14.3 Applications of Graphs

1. In Computer science graphs are used to represent the flow of computation.
2. Google maps uses graphs for building transportation systems, where intersection of two (or more) roads are considered to be a vertex and the road connecting two vertices is considered to be an edge, thus their navigation system is based on the algorithm to calculate the shortest path between two vertices.
    - Google Maps and Routes APIs are classic Shortest Path APIs. This a graph problem that's very easy to solve with edge-weighted directed graphs (digraphs).
    - The idea of a Map API is to find the shortest path from one vertex to every other as in a single source shortest path variant, from your current location to every other destination you might be interested in going to on the map.
    - The idea of by contrast Routing API to find the shortest path from one vertex to another as in a source sink shortest path variant, from s to t.
    - Shortest Path APIs are typically directed graphs. The underlying data structures and graphs too.
3. In Facebook, users are considered to be the vertices and if they are friends then there is an edge running between them. Facebook's Friend suggestion algorithm uses graph theory. Facebook is an example of undirected graph.
    - Facebook's Graph API is perhaps the best example of application of graphs to real life problems. The Graph API is a revolution in large-scale data provision.
    - On The Graph API, everything is a vertice or node. This are entities such as Users, Pages, Places, Groups, Comments, Photos, Photo Albums, Stories, Videos, Notes, Events and so forth. Anything that has properties that store data is a vertice.

- And every connection or relationship is an edge. This will be something like a User posting a Photo, Video or Comment etc., a User updating their profile with their Place of birth, a relationship status Users, a User liking a Friend's Photo etc.
- The Graph API uses this collection of vertices and edges (essentially graph data structures) to store its data. The Graph API is also a GraphQL API. This is the language it uses to build and query the schema.
- The Graph API has come into some problems because of it's ability to obtain unusually rich info about user's friends.

4. In World Wide Web, web pages are considered to be the vertices. There is an edge from a page u to other page v if there is a link of page v on page u. This is an example of Directed graph. It was the basic idea behind Google Page Ranking Algorithm.
5. In Operating System, we come across the Resource Allocation Graph where each process and resources are considered to be vertices. Edges are drawn from resources to the allocated process, or from requesting process to the requested resource. If this leads to any formation of a cycle, then a deadlock will occur.

6. Google Knowledge Graph: knowledge graph has something to do with linking data and graphs...graph-based representation of knowledge. It still isn't what is can and can't do yet.
7. Path Optimization Algorithms: Path optimizations are primarily occupied with finding the best connection that fits some predefined criteria e.g. speed, safety, fuel etc or set of criteria e.g. prodecures, routes.
    - In unweighted graphs, the Shortest Path of a graph is the path with the least number of edges. Breadth First Search (BFS) is used to find the shortest paths in graphs—we always reach a node from another node in the fewest number of edges in breadth graph traversals.
    - Any Spanning Tree is a Minimum Spanning Tree unweighted graphs using either BFS or Depth First Search.
8. Flight Networks: For flight networks, efficient route optimizations perfectly fit graph data strutures. Using graph models, airport procedures can be modeled and optimized efficiently. Computing best connections in flight networks is a key application of algorithm engineering. In flight network, graph data strutures are used to compute shortest paths and fuel usage in route planning, often in a multi-modal context. The vertices in flight networks are places of departure and destination, airports, aircrafts, cargo weights. The flight trajectories between airports are the edges. Turns out it's very feasible to fit graph data strutures in route optimizations because of precompiled full distance tables between all airports. Entities such as flights can have properties such as fuel usage, crew pairing which can themselves be more graphs.
9. GPS Navigation Systems: Car navigations also use Shortest Path APIs. Although this is still a type of a routing API it would differ from the Google Maps Routing API because it is single source (from one vertex to every other i.e. it computes locations from where you are to any other location you might be interested in going.) BFS is used to find all neighbouring locations.

