CS2233: Data Structures

Assignment 5
30th September, 2018

Problem Statement

- Input: An undirected, unweighted graph $G = (V, E)$.
- Goal: Serve the following requests:
  - Is $\{u, v\} \in E$?
  - Breadth-first Search (BFS) of G from a source vertex v.
  - Shortest path from a vertex u to v.

Input Format

General format:
A graph $G = (V, E)$ is defined by first providing the number of vertices $n = |V|$.
Henceforth you shall assume that the vertex set is $V = \{1, 2, \ldots, n\}$.
The edge set E is provided as a list of adjacency lists – each line indicating the adjacency list of a different vertex.
Requests arrive only after the definition of G.
Format in detail:
Each line of the input looks like one of the following:

- 'N' followed by number of vertices $n \in \mathbb{N}$.
- 'E' followed by vertices $u, v_1, v_2, \cdots, v_k \in [n]$ that indicates the adjacency list of vertex u. The list is given as a space-separated list.
- '?' followed by $u, v \in [n]$ with a space separating them.
- 'B' followed by a $u \in [n]$
- 'P' followed by $u, v \in [n]$ with a space separating them.

Each of the lines above ends with a '\n' character. All lists are given as elements separated by a space. No commas are used anywhere. All numbers used will fit inside an `int`. End of input is indicated by `EOF`.

Output Format

- If input line started with 'N' or 'E', then no corresponding output.
- If input line was "? u v": Output 1 if $\{u, v\} \in E$.
- If input line was "B u":
  Output a Breadth-first search of the graph starting from vertex u as a space-separated list of vertices. The BFS you compute has to *comply with the implementation rules* found in the next section.
- If input line was "P u v":
  If v is not reachable from u, output -1. Else output a shortest path from u to v as a space-separated list of vertices starting with u.

All output lines have to end with a '\n' character.

Implementation rules

- The input graph $G = (V, E)$ has to be stored as adjacency lists: use an array A of length $|V|$ such that $A[i]$ (with base index 1) is the head of the adjacency list of vertex number i. Minor variations due to base index or convenience is allowed.
- Store each vertex's adjacency list in the same order as provided in the input.
- Computing BFS requires a queue. Implement a queue yourself by using an array or linked list.
- During computation of BFS, if the vertex visited is u, then enqueue the neighbours of u in the same order as they appear in the adjacency list.

Design decisions

- Before deciding the way your nodes look in the adjacency lists, it might be wise to read the other assignment sheets. You might be able to create the nodes in a way that allows you to reuse the input handling routine for other assignments.
- There are only three possible colors for each vertex – White, Grey, Black. So just two bits should suffice to keep track of a vertex color.
- If you are issued consecutive requests of shortest path from the same source node, it is unnecessary to recompute the Breadth-first search from the same source for each request. You should avoid such recomputation.

Other Remarks

- A good starting point is to program a Queue. Test the queue thoroughly to make sure it does not become the source of bugs later on.
- **Deadline:** 14th October, 2018 .

Example input

Input:

```
---------------------------
N 4
E 1 3 4 2
E 2 1 3
E 4 3 1
E 3 2 1 4
? 2 4
B 2
B 1
P 2 4
N 14
E 1 13 5 4
E 2 3 13
E 3 2
E 4 1
E 7 9 13
E 5 10 8 14 1
E 9 6 7
E 6 9
E 8 10 5 14
E 10 8 5 14
E 11 12
E 12 11
E 13 1 2 7
E 14 8 5 10
? 12 11
? 2 1
B 7
P 7 1
P 7 10
P 7 12
P 8 14
P 8 1
B 8
B 11

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

Output:

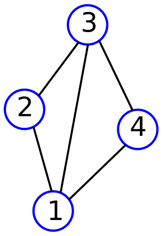
```
---------------------------
0
2 1 3 4
1 3 4 2
2 1 4
1
0
7 9 13 6 1 2 5 4 3 10 8 14
7 13 1
7 13 1 5 10
-1
8 14
8 5 1
8 10 5 14 1 13 4 2 7 3 9 6
11 12

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

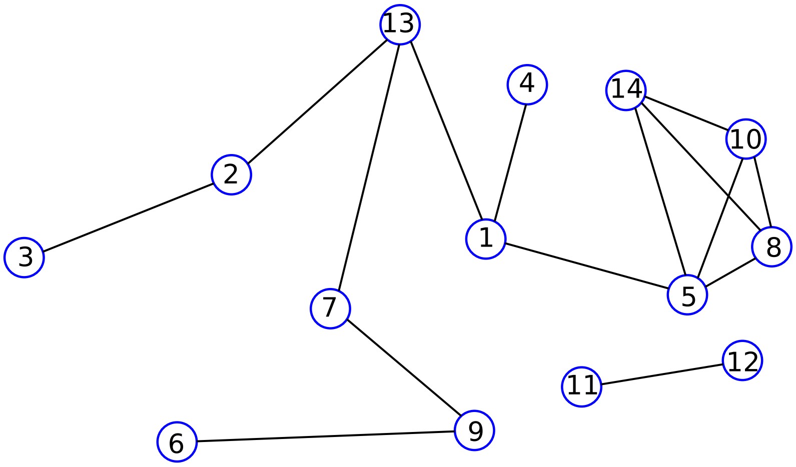
See next page for the graphs given in the above input.

Example graphs

Graph 1



Graph 2


13
4
14
10
2
1
8
3
5
7
12
11
9
6