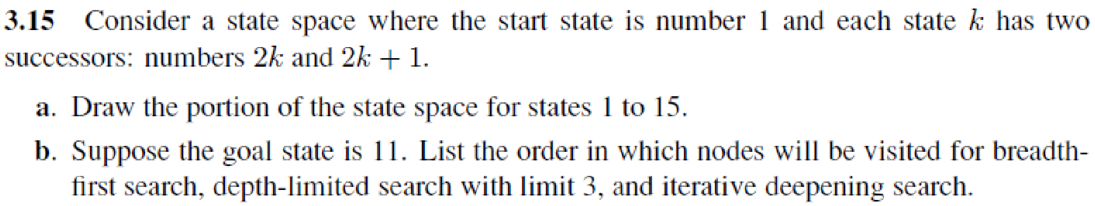
**Artificial Intelligence – Spring 2021**

Homework 2

Issued: March 15th, 2021 Due: March 22th, 2021

**Problem 1:**

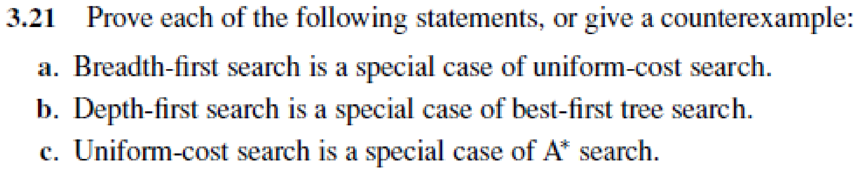


**3.15** Consider a state space where the start state is number 1 and each state $k$ has two successors: numbers $2k$ and $2k+1$.

**a.** Draw the portion of the state space for states 1 to 15.

**b.** Suppose the goal state is 11. List the order in which nodes will be visited for breadth-first search, depth-limited search with limit 3, and iterative deepening search.

**Problem 2:**



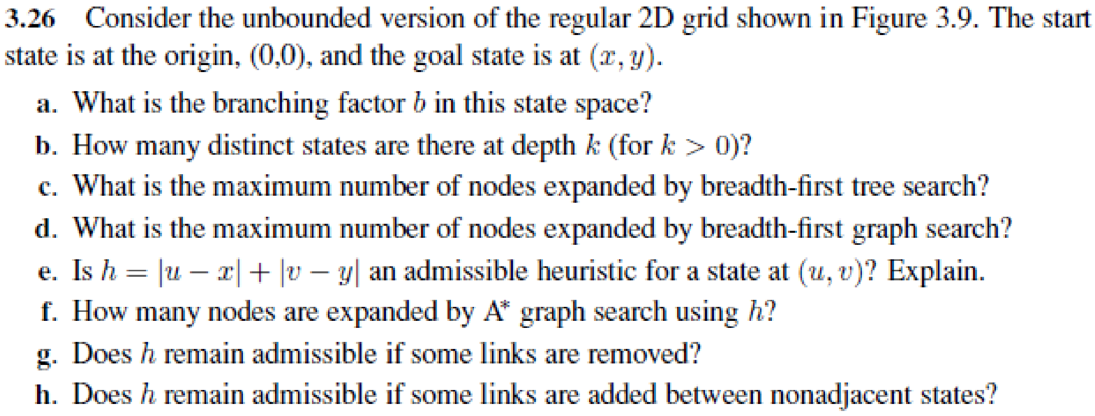
**3.21** Prove each of the following statements, or give a counterexample:

**a.** Breadth-first search is a special case of uniform-cost search.

**b.** Depth-first search is a special case of best-first tree search.

**c.** Uniform-cost search is a special case of A* search.

**Problem 3: (Figure 3.9 in the textbook)**



**3.26** Consider the unbounded version of the regular 2D grid shown in Figure 3.9. The start state is at the origin, (0,0), and the goal state is at $(x, y)$.

