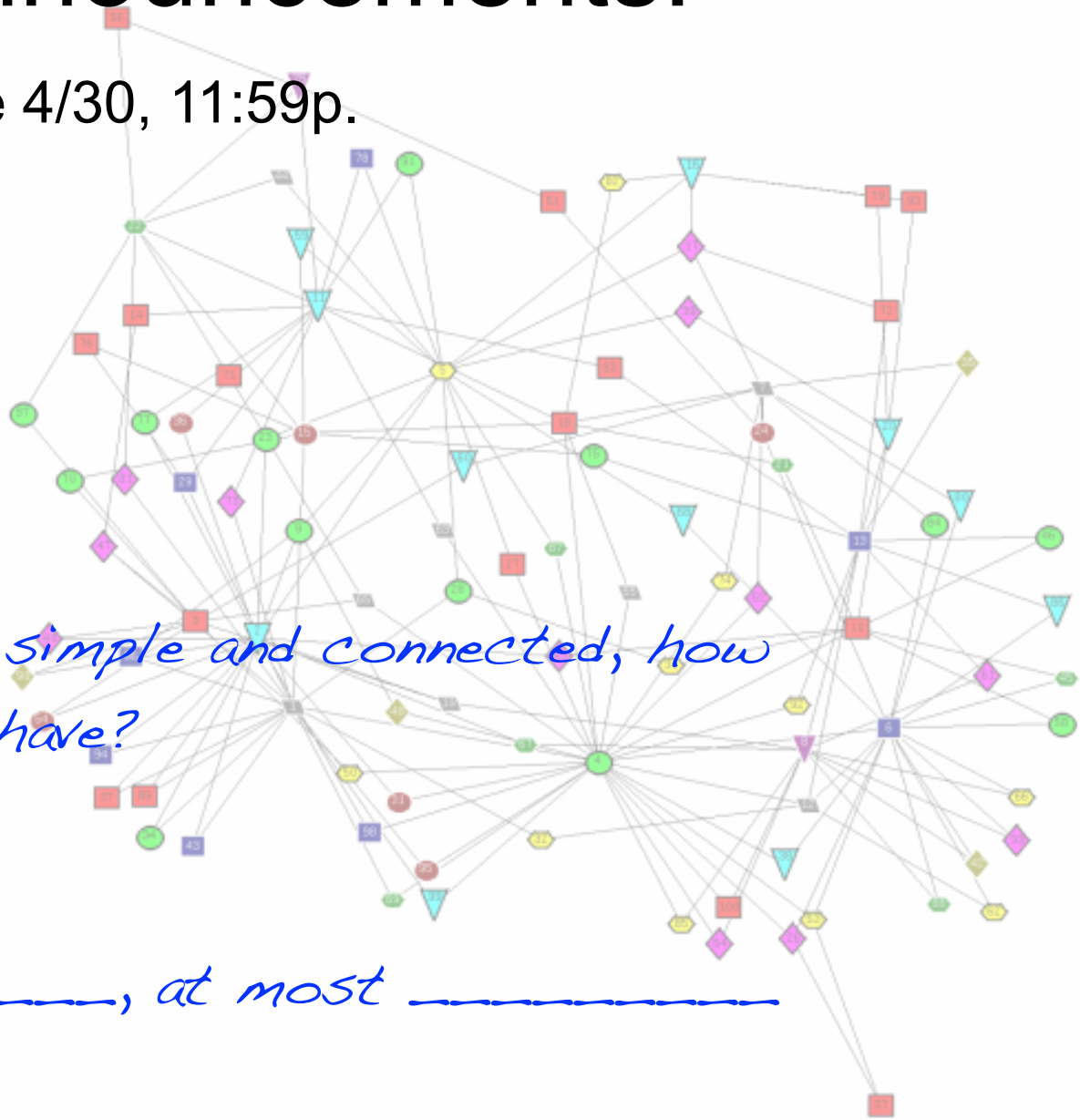
Today's announcements:

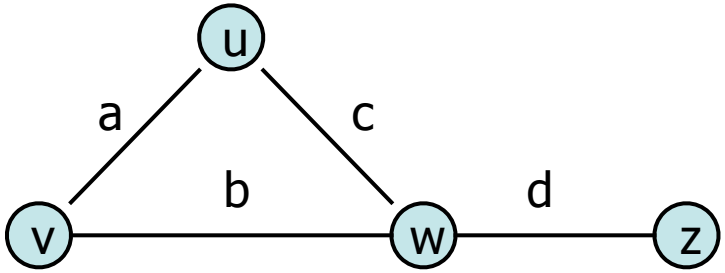
MP7 available, due 4/30, 11:59p.



Q: if this graph is simple and connected, how many edges does it have?