14.4 Summary

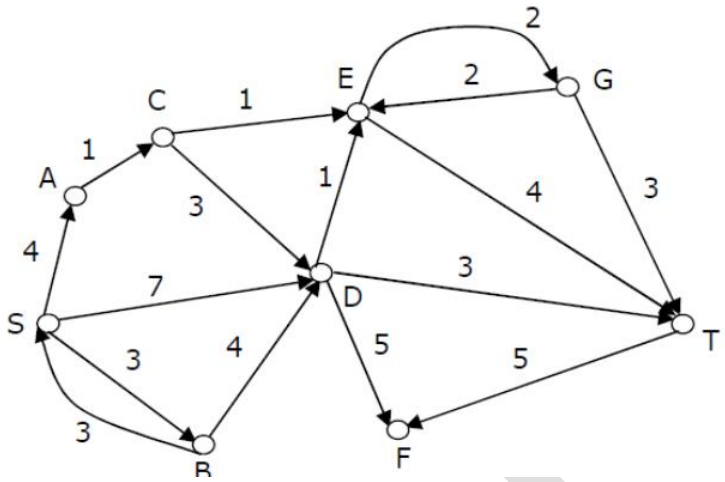
In previous chapter, we have studied Minimum Spanning Tree (MST) and its use in various algorithms like Kruskal's Algorithm, Prim's Algorithm. Based on this we have studied all-pair shortest path algorithms like Floyd Warshall's Algorithm, Dijkstra's Algorithm. We have studied the applications of various graph algorithms and data structures in day-to-day life.

14.5 Review Your Learning

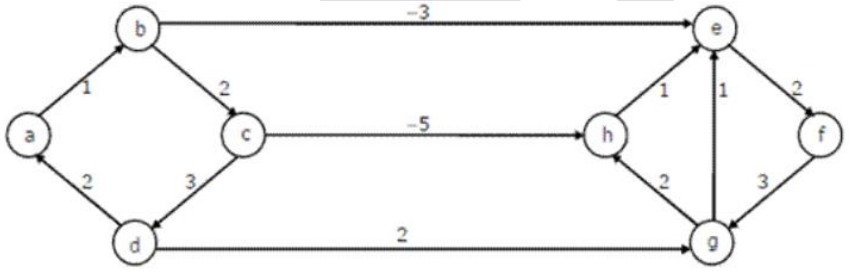
1. Are you able to find shortest path using Dijkstra's algorithm?
2. Are you able to find distance matrix and use it in Floyd Warshall's algorithm?
3. Explain the difference between Dynamic and Greedy programming approach. Give examples of shortest path algorithms in both categories.
4. Explain applications of all-pair shortest path algorithms.
5. Analyse how graph data structure is used in Google maps navigations.
6. Write a case study on Facebook friends list creation and recommendation techniques used in Facebook for finding close related friends/relatives.

14.6 Questions

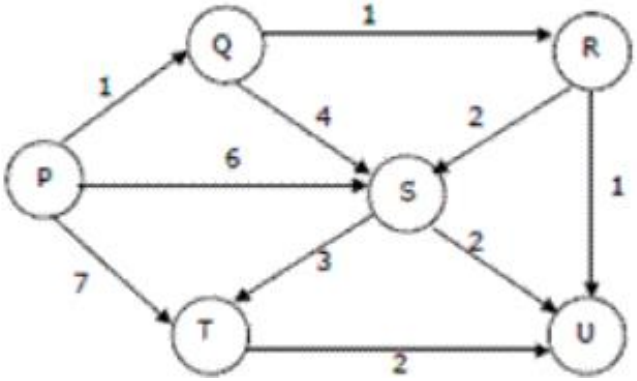
6. Consider the directed graph shown in the figure below. There are multiple shortest paths between vertices S and T. Which one will be reported by Dijstra?s shortest path algorithm? Assume that, in any iteration, the shortest path to a vertex v is updated only when a strictly shorter path to v is discovered.



