Final Exam

600.464/664 Artificial Intelligence
Spring 2020

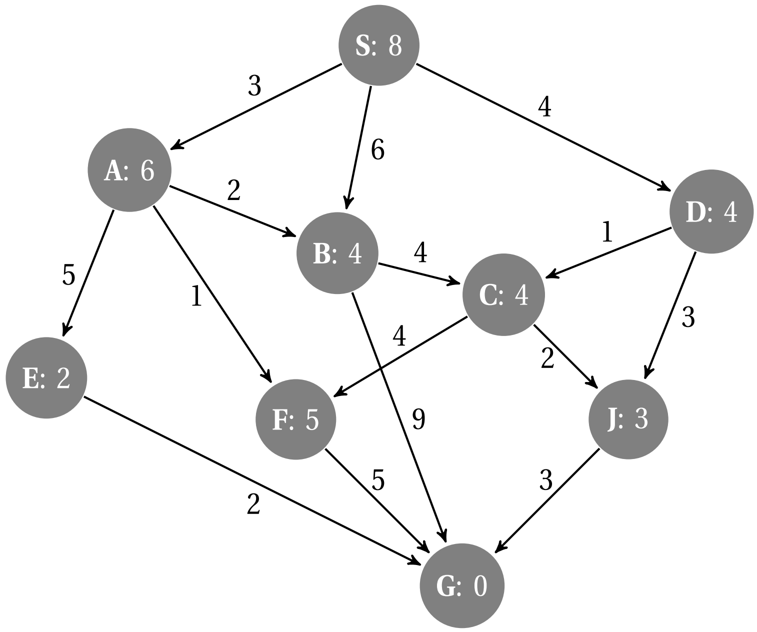
Name: Jason Zhang JHED: jzhan127

Instructions

- Please be sure to write your name in the space above!
- Please show ALL relevant work for your answers and provide explanations when prompted. Failure to do either will result in loss of credit.
- You may upload a edited pdf file (preferably), a scan of printout with hand-written answers, or any other document with answers.
- The exam is due by midnight on Gradescope.

Informed Search *10 points*

Consider the search space below, where **S** is the start node and **G** satisfies the goal test. Arcs are labeled with the cost of traversing them and the heuristic cost to the goal is reported inside nodes (so lower scores are better).

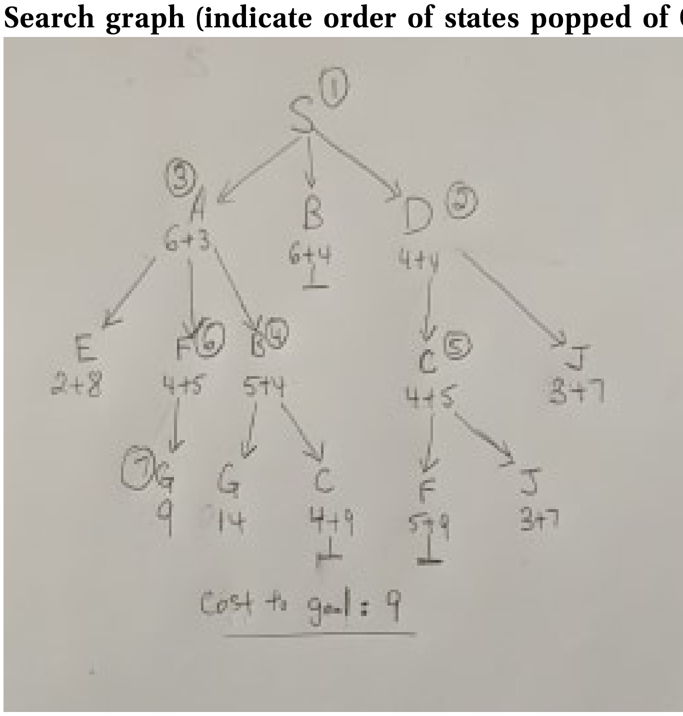


1. (10 points) For A* search, indicate which goal state is reached at what cost and list, in order, all the states popped off of the OPEN list. You use a search graph to show your work. Do not expand paths that revisit states at higher cost.

   Note: When all else is equal, nodes should be removed from OPEN in *alphabetical* order.

