    int V = 5;
    vector<int> adj[V];
    addEdge(adj, 0, 1);
    addEdge(adj, 0, 4);
    addEdge(adj, 1, 2);
    addEdge(adj, 1, 3);
    addEdge(adj, 1, 4);
```

```
    return 0;
}
```

C

```
// A C Program to demonstrate adjacency list
// representation of graphs
#include <stdio.h>
#include <stdlib.h>

// A structure to represent an adjacency list node
struct AdjListNode {
    int dest;
    struct AdjListNode* next;
};

// A structure to represent an adjacency list
struct AdjList {
    struct AdjListNode* head;
};

// A structure to represent a graph. A graph
// is an array of adjacency lists.
// Size of array will be V (number of vertices
// in graph)
struct Graph {
    int V;
    struct AdjList* array;
};

// A utility function to create a new adjacency list node
struct AdjListNode* newAdjListNode(int dest)
{
    struct AdjListNode* newNode
        = (struct AdjListNode*)malloc(
            sizeof(struct AdjListNode));
    newNode->dest = dest;
    newNode->next = NULL;
    return newNode;
}

// A utility function that creates a graph of V vertices
struct Graph* createGraph(int V)
{
    struct Graph* graph
        = (struct Graph*)malloc(sizeof(struct Graph));
    graph->V = V;
```

```
        V * sizeof(struct AdjList));

    // Initialize each adjacency list as empty by
    // making head as NULL
    int i;
    for (i = 0; i < V; ++i)
        graph->array[i].head = NULL;

    return graph;
}

// Adds an edge to an undirected graph
void addEdge(struct Graph* graph, int src, int dest)
{
    // Add an edge from src to dest.  A new node is
    // added to the adjacency list of src.  The node
    // is added at the beginning
    struct AdjListNode* check = NULL;
    struct AdjListNode* newNode = newAdjListNode(dest);

    if (graph->array[src].head == NULL) {
        newNode->next = graph->array[src].head;
        graph->array[src].head = newNode;
    }
    else {

        check = graph->array[src].head;
        while (check->next != NULL) {
            check = check->next;
        }
        // graph->array[src].head = newNode;
        check->next = newNode;
    }

    // Since graph is undirected, add an edge from
    // dest to src also
    newNode = newAdjListNode(src);
    if (graph->array[dest].head == NULL) {
        newNode->next = graph->array[dest].head;
        graph->array[dest].head = newNode;
    }
    else {
        check = graph->array[dest].head;
        while (check->next != NULL) {
            check = check->next;
        }
        check->next = newNode;
    }

    // newNode = newAdjListNode(src
```

```
// A utility function to print the adjacency list
// representation of graph
void printGraph(struct Graph* graph)
{
    int v;
    for (v = 0; v < graph->V; ++v) {
        struct AdjListNode* pCrawl = graph->array[v].head;
        printf("\n Adjacency list of vertex %d\n head ", v);
        while (pCrawl) {
            printf("-> %d", pCrawl->dest);
            pCrawl = pCrawl->next;
        }
        printf("\n");
    }
}

// Driver program to test above functions
int main()
{
    // create the graph given in above fugure
    int V = 5;
    struct Graph* graph = createGraph(V);
    addEdge(graph, 0, 1);
    addEdge(graph, 0, 4);
    addEdge(graph, 1, 2);
    addEdge(graph, 1, 3);
    addEdge(graph, 1, 4);
    addEdge(graph, 2, 3);
    addEdge(graph, 3, 4);

    // print the adjacency list representation of the above
    // graph
    printGraph(graph);

    return 0;
}
```

Java

```
// Java code to demonstrate Graph representation
// using ArrayList in Java

import java.util.*;

class Graph {

    // A utility function to add an e in an
```

```
    {
        adj.get(u).add(v);
        adj.get(v).add(u);
    }

    // A utility function to print the adjacency list
    // representation of graph
    static void
    printGraph(ArrayList<ArrayList<Integer> > adj)
    {
        for (int i = 0; i < adj.size(); i++) {
            System.out.println("\nAdjacency list of vertex"
                               + i);
            System.out.print("head");
            for (int j = 0; j < adj.get(i).size(); j++) {
                System.out.print(" -> "
                                 + adj.get(i).get(j));
            }
            System.out.println();
        }
    }

    // Driver Code
    public static void main(String[] args)
    {
        // Creating a graph with 5 vertices
        int V = 5;
        ArrayList<ArrayList<Integer> > adj
            = new ArrayList<ArrayList<Integer> >(V);

        for (int i = 0; i < V; i++)
            adj.add(new ArrayList<Integer>());

        // Adding edges one by one
        addEdge(adj, 0, 1);
        addEdge(adj, 0, 4);
        addEdge(adj, 1, 2);
        addEdge(adj, 1, 3);
        addEdge(adj, 1, 4);
        addEdge(adj, 2, 3);
        addEdge(adj, 3, 4);

        printGraph(adj);
    }
}
```

Python3

```
"""

# A class to represent the adjacency list of the node


class AdjNode:
    def __init__(self, data):
        self.vertex = data
        self.next = None


# A class to represent a graph. A graph
# is the list of the adjacency lists.
# Size of the array will be the no. of the
# vertices "V"
class Graph:
    def __init__(self, vertices):
        self.V = vertices
        self.graph = [None] * self.V

    # Function to add an edge in an undirected graph
    def add_edge(self, src, dest):
        # Adding the node to the source node
        node = AdjNode(dest)
        node.next = self.graph[src]
        self.graph[src] = node

