# Midterm

CS440, Fall 2003

This test is closed book, closed notes, no calculators. You have 1:30 hours to answer the questions. If you think a problem is ambiguously stated, state your assumptions and solve the problem under those assumptions. You can use both sides of the test book to write your answers.

| | |
|---|---|
| Name: | |
| ID: | |

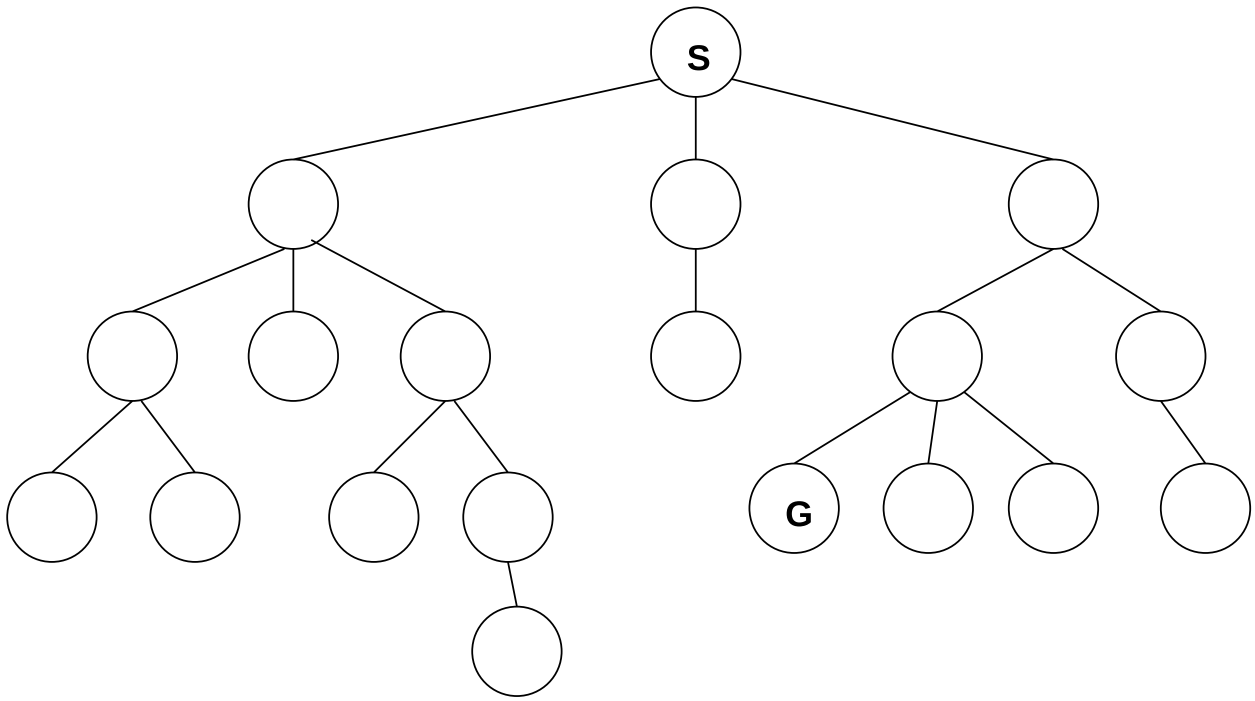
| Problem | Score | Max. score |
|---|---|---|
| 1 | | 28 |
| 2 | | 12 |
| 3 | | 14 |
| 4 | | 14 |
| 5 | | 18 |
| 6 | | 14 |
| Total | | 100 |

