

CMSC 421 Homework 2

Due Date: Tuesday, October 14 in class

1. [15 points] CSP formulation

- Russell & Norvig Exercise 5.5. Note: Your formulation should clearly state what the variables are, the domain of each variable, and the set of constraints on the variables. Your formulation should be general (i.e., it should apply to any set of rectangles, classes, professors, etc.).
- Give a short description of a problem of your choice in english and then give the formulation as a CSP.

2. [15 points] CSP Formulation and Solving

Consider the following problem:

A delivery robot needs to schedule delivery activities a, b, c, d, and e. An activity may only happen at time 1, 2, 3, or 4 (we assume it is instantaneous). Activity b must not happen at 3 and activity c must not happen at 2. Activities a and b must not occur simultaneously, nor should activities b and c and activities b and d. Activities a and d must occur simultaneously. Activity c must occur before d, while e must happen before a, b, c, and d.

- (a) Express this problem as a constraint satisfaction problem. What are the variables, their original domains, and the constraints? (Note: The original domain of a variable contains all possible values of the variable before unary constraints are applied. Your set of constraints must therefore contain all unary constraints.) If appropriate, define the notations you use to denote the relations.
- (b) Find a solution of this problem (by hand) using the backtracking algorithm with forward checking and the most-constrained-variable heuristic. Write out the steps performed by the algorithm.
- (c) Draw the graph constraint of the problem. Associate with each node of this graph the domain of the corresponding variable, after all unary constraints have been applied.
- (d) Generate by hand a trace of the execution of the algorithm AC3 as presented in class. At each loop of AC3, indicate the state of the queue and the variable values that are removed.

3. [15 points] Game Trees and Search (Based on Russell & Norvig 6.3) Recall the game described in class. In the game, there are two players, Red and White. They are placed on a 5 square horizontal board as discussed in class, with red at the left end and white at the right end.

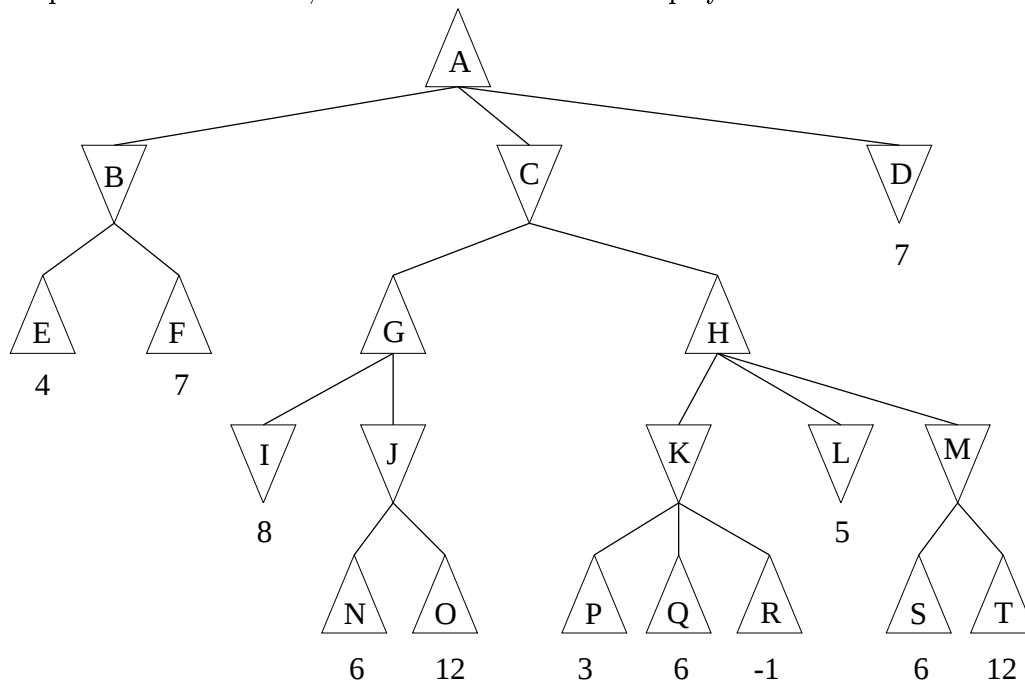
The rules are:

- Red goes first.
- On their turn, a player must move their piece.
- They must move to a neighboring square, or if their opponent is adjacent to them, with a blank on the far side, they can hop over them.

- The player that makes it to the far side first wins.
- (a) Draw the game tree for this game. For consistency, in the case where a piece may move either left or right, always have the first child of a node be a *Left* move, and the second child correspond to a *Right* move.
 - (b) Solve this game using Minimax search. Show the final values at each node. See Russell & Norvig 6.3 for additional details.
 - (c) Solve this game using alpha-beta pruning. Clearly mark branches that can be deleted.

4. [10 points] Alpha-Beta Pruning Procedure

When asked to perform Alpha-Beta pruning in this problem, indicate the nodes that will be pruned. Fill in the values for the internal nodes using the given values at the leaves and the Minimax procedure. Perform Alpha-Beta pruning twice on this tree, first assuming left-to-right node expansion, and second assuming right-to-left node expansion. In this tree, the root node is the MAX player.



5. [5 points] Propositional Logic: Models

How many models (distinct assignments of truth values to A, B, and C) satisfy:

$$(A \wedge B) \Rightarrow (B \Rightarrow C)$$

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6. [5 points] Propositional Logic: Validity

Tell if each of the following sentences is valid (that is, True in all models), unsatisfiable, or neither:

$$\text{WET} \Rightarrow \text{RAIN}$$

$$(\text{WET} \Rightarrow \text{RAIN}) \Rightarrow (\neg \text{RAIN} \Rightarrow \text{WET})$$

$$(\text{WET} \wedge (\text{WET} \Rightarrow \text{RAIN})) \vee \neg \text{RAIN}$$

7. [10 points] First-order Logic Representation

Represent the following sentences in first-order logic:

- (a) *All Martians speak the same language*
Use $\text{Speak}(x, l)$ to mean that person x speaks language l . Use $\text{Martian}(x)$ to mean that person x is a Martian.
- (b) *Politicians can fool some of the people all of the time and they can fool all of the people some of the time, but they can't fool all of the people all of the time*

8. [25 points] First-Order Logic Resolution

Dipsy has been murdered and Tinkey-Winkey, Laa-Laa, and Po are the only suspects. Chief detective Barney is on the case, and brings them in for questioning. Each one tells the truth except for the culprit, who may be lying. Here is what they told Barney.

- Tinkey-Winkey says that she is innocent. She says that Laa-Laa and Dipsy were not friends, and Po and Dipsy were not friends.
- Laa-Laa says that he is innocent, plus that he and Dipsy were friends.
- Po says that she is innocent, and that Laa-Laa and Dipsy were not friends.

As an astute detective, Barney makes the following assumptions about the world:

- Friends don't murder each other.
- There is exactly one killer, and it is one of the Teletubbies.
- The killer may lie, but the other Teletubbies always tell the truth.

Your task is to do the following:

- (a) Write a set of FOL sentences representing the information learned when interviewing the three suspects.
- (b) Write a set of FOL sentences representing the general knowledge assumptions you've made. If necessary for (e) below, include here any other general knowledge sentences that you need.
- (c) Convert all of your sentences in (a) and (b) to clausal normal form.
- (d) State the goal to be solved as an FOL sentence and solve the crime using a resolution refutation proof, showing your result as a proof that derives False.
- (e) Po later tells you that she was a friend of Dipsy. Is the knowledge base containing all of the sentences satisfiable? If so, give an interpretation that makes it true. If not, prove unsatisfiability using resolution.