A: at least _____, at most _____

Graphs: Adjacency List



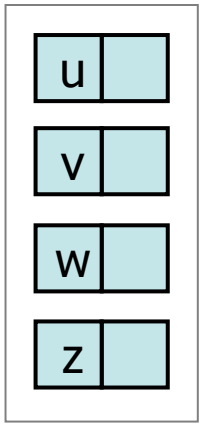
Some functions we'll compare:

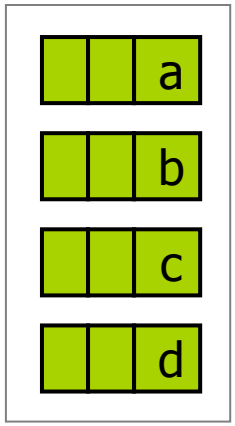
insertVertex(vertex v)

removeVertex(vertex v)

areAdjacent(vertex v, vertex u)

incidentEdges(vertex v)

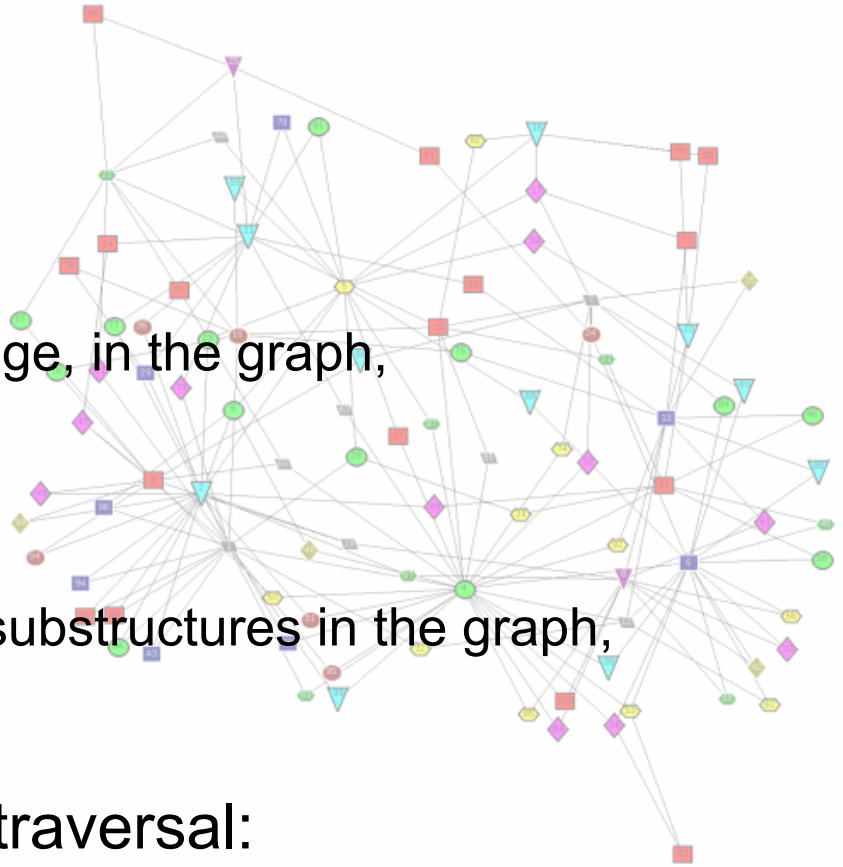




Graphs: Asymptotic Performance

• n vertices, m edges • no parallel edges • no self-loops • Bounds are big-O	Edge List	Adjacency List	Adjacency Matrix
Space	$n + m$	$n + m$	n^2
incidentEdges(v)	m	$\deg(v)$	n
areAdjacent (v, w)	m	$\min(\deg(v), \deg(w))$	1
insertVertex(o)	1	1	n^2
insertEdge(v, w, o)	1	1	1
removeVertex(v)	m	$\deg(v)$	n^2
removeEdge(e)	1	1	1

Graphs – traversal



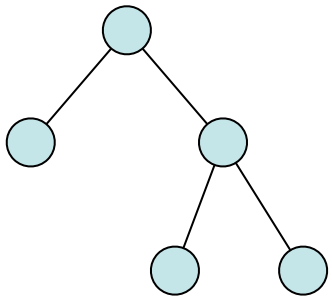
Objective:

Visit every vertex and every edge, in the graph,

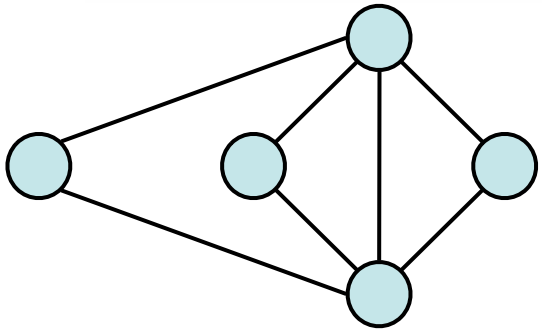
Purpose:

We can search for interesting substructures in the graph,

Contrast graph traversal to BST traversal:



•Ordered
•Obvious start



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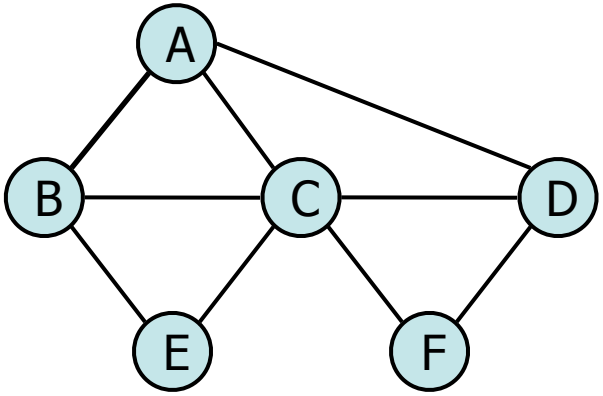
Graphs: Traversal - BFS

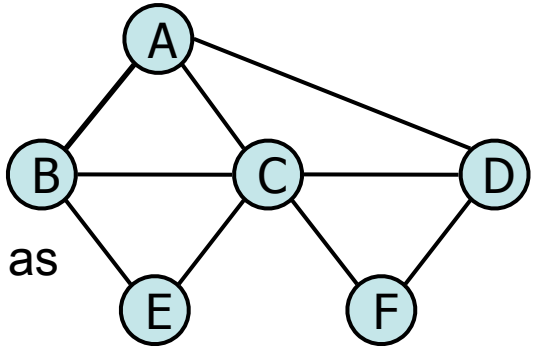


http://www.cs.duke.edu/csed/jawaa2/examples/BFS.html

http://www.student.seas.gwu.edu/~idsv/idsv.html

Graphs: Traversal – BFS

Visits every vertex and classifies each edge as either “discovery” or “cross”

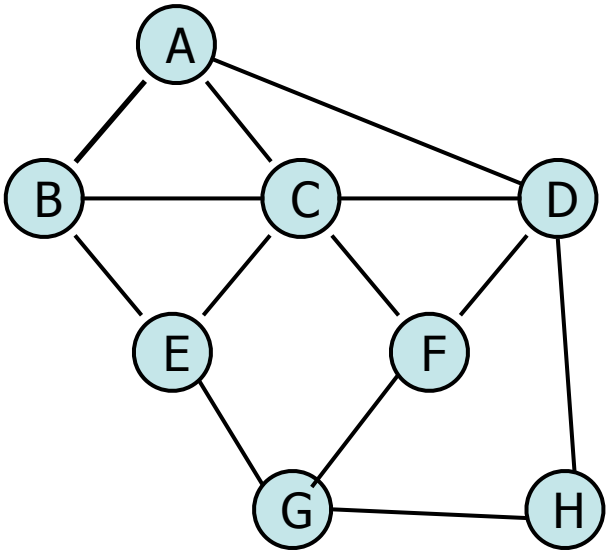



```
Algorithm BFS(G)
    Input: graph G
    Output:  labeling of the edges of G as discovery edges and back edges

For all u in G.vertices()
  setLabel(u, UNEXPLORED)
For all e in G.edges()
  setLabel(e, UNEXPLORED)
For all v in G.vertices()
  if getLabel(v) = UNEXPLORED
    BFS(G,v)
```

```
Algorithm BFS(G,v)
    Input: graph G and start vertex v
    Output:  labeling of the edges of G in the connected component of v as discovery edges and cross edges
queue q;
setLabel(v, VISITED)
q.enqueue(v);
While !(q.isEmpty)
  q.dequeue(v)
  For all w in G.adjacentVertices(v)
      if getLabel(w) = UNEXPLORED
          setLabel((v,w),DISCOVERY)
          setLabel(w, VISITED)
          q.enqueue(w)
      else if getLabel((v,w)) = UNEXPLORED
          setLabel((v,w),CROSS)
```

Graphs: BFS example



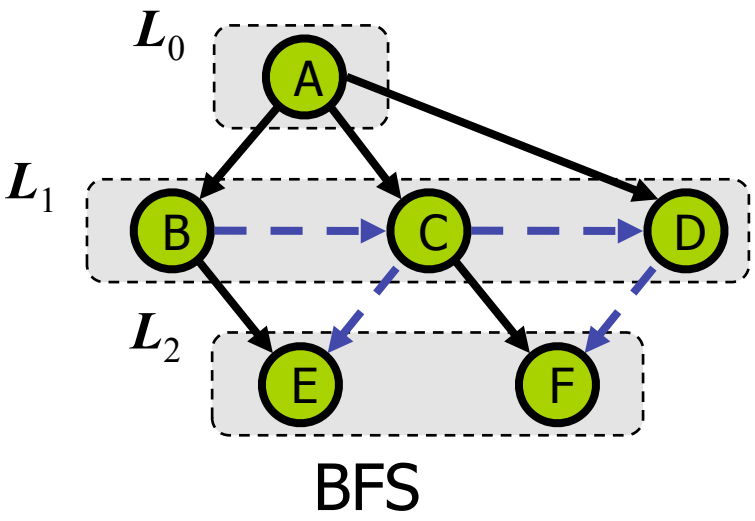
A	C B D
B	A C E
C	B A D E F
D	A C F
E	B C G
F	C D G
G	E F H
H	D G

While loop

For loop

TOTAL RUNNING TIME:

Graphs: BFS properties



BFS

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