# 1 Search

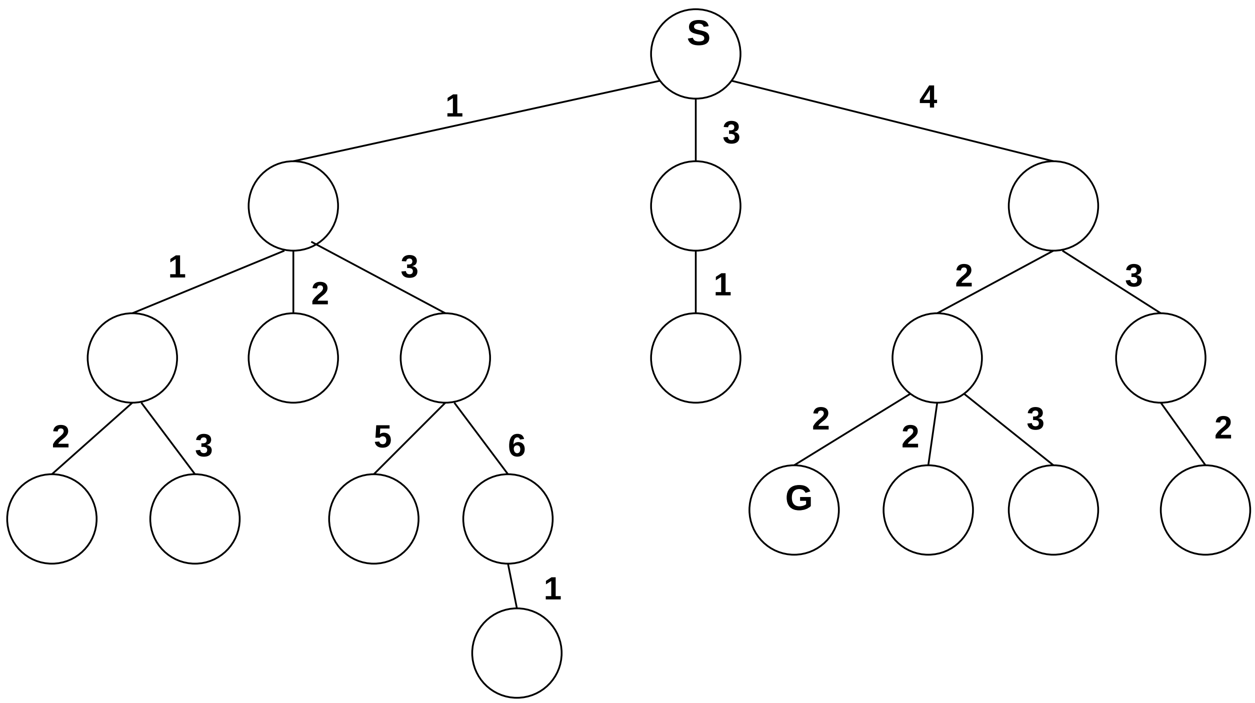
In this problem you need to use four search methods applied to a state represented as a tree. The goal is to find a path from the start node **S** to the goal node **G**. If the goal cannot be found, state so.

Note: if you need to break ties, use the FIFO ordering.

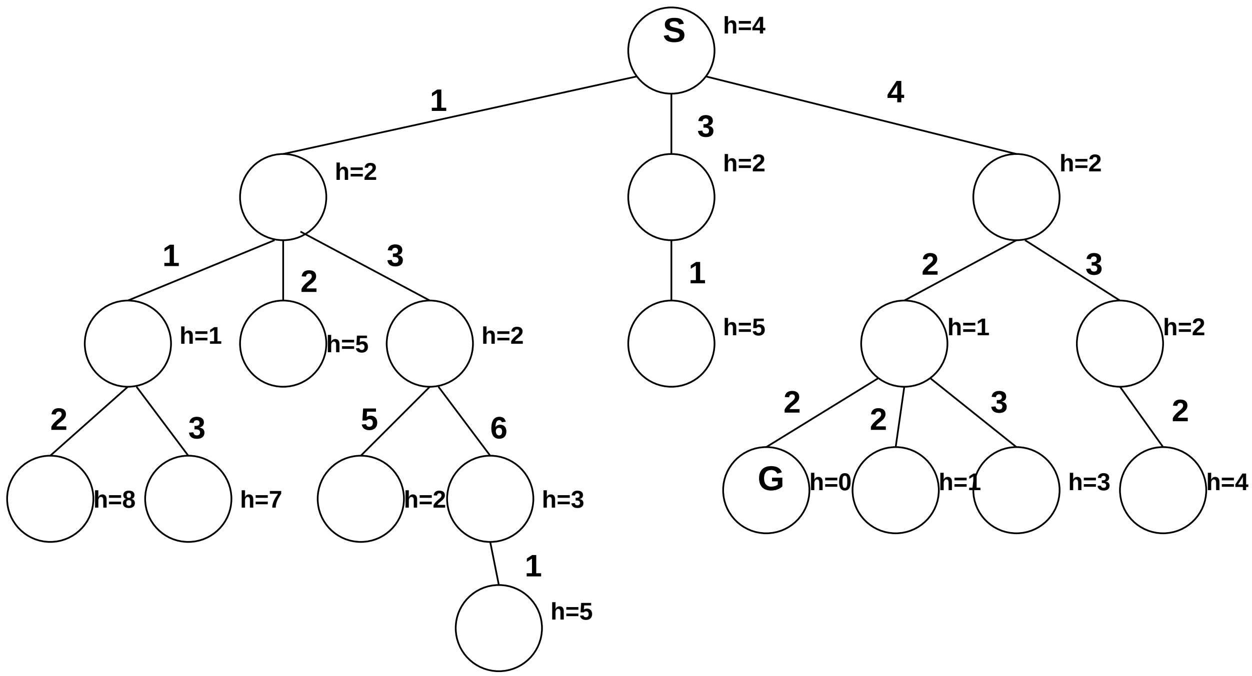
(a) [7] Depth-first iterative deepening. Expand children left-to-right. Next to each node write the number(s) indicating when the node was expanded or the goal test was performed.