   Path to goal (cost): 9

   Search graph (indicate order of states popped of OPEN list with numbers):



First Order Logic *15 points*

2. (5 points) Convert the following sentences into first-order predicate calculus logic:

   If a team wins a game, it is happy.

   Answer: $[\forall x\ Team(x) \land \exists y\ Game(y) \land Wins(x, y)] \Rightarrow Happy(x)$

   If a team plays a game, is better than the opponent, and is in good form, it wins the game.

   Answer: $\forall x\ Team(x) \land \exists y\ Team(y) \land \exists z\ Game(z) \land Plays(x, z, y) \land Better(x, y) \land GoodForm(x) \Rightarrow [Wins(x, z)]$

   The Blue Jays play a game against the Tigers.

   Answer: $\exists x\ Game(x) \land Plays(BlueJays, x, Tigers)$

   The Blue Jays are better than the Tigers.

   Answer: $Better(BlueJays, Tigers)$

   The Blue Jays are in good form.

   Answer: $GoodForm(BlueJays)$

3. (5 points) Convert all rules to Conjunctive Normal Form (CNF). You do not need to restate rules that are already in CNF.
   Answer:

   (a) $\neg Team(x) \lor \neg Game(y) \lor \neg Wins(x, y) \lor Happy(x)$

   (b) $\neg Team(x) \lor \neg Team(y) \lor \neg Game(z) \lor \neg Plays(x, z, y) \lor \neg Better(x, y) \lor \neg GoodForm(x) \lor Wins(x, z)$

   (c) $Game(x) \land Plays(BlueJays, x, Tigers)$

(d) Others already in CNF

4. (5 points) Carry out a resolution proof of the statement *The Blue Jays are happy.*
Answer:

14.

3 relevant fields Name, Position, Company

- Albert Altman

4. The blue jays are happy:

$\neg Happy(BlueJay)$ $\qquad$ $\neg Team(x) \lor \neg Game(y) \lor \neg Wins(x, y) \lor Happy(x)$

$\neg Team(x) \lor \neg Game(y) \lor \neg Wins(x, y)$ $\qquad$ $\neg Team(x)\ \neg Team(y) \lor \neg Game(z) \lor \neg Plays(x, z, y) \lor \neg Better(x, y)$
$\neg GoodForm(x) \lor Wins(x, z)$

$\neg Team(x) \lor \neg Team(y) \lor \neg Game(z)$
$\lor \neg Plays(x, z, y) \lor \neg Better(x, y)$
$\neg GoodForm(x)$

$Better(BJ, Tigers)$

$GoodForm(BJ)$

$\neg Team \lor \neg Team(y) \neg Game(z)$
$\lor \neg Plays(x, z, y)$

$Game(x) \land Plays(BJ, x, T)$

$\neg Team \lor \neg Team(y) \lor \neg plays(x, z, y) \land \neg Team \lor \neg Team(y) \lor \neg Game(z)$

$\neg Team(x) \lor \neg Team(y) \lor (\neg plays(x, z, y) \lor \neg Game(z))$

$\neg Team(x) \lor \neg Team(y) \lor \neg (plays(x, z, y) \land Game(z))$

$Game(x) \land Plays(BJ, x, T)$

$\neg Team(x) \lor \neg Team(y)$ $\qquad$ $Team(BlueJays)$

$Team(Tigers)$

$\square$ Therefore we have proven the statement.

Constraint Satisfaction *15 points*

Consider the following Mini Sodoku puzzle.
(numbers are assigned values, letters are names for cells)

