http://www.cs.unh.edu/~ruml/cs758
Graph Traversal

Graphs
Breadth-first
The Algorithm
The Full Algorithm
Break
Factoids
Proof
Depth-first Search
Edges
EOLQs
directed, arc/edge, weighted, labeled. drawings
representation
relations → edges
cycle, DAG, tree, planar
Breadth-first Search

traversal: graph → forest
1. foreach vertex, label it undiscovered and $v.d \leftarrow \infty$
2. $start$’s label $\leftarrow$ discovered, $d \leftarrow 0$, $\pi \leftarrow$ nil
3. $Q \leftarrow \{start\}$
4. while $Q$ not empty
5. $u \leftarrow$ dequeue($Q$)
6. foreach neighbor $v$ of $u$
7. if $v$ is undiscovered
8. label $v$ discovered, $v.d \leftarrow u.d + 1$, $v.\pi \leftarrow u$
9. enqueue $v$ in $Q$
10. label $u$ finished

Which vertices does $Q$ hold (at line 4)?
Do we really need all the labels?
What’s the time complexity?
The Full Algorithm

1. foreach vertex, label it undiscovered and $v.d \leftarrow \infty$
2. foreach vertex $s$
3. if $s$ is undiscovered
4. $s.label \leftarrow$ discovered, $s.d \leftarrow 0$, $s.\pi \leftarrow$ nil
5. $Q \leftarrow \{ s \}$
6. while $Q$ not empty
7. $u \leftarrow$ dequeue($Q$)
8. foreach neighbor $v$ of $u$
9. if $v$ is undiscovered
10. label $v$ discovered, $v.d \leftarrow u.d + 1$, $v.\pi \leftarrow u$
11. enqueue $v$ in $Q$
12. label $u$ finished

Which vertices does $Q$ hold (at line 4)?
Do we really need all the labels?
What’s the time complexity?
Break

- asst 7
- asst 8
- midterm
- wildcard vote in one month
1. Distances we assign always stay the same or go down.

2. $v.d \geq \delta(s,v)$
   Proof: Show $v.d \geq \delta(s,v) \forall v$ via induction over iterations:
   Holds at start.
   $v.d$ is updated to $u.d + 1 \geq \delta(s,u) + 1 \geq \delta(s,v)$.

3. $d$ values in queue are nondecreasing and last in queue exceeds first by at most 1.
   Proof: By induction. True when queue is $s$.
   Preserved by dequeue.
   Enqueue: $\text{new}.d = \text{removed}.d + 1 \leq \text{first}.d + 1$ and \text{last}.d \leq \text{removed}.d + 1 = \text{new}.d.$

4. At termination, $v.d = \delta(s,v) = \text{shortest path length}$
Proof

Claim: at termination, $v.d = \delta(s, v) = \text{shortest path length}$

Consider $v$ with minimum incorrect distance, and $u$ that is before it on a shortest path. $v.d > \delta(u) + 1 = u.d + 1$. When $u$ is dequeued:

if $v$ is undiscovered, it would then be correct, contradiction.
if $v$ is already finished, then $v.d \leq u.d$, contradiction.
if $v$ is discovered, let $w$ be predecessor. $v.d = w.d + 1$ and $w.d \leq u.d$ so $v.d \leq u.d + 1$, contradiction.
Depth-first Search

DFS
1. forall vertices, label ← undiscovered
2. DFS-visit\((start)\)

DFS-visit\((u)\)
3. label \(u\) discovered
4. foreach neighbor \(v\) of \(u\)
5. if \(v\) is undiscovered
6. \(v.\pi ← u\)
7. DFS-visit\((v)\)
8. label \(u\) finished

What’s the time complexity?
Discovery and finish times are parenthesized
Vs breadth-first?
### Edges

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- **tree**: in depth-first tree
- **back**: connects to ancestor in tree
- **forward**: non-tree edge connecting to descendant in tree
- **cross**: others: non-ancestors/non-descendants or different DFS tree

when edge is explored, label of arc dest gives type
For example:

- What’s still confusing?
- What question didn’t you get to ask today?
- What would you like to hear more about?

Please write down your most pressing question about algorithms and put it in the box on your way out.

*Thanks!*