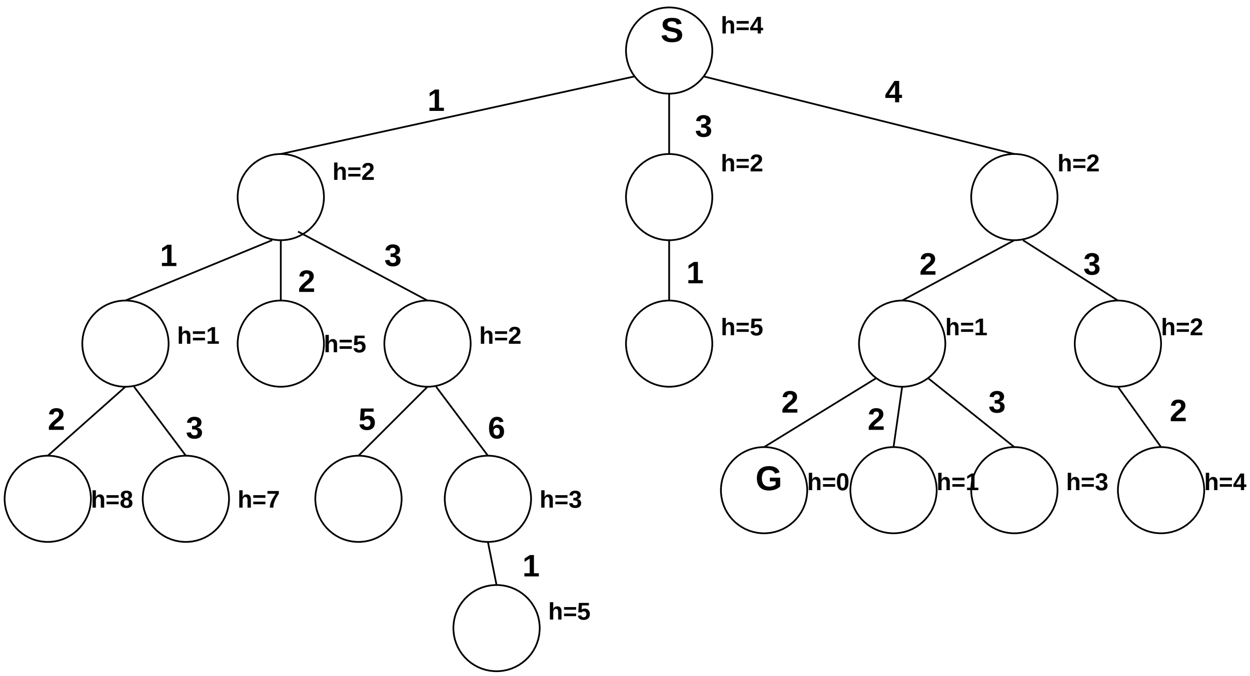
(b) [7] Uniform-cost search. Each arc is labeled with the associated operator cost. In each node write the number indicating when the node was expanded or the goal test was performed. Next to each node inserted on the fringe write the $g$ value of the node. DO NOT write $g$ values of the nodes that are never inserted on the fringe.



