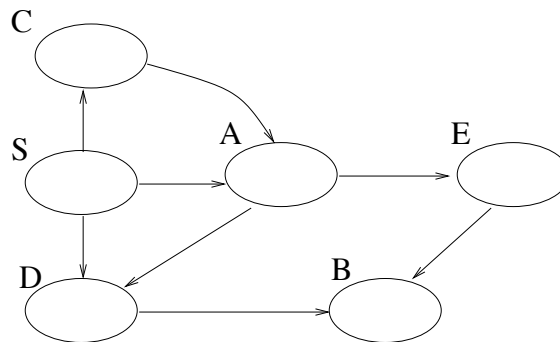


## Homework 6

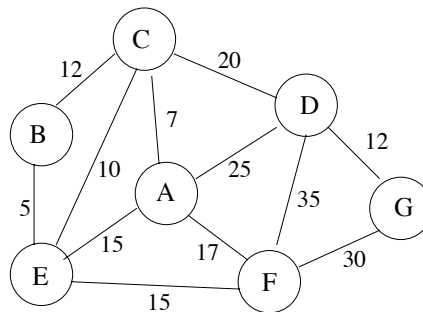
December 4, 2007

Due Date: December 11

- (5 pts) Complete the on-line course evaluation that is found at <http://evals.wustl.edu/>. I read these carefully and adjust my course according to the comments. So along with check the boxes, please spend a little time answering the questions. It is really helpful for me to both know what portions of the course you really liked as well as your suggestions for improvement. Thanks.
- (15 pts) Consider the following directed graph. You should assume that all lists of adjacent vertices are in alphabetical order.

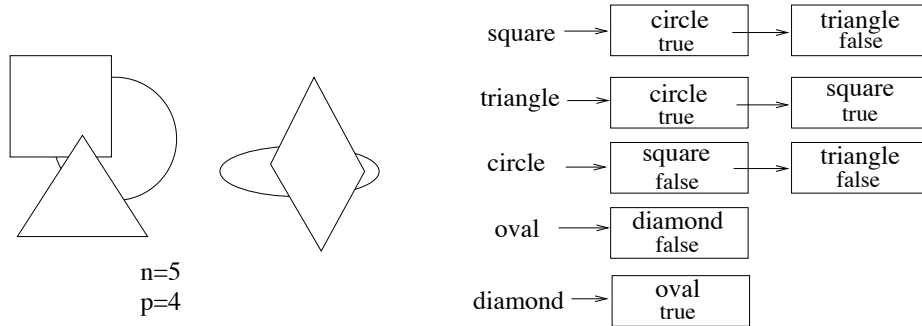


- (6 pts) Show the breadth-first search tree with  $S$  as the source.
  - (6 pts) Show the discovery and finishing time for all vertices when DFS is run (visiting the vertices in the top-level DFS method in alphabetical order).
  - (3 pts) Suppose  $S$ ,  $A$ ,  $B$ ,  $C$ ,  $D$ , and  $E$  represent tasks that must be completed as part of a process and that an edge from  $X$  to  $Y$  means that  $X$  must be completed before  $Y$ . Name the algorithm you would use to find a valid order to complete the tasks. Then give the valid order that would be output for the graph shown above.
- (15 pts) In the graph below each vertex represents an island and each edge would be the cost (in millions of dollars) to build a bridge to connect those two islands via a road. You must find a way to build bridges so that one can drive between any two islands with the goal of minimizing the construction cost.



- (5 pts) State the name of the algorithm you will use to solve this problem. You may have a choice – pick whichever you want as long as it solves the given problem.

- (b) (10 pts) Illustrate the execution of the algorithm you selected on the above graph. Show your work in enough detail that we can see how you reached your solution. (1/4 to 1/2 a page should be adequate – you need not illustrate the details of any data structures used)
4. (15 pts) Consider the task of redrawing a set of graphic objects in a drawing program. Assume there is an iterator available to iterate over all graphic objects and for each graphic object  $x$  there is a list of objects it overlaps with (which can you iterate over) where each list element has two data fields: the object  $o$  that  $x$  overlaps, a boolean indicating if  $x$  is on top of  $o$ . Let  $b$  be the number of objects and  $p$  the number of pairs of objects that overlap. Below is a simple example showing the lists for each of 5 objects in the picture.



When an object is displayed it is drawn in its entirety and will cover anything already drawn that occupies the same space. You are to select/design the most efficient algorithm you can to determine the order in which to display the objects so they appear correctly (or report that it is not possible to do this while drawing an entire object at a time). Then analyze the worst-case asymptotic time complexity of your algorithm (given that the data structure described above is already built) in terms of  $b$  and  $p$ . If you build any additional data structures then include that in the time complexity analysis for your algorithm.

