## IT5003 Semester 2 2024/2025 Data Structures and Algorithms

# Tutorial 08 Graph Traversal + unweighted SSSP For Week 11 (Sat)/12 (Mon)

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## **1** Introduction and Objective

Now that we have stored our graphs in one (or more – by now you should realize that you can do this) graph data structure(s) — or even not explicitly storing our graph (implicit graph), we want to run various (graph) algorithms on it.

In this tutorial, we will focus on two graph traversal algorithms: Depth-First Search (DFS) and Breadth-First Search (BFS) and concentrate on what they can do on top of just traversing the underlying graph.

We will heavily use https://visualgo.net/en/dfsbfs in this tutorial.

## 2 Tutorial Questions

#### Prelude: BFS Review

Q0). As Prof Halim usually start with DFS first after introducing graph data structure, we skipped BFS review during the previous tutorial. It is now time to properly review this important algorithm (that will be revisited again for unweighted SSSP problem soon). Tutor can use https://visualgo.net/en/dfsbfs, load any graph, and BFS from any randomly selected source vertex.

#### **Review the Harder Topics**

Q1). Tutor will spend some time (depending on the requests) to review any remaining harder topics about graph traversal that may not be clear even after Week 09+10 classes. In recent years, these are the usually harder topics for students, in decreasing order of difficulty:

- Important to be properly discussed in S2 AY 2024/25 as it was skipped during lecture 09: https://visualgo.net/en/dfsbfs?slide=7-7 to 7-9 (about back edge/detecting cycle in a directed graph)
- 2. https://visualgo.net/en/dfsbfs?slide=7-10 to 7-11 (toposort, revisited below)
- 3. https://visualgo.net/en/dfsbfs?slide=7-6 to 7-9 (finding connected components; check your understanding about the  $O(V \times (V + E))$  versus just O(V + E) analysis again) For S2 AY 2024/25, this has been tested in PS5 A
- 4. https://visualgo.net/en/dfsbfs?slide=9 (undirected bipartite graph checker) For S2 AY 2024/25, this has been tested in PS5 B
- 5. https://visualgo.net/en/dfsbfs?slide=8 (the other more advanced graph traversal topics that are not the main focus of CS2040/C/S and IT5003 are optional and such questions will be answered offline, after/outside class and will not be part of this semester's CS2040/C/S and IT5003 final assessment)

#### Deeper Stuffs about Topological Sort



Figure 1: A Sample DAG (ignore edge weights for this question)

Q2). The modified DFS or modified BFS (Kahn's) topological sort algorithm given in class (please review https://visualgo.net/en/dfsbfs, 'topological sort', either the DFS or BFS version) only gives <u>one</u> valid topological ordering. How can we find **all** possible valid topological orderings for a given DAG? For example, there are **1008** possible valid topological orderings of the DAG in Figure 1. Starting point: What kind of DAG has the smallest/largest number of possible valid topological ordering, respectively?

Q3). The modified BFS (Kahn's) topological sort algorithm is actually quite interesting (read the details at https://en.wikipedia.org/wiki/Topological\_sorting#Kahn's\_algorithm). Can we change the underlying data structure (from a normal queue that is used in the modified BFS @ VisuAlgo) into another data structure? What if we replace the queue with a stack? What if we replace the queue with a hash table)?

## Graph Modeling Exercise Part 1

Q4). The tutor will randomly imagine **one** real life scenario (that can be modeled as a graph problem) and will ask random student to model that scenario into a graph. Students have to describe what the set of vertices represent, what the set of edges represent, are the graphs weighted/directed/connected?, what are the graph (for now, limit to graph traversal) problem being asked?, should we explicitly store the graph?, etc...

## Hands-on

TA will run the second half of this session with a few to do list:

- PS5 Debrief (A Quick One),
- Very quick review of Prof Halim's https://github.com/stevenhalim/cpbook-code/blob/master/ch4/sssp/bfs.py, https://github.com/stevenhalim/cpbook-code/blob/master/ch4/sssp/bfs.java,
- Speedrun dfsbfs of VisuAlgo Online Quiz: https://visualgo.net/training?diff=Medium&n=5&tl=5&module=dfsbfs
- Live solve another chosen Kattis problem involving Graph Traversal (topological sorting variant).

## Problem Set 6

We will discuss some hints for the easier subtasks of the last (hardest) PS6.

WARNING: Anyone who still relying too much on TA/peer hints/or gen AI to get unstuck in the much longer ( $\approx 2$  weeks) PS need to prepare to say goodbye to lots of marks for the 2 hours final later.