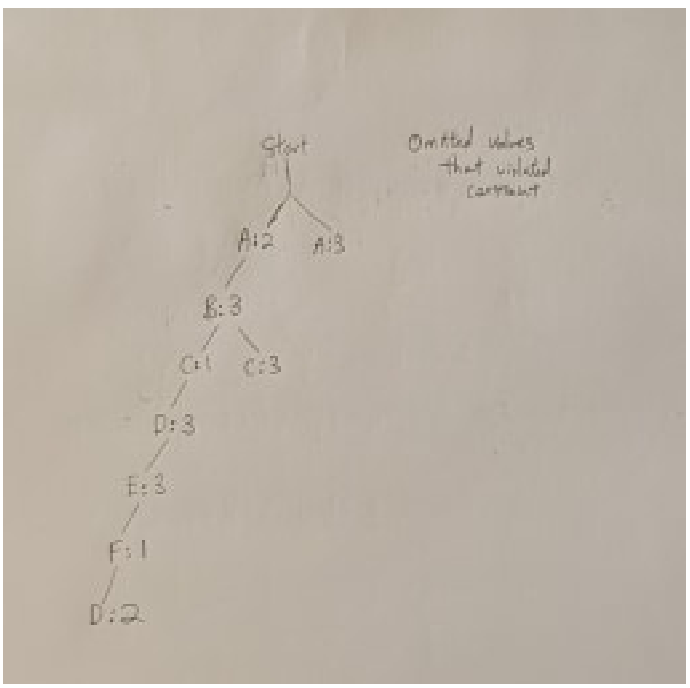
A	B	**1**
C	**2**	D
E	F	G

Recall the rules of Sudoku:

- Each cell is assigned a number (in Mini Sudoku, the numbers are 1, 2, and 3).
- No row can have the same number twice.
- No column can have the same number twice.

These rules can be specified by constraints. You do not need to formally write these constraints down.

5. (8 points) Carry out backtracking search. Explore the search space in the alphabetic order of the cell names, and assign values in numerical order (i.e., first assign 1, then 2, then 3). Draw the search tree. Stop and backtrack at leaves where constraints allow no valid variable assignment.



6. (7 points) Now, use the minimum remaining values (MRV) heuristic. Fill in the following table. Start with a row that specifies the remaining possible values for each variable. Then commit one variable to a value following the MRV heuristic (in case of ties follow alphabetical order).

Step		A	B	C	D	E	F	G
	remaining values	2 3	3	1 3	3	1 2 3	1 3	2 3
1	assigned value		3					
	remaining values	2		1 3	3	1 2 3	1	2 3
2	assigned value	2	3					
	remaining values			1 3	3	1 3	1	2 3
3	assigned value	2	3		3			
	remaining values			1		1 3	1	2
4	assigned value	2	3	1	3			
	remaining values					3	1	2
5	assigned value	2	3	1	3	3		
	remaining values						1	2
6	assigned value	2	3	1	3	3	1	
	remaining values							2
7	assigned value	2	3	1	3	3	2	2

Planning *15 points*

An evil robot has almost completed his evil plan for the total destruction of the human race. He has two nasty chemicals called A and B which are currently stored in containers 1 and 2 respectively. All he has to do now is mix them together in container 3. His designer, an equally evil computer scientist, has equipped the evil robot with a propositional planning system that allows him to reason about the locations of particular things and about moving a thing from one place to another.

7. (5 points) Explain how this problem might be represented within a propositional planning system. Give specific examples of the way in which the start state and goal can be represented.
Answer:
The problem can be represented in a propositional planning system by representing the states as conjunctions of predicates. For example, a start state may be represented as: (we define the contains as C1, C2, C3 and chemicals as A, B and our robot be R). $\forall x \neg Carrying(R, x) \wedge Contains(C1, A) \wedge Contains(C2, B) \wedge \neg Contains(C3, A) \wedge \neg Contains(C3, B)$.
A Goal state could be:
$\neg Contains(C1, A) \wedge \neg Contains(C2, B) \wedge Contains(C3, A) \wedge Contains(C3, B)$
Now to represent actions in this system we do something similar to how STRIPS encodes operations in which there is an Operation, which could be an action like PickUp, a precondition, essentially the state before applying the operation, and the effect, which is the state after the operation.

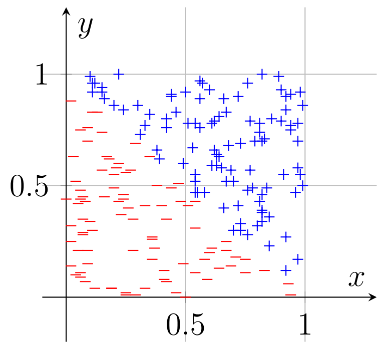
8. (5 points) Describe in detail an algorithm that can be used to find a plan using this form of representation.
Answer:
We could have our algorithm search through all our possible actions in a brute force fashion. All the possible action sequences will constitute our situations. The situation space(space of all situations) is where our search algorithm(planner) will look through. It looks at possible actions and then possible actions from those actions, and so on and so forth until it finds a sequence of actions that leads to a goal state. When it reaches the goal state it will return that sequence of actions chosen as our plan.With brute force strategy we are guaranteed to find a working plan for our system above. A more efficient alternative would be to search backwards from the goal state to the initial state(regression planning), this will reduce our branching factor as we search. The regression planning strategy works due to the fact that as we search backwards, we have enough information to construct a partial precondition state from our current state and thus we are able to regress to that precondition state as we regress, effectively cutting down the actions we have to search through as we go back.