5. (5 pts) Suppose that when implementing Dijkstra's algorithm you used a priority queue ADT implemented by George W. Bush. Suppose that President Bush (who has not taken CSE 241), implements the priority queue as an unsorted doubly-linked list that supports a tracker that can locate an element in constant time. (This is trivially done by having the tracker object just hold a reference to the list node).

What is the asymptotic time complexity of Dijkstra's algorithm when using President Bush's priority queue? Your answer should be a function of  $n$ , the number of vertices and  $m$ , the number of edges in the graph. You should briefly explain your answer.

6. (20 pts) A search-engine company has decided on the following method to rank web page quality based on an individual's preference. Each individual can give a web page  $X$  that they consider to be a very high quality page. For every other web page its quality is defined as the minimum number of hyperlinks that must be followed from page  $X$  to get to it. (In class we will discuss some of the methods used to rank web page quality). Suppose that there are  $p$  web pages being considered with a total of  $\ell$  hyperlinks. You must:
- Formulate this problem as a graph problem. Give enough detail so that given a set of web pages and hyperlinks someone could, without any ambiguities, create the graph. So it should be clear if the graph is directed or undirected, weighted or unweighted, ...
  - Select a graph representation under the assumption that  $p$  is roughly 1,000,000 and  $\ell$  is roughly 10,000,000 (i.e. on average each web page as 10 links).

- Select/Design the most efficient algorithm you can to compute the quality measure defined above for all  $p$  web pages and analyze the time complexity of your algorithm.
7. (20 pts) Two students have a container filled with 8 liters of a beverage they wish to divide evenly between them. They have two containers with capacities of 3 and 5 liters, respectively. These containers can only be used to measure their capacity (i.e. you may NOT fill the 3 liter container a third of the way to measure 1 liter). However, you can do something like filling the 5 liter container and then use it to fill the 3 liter container. You then know that the 5 liter container holds 2 liters. No other measuring device is available. The students wish to find the minimum sequence of pours that end with two containers each holding exactly 4 liters.
- (a) Represent the set of possible solutions using a graph. Specifically, create a vertex  $v = (v_1, v_2, v_3)$  for each triple of non-negative integers that sum to 8 where the first number ( $v_1$ ) represents the amount in the original container, the second number ( $v_2$ ) represents the amount in the 3 liter container, and the third number ( $v_3$ ) represents the amount in the 5 liter container. You are to complete the description of the graph by describing that edges you would put in the graph. Be sure to indicate if the edges are directed or undirected, and whether they are weighted or unweighted.
- (b) Name the graph algorithm that would most efficiently determine the fewest pours needed to solve the problem. You should be specific about describing any parameters required by the algorithm you choose and also clearly state how the sequence of pours in the optimal solution is found.
8. (5 pts) Below is the table showing memory where 0 represents `null` and the other memory locations are labeled by addresses 1 to 8. Each memory cell has two fields (left and right). Any value that is a number is a pointer/reference.

cell	left	right
1	7	4
2	0	7
3	4	2
4	b	2
5	3	8
6	0	1
7	a	4
8	7	1

- (a) (3 pts) Draw memory as a graph with a vertex for memory cells 1 to 8. Please have the left pointer originate from the left half of the vertex, and the right pointer originate from the right half of the vertex.
- (b) (2 pts) Suppose that the only variable held by the program is a reference to cell 5. What memory cells are garbage?

**Extra Credit Problem:**

9. (5 pts) You are working on techniques for coordinating groups of mobile robots. Each robot has a radio transmitter that it uses to communicate with a base station, and if the robots get within 10 feet of each other then problems arise with interference among the transmitters. So a natural problem arises: how to plan the motion of the robots in such a way that each robot gets to its intended destination, but in the process the robots don't come too close together.

We can model this problem abstractly as follows. Suppose that we have an undirected graph  $G = (V, E)$ , representing the floor plan of a building, and there are two robots initially located at vertices  $a$  and  $b$  in the graph. The robot that begins at vertex  $a$  wants to travel to vertex  $c$ , and the robot that begins at vertex  $b$  wants to travel to vertex  $d$ . Assume that at each step, one of the robots can move across a single edge. How can you find a solution with the fewest steps to get the two robots from their starting to desired locations while ensuring that the two robots are never within 10 feet of each other.

Describe how you would solve this problem. Give enough details so you are sure we understand your solution. What is the time complexity of your solution as a function of  $|V|$  and  $|E|$ ? *Hint: You might want to create a new graph from the one described above.*