**a.** What is the branching factor $b$ in this state space?

**b.** How many distinct states are there at depth $k$ (for $k > 0$)?

**c.** What is the maximum number of nodes expanded by breadth-first tree search?

**d.** What is the maximum number of nodes expanded by breadth-first graph search?

**e.** Is $h = |u - x| + |v - y|$ an admissible heuristic for a state at $(u, v)$? Explain.

**f.** How many nodes are expanded by A* graph search using $h$?

**g.** Does $h$ remain admissible if some links are removed?

**h.** Does $h$ remain admissible if some links are added between nonadjacent states?

**Problem 4:**

**5.9** This problem exercises the basic concepts of game playing, using tic-tac-toe (noughts and crosses) as an example. We define $X_n$ as the number of rows, columns, or diagonals with exactly $n$ $X$'s and no $O$'s. Similarly, $O_n$ is the number of rows, columns, or diagonals with just $n$ $O$'s. The utility function assigns $+1$ to any position with $X_3 = 1$ and $-1$ to any position with $O_3 = 1$. All other terminal positions have utility 0. For nonterminal positions, we use a linear evaluation function defined as $Eval(s) = 3X_2(s)+X_1(s)-(3O_2(s)+O_1(s))$.

**a.** Approximately how many possible games of tic-tac-toe are there?

**b.** Show the whole game tree starting from an empty board down to depth 2 (i.e., one $X$ and one $O$ on the board), taking symmetry into account.

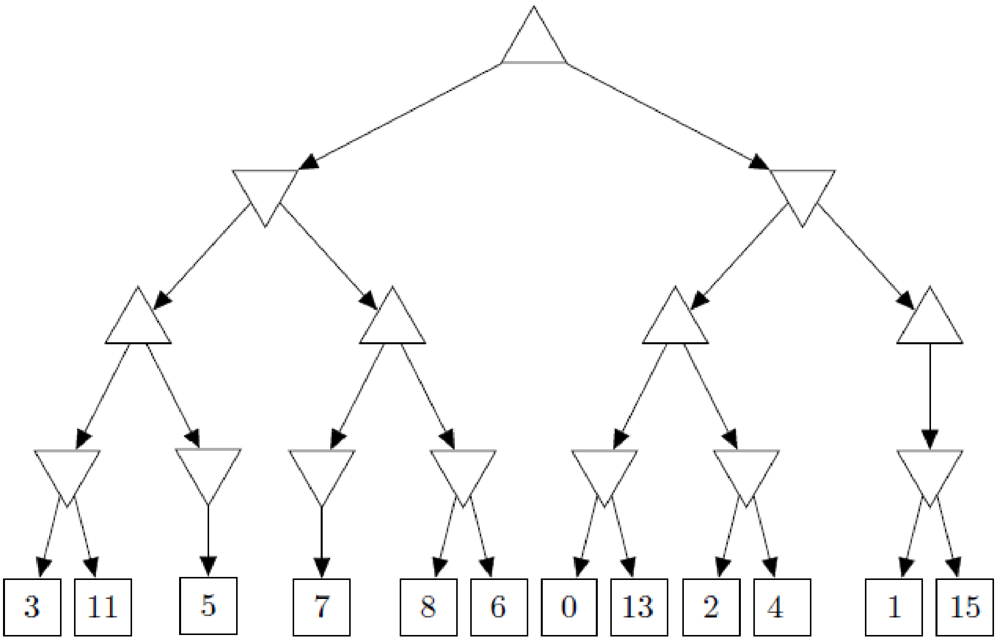
**c.** Mark on your tree the evaluations of all the positions at depth 2.

**d.** Using the minimax algorithm, mark on your tree the backed-up values for the positions at depths 1 and 0, and use those values to choose the best starting move.

**e.** Circle the nodes at depth 2 that would *not* be evaluated if alpha–beta pruning were applied, assuming the nodes are generated in the optimal order for alpha–beta pruning.

**Problem 5:**

On the minimax game tree below cross out the branches removed by alpha-beta pruning assuming left to right traversal.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