9. (2 points) Give a specific example of a successor-state axiom using the representation you suggested.
Answer:
A successor state axiom for our representation could be: $HaveContainer^{t+1} \Leftrightarrow HaveContainer^{t} \wedge \neg PutDown^{t}$. This essentially states that our fluent HaveContainer can be conditioned to be true in the event that the situation that causes us to not have the container is not true.

10. (3 points) Explain why in this particular planning problem it might be necessary to include one or more precondition axioms and give an example of such an axiom using your representation.
Answer:
It is important due to the fact that there are limitations in our system perhaps by our robot in the sense that it should not logically/physically be able to pick up. We need to see if the robot can actually perform the action in essence and We need to be able to filter our the situation space in order to ignore non relevant actions. An example of a precondition could be only pickup a container if you are not currently holding one: $\forall x\ pickup(R, x) \Leftrightarrow \forall z\ Carrying(R, z)$

Machine Learning **15 points**

Consider the following plot of data points.



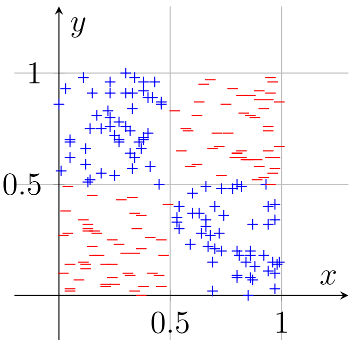
11. (5 points) Write down the formula for a linear classifier function $f(x, y) \to$ *value* where positive output *values* correspond to the sign **+** and negative *values* correspond to the sign **–**. The classifier should classify all training examples corrrectly.

$$f(x,y) = \begin{cases} 1 & y > -x+1 \\ -1 & y < -x+1 \end{cases}$$

1 is positive examples

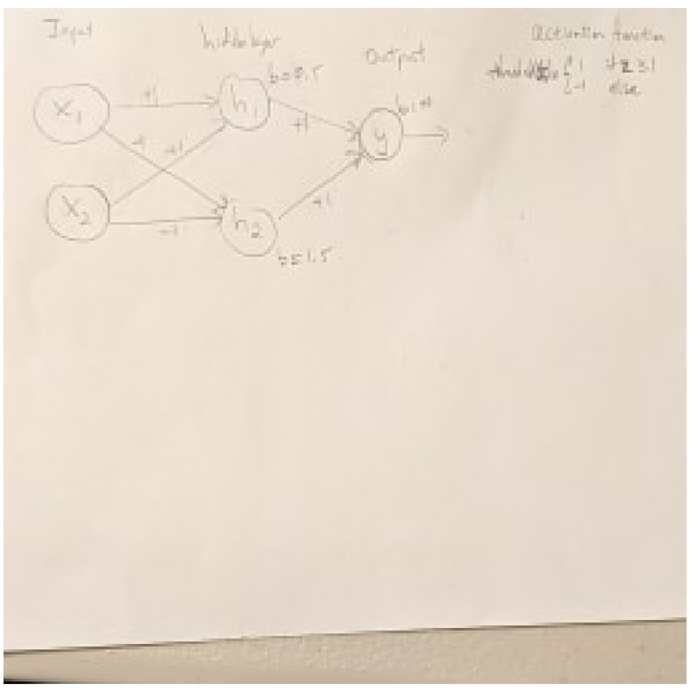
-1 is negative examples

Now consider the following plot of data points.



