CMSC 671 (Introduction to AI) – Fall 2018

Homework 3: CSPs, Games, and Probabilities (76 points)
Turnin: Blackboard.

Please submit **Parts I–III** together as a **single PDF file** named *lastname*_hw3.pdf, with parts clearly marked and delineated, and **Part IV** as a file named *lastname*_hw3.zip containing python code.

All files must start with your last name and have your full name(s) in the file, at/near the top. All parts of this assignment must be turned in individually.

PART I. CONSTRAINT SATISFACTION EXERCISES (30 POINTS)

For these questions, you will be trying to solve a constraint satisfaction problem pertaining to feeding customers at a diner. You'll be trying to feed five people, in this order: Alice, Bob, and Eve. However, there are rules about who will eat what.

Egg soup (soup)	**Omelettes (breakfast)**	**Gazpacho (soup)**
Starch Eggs Salt	Eggs Butter Cheese	Peppers Starch Onions

Intensional constraints:

- Bob doesn't like peppers.
- Eve is vegan (no eggs, butter, or cheese).
- No meal should be the same as the meal that immediately follows it.
- Alice and Eve hate each other and will not eat the same kind of food (breakfast *vs.* soup).

There are several ways to express this as a constraint satisfaction problem. For this assignment, you will be using people as variables (A, B, E), and food as values that are assigned (*e, o, g*).

Part A: Constraints (7 pts)

Assignment:

1. Give all extensional constraints, expanding out the English statements above. Use equality and set membership (=, ≠, ∈, ∉). *4 pts*
2. Draw the complete **constraint graph**. Label the arcs and nodes clearly. *3 pts*

Part B: Backtracking search (18 pts)

You will use **simple backtracking search** to find a solution to this constraint satisfaction problem. The variable ordering heuristic is to make assignments to variables in alphabetical order (A, B, E); the value ordering heuristic is to consider the values in the order *e*, *o*, *g*. Indicate instantiations with arrows: A←*o*, B←*e*, etc.

Assignment:

3. What are *b* and *d* of the tree? *2 pts*
4. Show the complete search tree to depth 3 (counting the initial state). Nodes must clearly show the current state. *5 pts*
5. What is the final instantiation found by backtracking search? *3 pts*
6. How many nodes are visited (selected) by this search method? *4 pts*
7. How many would be visited by BFS? How many by DFS? *4 pts*

Part C: Solution spaces (5 pts)

Assignment: Answer the following questions, in your own words.

8. How large is the search space for this problem? That is, how many different assignments, *legal or illegal*, are there? *2 pts*
9. For this problem, how many different *solutions* (legal instantiations) are there? *3 pts*

PART II. GAME PLAYING: ROLLING DICE (20 POINTS)

Consider a (very modified) dice-rolling game “Going to Boston,”[1] where two players alternate rolling three fair six-sided dice. The rules are as follows:

- Players take turns rolling all three dice and scoring as follows:
  a. 3-of-a-kind (Ex: ⚁ ⚁ ⚁, ⚅ ⚅ ⚅): 12 points, and the **game ends**.
  b. 2-of-a-kind (Ex: ⚃ ⚂ ⚂, ⚄ ⚁ ⚄): 4 points, and it’s the other player’s turn.
  c. No matching dice (Ex: ⚀ ⚄ ⚁, ⚁ ⚃ ⚅): choose *either*
     i. Take 2 points, *or*
     ii. Re-throw the dice once and scoring as above. If no matches are rolled, a player loses 2 points.
     iii. Either way, it’s the other player’s turn.
- The game stops after some fixed number of rounds.
- The player with the highest score is the winner.

Assignment: Answer the following questions about playing this game.

10. Draw the 2-ply (one move for each player) expectiminimax tree for this problem. *10 pts*
    - Use upward triangles for MAX, downward triangles for MIN, and circles for chance nodes.
    - Label **every** arc from a chance node with its probability.
    - Label MIN and MAX nodes with the current game state.
    - Assume that a player who rolls no matching dice, case iii, has an equal chance of choosing to re-roll or to stop.
11. Using the static evaluation function (score(player1) - score(player2)), evaluate the leaf nodes, then back up the leaf values to the root of the tree. Annotate each of the nodes in the tree with its backed-up minimax value. *7 pts*
12. It’s not wise to choose randomly whether to reroll or stop, because one of those is a better option. Which is the better choice, and why? Please justify your answer using the values in your tree. *3 pts*

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[1] Original: icebreakerideas.com/dice-games/#Going_to_Boston_Dice_Game

PART III. BAYES' NETS AND PROBABILITY (16 POINTS)

Assignment: For the Bayesian network shown, calculate the following:

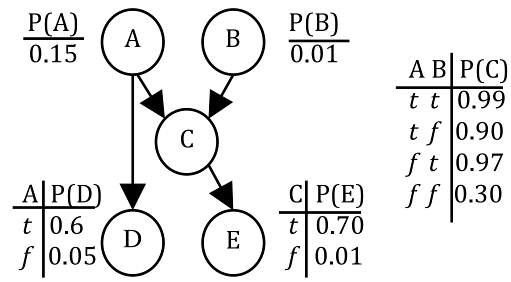

Figure 1: A five-variable Belief Net with associated complete CPTs.

13. Compute P(A, ¬B, C) using the chain rule. *3 pts*
14. Compute P(E) using inference by enumeration. *3 pts*
15. Using the rules for determining when two variables are (conditionally) independent of each other in a BN, answer the following true or false: *5 pts*
    a. $A \perp\!\!\!\perp E$
    b. $B \perp\!\!\!\perp E \mid C$
    c. $A \perp\!\!\!\perp B$
    d. $A \perp\!\!\!\perp B \mid C$
    e. $A \perp\!\!\!\perp B \mid E$
16. Write, in summation form, the formula for computing P(E, ¬A) using inference by enumeration. (You do *not* need to actually compute the probability.) *5 pts*

PART IV. MULTI-AGENT SYSTEMS (10 POINTS)

Assignment: For each of the two normal-form two-player games below, identify the Nash equilibria (if there are any). Explain why these strategy sets are the Nash equilibria of the game, or why no Nash equilibria exist if this is the case.

17. Chicken: Two drivers are headed for a one-lane bridge. If they both swerve out of the way, they "tie" (nobody scores). If one swerves and the other drives straight on, the one who swerved loses a point and the other gains a point. If neither swerves, they both lose big. *5 pts*

	Straight	**Swerve**
Straight	-10, -10	+1, -1
Swerve	-1, +1	0, 0

18. Rock-Paper-Scissors: each of two players chooses one of Rock, Paper, or Scissors, then the players reveal their choices to each other simultaneously. Rock beats scissors, scissors beats paper, and paper beats rock, as shown. *5 pts*

	R	**P**	**S**
R	0, 0	-1,+1	+1, -1
P	+1, -1	0, 0	-1, +1
R	-1, +1	+1, -1	0, 0