(c) [7] $A^*$ search. Each arc is labeled with the associated operator cost. Next to each node are the values of the heuristic function $h$ for that node. In each node write the number indicating when the node was expanded or the goal test was performed. Next to each node inserted on the fringe write the $f$ value of the node. DO NOT write $f$ values of the nodes that are never inserted on the fringe.



(d) [7] Hill-climbing search without random restarts. Each arc is labeled with the associated operator cost. Next to each node are the values of the heuristic function $h$ for that node. In each node write the number indicating when the node was expanded or the goal test was performed. Next to each node inserted on the fringe write the $f$ value of the node. DO NOT write $f$ values of the nodes that are never inserted on the fringe.



## 2 Heuristics

Consider the 8-puzzle problem (3x3 grid with eight tiles numbered 1 through 8.) The goal is to move the tiles from a start configuration to a goal configuration. Valid moves are vertical or horizontal moves into an adjacent position with no tile. Each move has cost 1.

(a) [4] List at least two admissible heuristics for this problem.

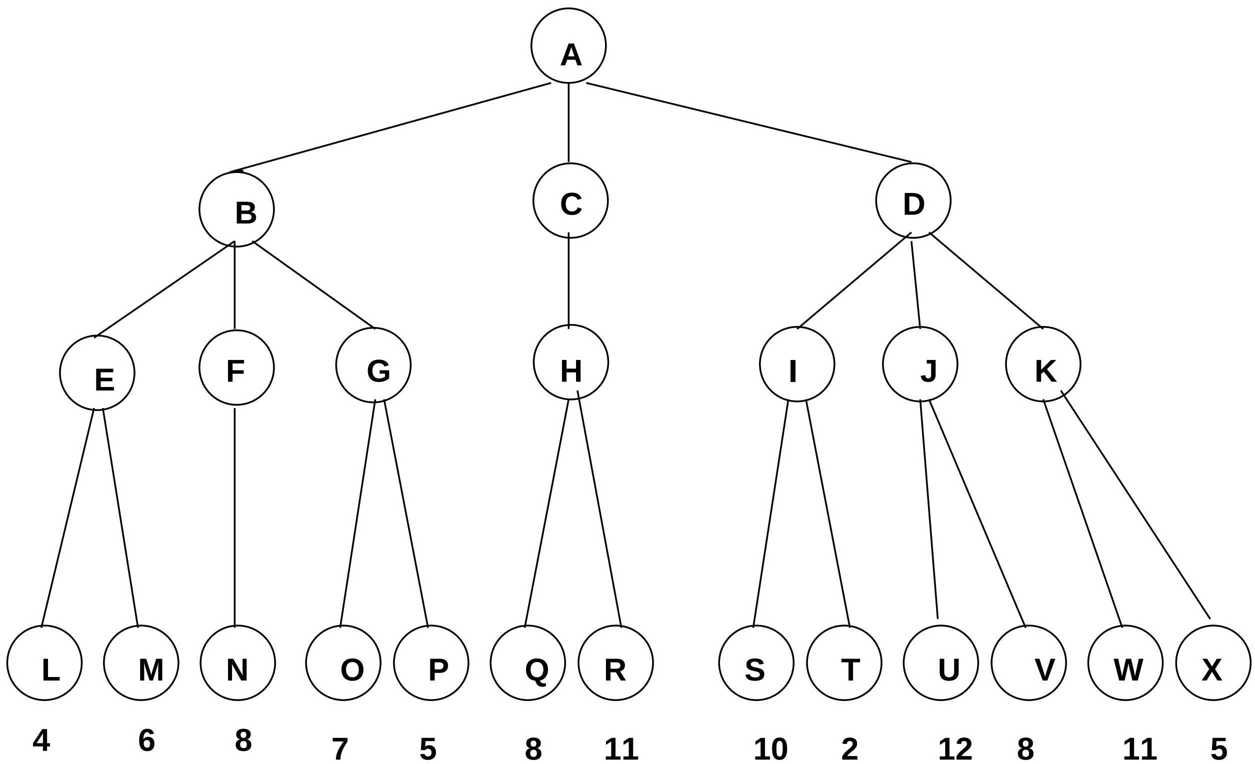
(b) [4] Let $d_i$ be the number of vertical and horizontal moves the tile $i$ would need to make from its current position in order to reach the goal configuration, assuming no other tiles are on the board. Let $h = \sum_{i=1}^{8} \alpha_i d_i$, be a heuristic, where $0 \leq \alpha_i \leq 1$ is a constant weight factor for each tile and $\sum_{i=0}^{8} \alpha_i = 1$. Is $h$ admissible? Justify your answer.