        # Adding the source node to the destination as
        # it is the undirected graph
        node = AdjNode(src)
        node.next = self.graph[dest]
        self.graph[dest] = node

    # Function to print the graph
    def print_graph(self):
        for i in range(self.V):
            print("Adjacency list of vertex {}\n head".format(i), end="")
            temp = self.graph[i]
            while temp:
                print(" -> {}".format(temp.vertex), end="")
                temp = temp.next
            print(" \n")


# Driver program to the above graph class
if __name__ == "__main__":
    V = 5
    graph = Graph(V)
    graph.add_edge(0, 1)
    graph.add_edge(0, 4)
```

```
    graph.add_edge(2, 3)
    graph.add_edge(3, 4)

    graph.print_graph()

# This code is contributed by Kanav Malhotra
```

C#

```
// C# code to demonstrate Graph representation
// using LinkedList in C#
using System;
using System.Collections.Generic;

class Graph {
    // A utility function to add an edge in an
    // undirected graph
    static void addEdge(LinkedList<int>[] adj, int u, int v)
    {
        adj[u].AddLast(v);
        adj[v].AddLast(u);
    }

    // A utility function to print the adjacency list
    // representation of graph
    static void printGraph(LinkedList<int>[] adj)
    {
        for (int i = 0; i < adj.Length; i++) {
            Console.WriteLine("\nAdjacency list of vertex "
                              + i);
            Console.Write("head");

            foreach(var item in adj[i])
            {
                Console.Write(" -> " + item);
            }
            Console.WriteLine();
        }
    }

    // Driver Code
    public static void Main(String[] args)
    {
        // Creating a graph with 5 vertices
        int V = 5;
        LinkedList<int>[] adj = new LinkedList<int>[ V ];

        for (int i = 0; i < V; i++)
```

```
        addEdge(adj, 0, 1);
        addEdge(adj, 0, 4);
        addEdge(adj, 1, 2);
        addEdge(adj, 1, 3);
        addEdge(adj, 1, 4);
        addEdge(adj, 2, 3);
        addEdge(adj, 3, 4);

        printGraph(adj);

        Console.ReadKey();
    }
}

// This code is contributed by techno2mahi
```

Javascript

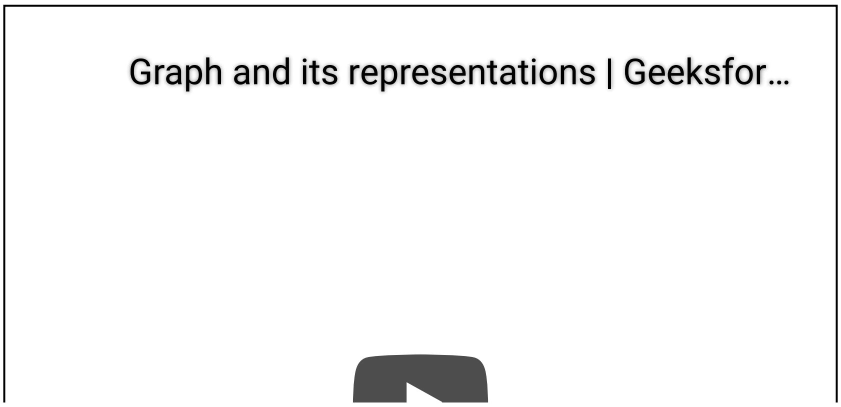
```
<script>
// Javascript code to demonstrate Graph representation
// using ArrayList in Java

// A utility function to add an edge in an
    // undirected graph
function addEdge(adj,u,v)
{
    adj[u].push(v);
        adj[v].push(u);
}

// A utility function to print the adjacency list
    // representation of graph
function printGraph(adj)
{
    for (let i = 0; i < adj.length; i++) {
            document.write("<br>Adjacency list of vertex" + i+"<br>");
            document.write("head");
            for (let j = 0; j < adj[i].length; j++) {
                document.write(" -> "+adj[i][j]);
            }
            document.write("<br>");
        }
}

// Driver Code
// Creating a graph with 5 vertices
        let V = 5;
        let adj= [];
```

```
        // Adding edges one by one
        addEdge(adj, 0, 1);
        addEdge(adj, 0, 4);
        addEdge(adj, 1, 2);
        addEdge(adj, 1, 3);
        addEdge(adj, 1, 4);
        addEdge(adj, 2, 3);
        addEdge(adj, 3, 4);

        printGraph(adj);


// This code is contributed by avanitrachhadiya2155
</script>
```

Output

```
Adjacency list of vertex 0
head -> 1-> 4

Adjacency list of vertex 1
head -> 0-> 2-> 3-> 4

Adjacency list of vertex 2
head -> 1-> 3

Adjacency list of vertex 3
head -> 1-> 2-> 4

Adjacency list of vertex 4
head -> 0-> 1-> 3
```

Pros: Saves space O(|V|+|E|) . In the worst case, there can be C(V, 2) number of edges in a graph thus consuming O(V^2) space. Adding a vertex is easier. Computing all neighbors of a vertex takes optimal time.
Cons: Queries like whether there is an edge from vertex u to vertex v are not efficient d can be done O(V).
In Real-life problems, graphs are sparse($|E| << |V|^2$). That's why adjacency lists



Reference:
http://en.wikipedia.org/wiki/Graph_%28abstract_data_type%29

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