7. Dijkstra's single source shortest path algorithm when run from vertex a in the below graph, computes the correct shortest path distance to??



8. Suppose we run Dijkstra's single source shortest-path algorithm on the following edge weighted directed graph with vertex P as the source. In what order do the nodes get included into the set of vertices for which the shortest path distances are finalized?



9. Dijkstra's Algorithm is used to solve _____ problems.

   a) All pair shortest path

   b) Single source shortest path

c) Network flow

d) Sorting

10. Dijkstra’s Algorithm cannot be applied on _____

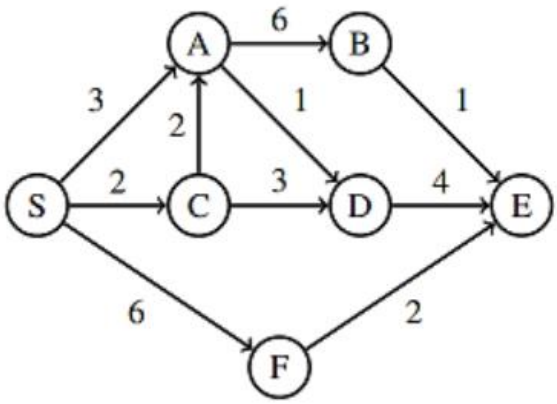
a) Directed and weighted graphs

b) Graphs having negative weight function

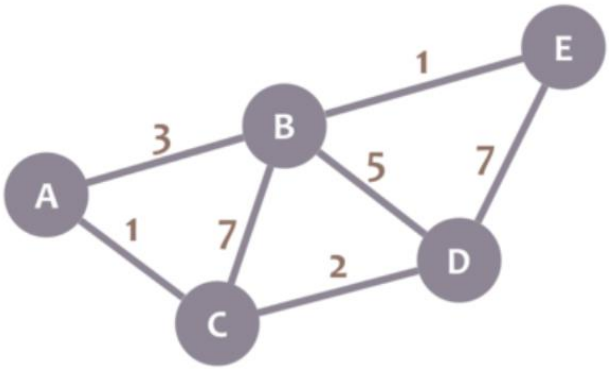
c) Unweighted graphs

d) Undirected and unweighted graphs

11. Run Dijkstra's on the following graph and determine the resulting shortest path tree.



12. Find Shortest Path using Dijkstra’s Algorithm for following graph.



13. Enlist and explain all-pair shortest path algorithms.
14. Explain Warshall’s Algorithm with example.
15. Explain application of Floyd Warshall’s and Dijkstra’s Algorithm in day-to-day life.

14.7 Further Reading

6. https://runestone.academy/runestone/books/published/pythonds/Graphs/DijkstrasAlgorithm.html
7. https://www.oreilly.com/library/view/data-structures-and/9781118771334/18_chap14.html
8. https://medium.com/javarevisited/10-best-books-for-data-structure-and-algorithms-for-beginners-in-java-c-c-and-python-5e3d9b478eb1
9. https://examradar.com/data-structure-graph-mcq-based-online-test-3/
10. https://www.tutorialspoint.com/data_structures_algorithms/data_structures_algorithms_online_quiz.htm
11. https://www.mdpi.com/2227-7390/8/9/1595/htm

14.8 References

1.http://www.nitjsr.ac.in/course_assignment/CS01CS1302A%20Book%20Fundamentals%20of%20Data%20Structure%20(1982)%20by%20Ellis%20Horowitz%20and%20Sartaj%20Sahni.pdf

2.https://www.geeksforgeeks.org/graph-data-structure-and-algorithms/

3.https://www.geeksforgeeks.org/prims-mst-for-adjacency-list-representation-greedy-algo-6/

4.https://www.geeksforgeeks.org/kruskals-minimum-spanning-tree-algorithm-greedy-algo-2/

5.http://wccclab.cs.nchu.edu.tw/www/images/Data_Structure_105/chapter6.pdf