(c) [4] Given any two admissible heuristics, $h_1$ and $h_2$, order the following three heuristics according to their utility (best to worst): $min(h_1, h_2)$, $\max(h_1, h_2)$, and $.2 \times h_1 + .8 \times h_2$? Justify you answer.

## 3 Games

Consider the game tree shown below. Utilities of each leaf node are shown below the corresponding node. Let game be a two-player, zero-sum game. The root node corresponds to the MAX player.

(a) [5] Compute backed-up values next to each node that will be used in the minimax algorithm.




(b) [2] Which move should the first player choose?

(c) [7] Now use the alpha-beta search instead of the minimax algorithm. Which move should the first player make now? What nodes are NOT examined in the alpha-beta search?

## 4 Logic

Answer whether each of the following sentences are true or false.

1. [2] $((P \Rightarrow Q) \Rightarrow P) \Rightarrow P$ is valid.

2. [2] A non-valid sentence is unsatisfiable.

3. [2] $(A \vee B) \Rightarrow C$ can be represented as a (set or) Horn clause(s).

4. [2] Resolution in Boolean logic is NOT a complete inference rule for knowledge bases (KBs) expressed as conjunctive normal forms (CNFs).

5. [2] $\forall x(x = x) \vee (x > 0) \vee (x < 0)$.

6. [2] $\exists x \forall y \; x = y$.

7. [2] $R(F(y), y, x)$ and $R(x, F(A), F(v))$ are unifiable.

## 5 Inference

Consider the following knowledge base (KB) in English. Anyone who can speak French likes Camembert (cheese). Martians do not like Camembert. Some Martians are green.

(a) [6] Write the above KB premises using FOL.

(b) [5] Convert the KB into conjunctive normal form (CNF).

(c) [2] Write the query sentence “Someone not speaking French is green”.

(d) [5] Prove using resolution refutation whether or not the query sentences is entailed by the KB. Show your answer as a refutation tree.

## 6 Constraint satisfaction

Consider the following scheduling problem: there are five ferries, F1, F2, F3, F4, and F5, and three ferry pilots, P1, P2, and P3. The ferries are used according to the following schedule:

| Ferry | In use |
|---|---|
| F1 | 6am-10am |
| F2 | 8am-noon |
| F3 | 11am-3pm |
| F4 | 10am-11am and 2pm-6pm |
| F5 | noon-1pm and 4pm-7pm |

Each ferry has to be piloted by one (and only one) pilot and one pilot can pilot only one ferry at a time. If a pilot is free, it can move to any ferry. Pilot P3 does not know how to pilot F4. Pilots P3 and P2 are both novices and cannot handle F5. Also, pilot P2 has a dentist appointment at 7am.

(a) [4] One way to formulate this problem is to let each ferry F1, . . ., F5, represent a variable, and each pilot P1, P2, P3 be one possible value of that variable. What are the possible values of each variable?

(b) [4] Draw the constraint graph for this scheduling problem, assuming the formulation in (a).

(c) [6] Solve the scheduling problem using hill-climbing with min-conflicts cost function. Assume initial state to be F1=P1, F2=P2, F3=P3, F4=P2, F5=P1. Show the state at each iteration of the hill-climbing algorithm.