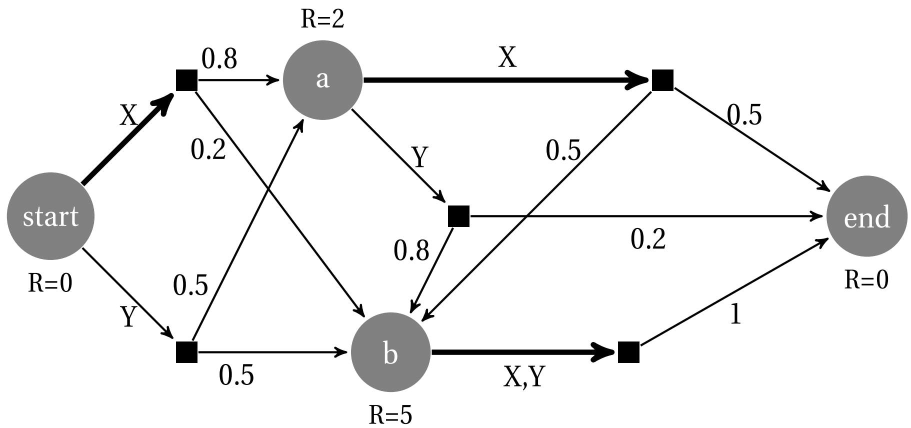
12. (10 points) Draw a neural network with weight values that classifies all values correctly. You may use the following activation function.

$$\text{threshold}(z) = \begin{cases} 1 & \text{if } z \geq 1 \\ -1 & \text{else} \end{cases}$$



Reinforcement Learning *15 points*

Consider the *non-deterministic* reinforcement environment drawn below. States are represented by circles, and actions by squares. The Probability of a transitions is indicated on the arc from actions to states. *Immediate* rewards are indicated above and below states. Once the agent reaches the **end** state the current episode ends.



13. (15 points) Consider two possible policies: always take action **X** or always take action **Y**. For each policy, compute the answers to the following questions.

    (a) What paths could be taken?

    (b) What is each path's probability?

    (c) What is each path's reward?

    (d) What is the utility of each state?

13 a. Always take x:

1. Start → a → b → end
2. Start → a → end
3. Start → b → end

Always take y:

1. Start → b → end
2. Start → a → b → end
3. Start → a → end

b. Always take x:

1. Start → a → b → end = 0.8 · 0.5 = 0.4
2. Start → a → end = 0.8 · 0.5 = 0.4
3. Start → b → end = 0.2 · 1 = 0.2

Always take y:

1. Start → b → end = 0.5 · 1 = 0.5
2. Start → a → b → end = 0.5 · 0.8 = 0.4
3. Start → a → end = 0.5 · 0.2 = 0.1

c. *corresponding to the above paths

Always take x:	Always take y:
1. 2+5=7	1. 5
2. 2	2. 2+5=7
3. 5	3. 2

d. Always take x:

Start: 2·0.8 + 0.2·5 + 0.5·5 = 5.1

a: 0.5·5 = 2.5

b: 0

end: 0

Always take y:

Start: 0.5·2 + 0.5·5 + 0.8·5 = 7.5

a: 0.8·5 = 4

b: 0

end: 0

Natural Language Processing *15 points*

We plan to build a database of which persons were hired at which company from the corpus of news paper articles.

The database table looks like follows:

Name	Position	Company
Joe Johnson	sales representative	IBM
Frida Feldman	lawyer	Microsoft
...	...	...

Consider the following sentences

- *Albert Altman was hired by Apple as a software developer.*
- *Booking.com hired Brianna Bayer as an accountant.*
- *Comcast hired as their new CEO Catherine Carter.*

14. (3 points) For each sentence, write a string pattern matching expression that extracts the relevant information (use any pattern matching formalism you like).

    Answer:
    Three relevant fields are Name, Position, and Company:
    Albert Altman was hired by Apple as a software developer.
    Pattern: [name] + "was hired by" + [Company] + "as a" + [Position]
    In this case name: Albert Altman, Company: Apple, Position: software developer.

    Booking.com hired Brianna Bayer as an accountant.
    Pattern: [Company] + "hired" + [name] + "as an" + [position]
    In this case name"Brianna Bayer, Company: Booking.com, Position: accountant.

    Comcast hired as their new CEO Catherine Carter.
    Pattern: [Company] + "hired as their new" + [position] + [name].
    In this case name: Catherine Carter, company: Comcast, position:CEO

15. (3 points) Annotate each sentence with dependency relationships with appropriate labels.
    Answer:

15. NNP VB NNP Prep

Albert Altman was hired by Apple as a software developer.

Subject of is hiring NN

NNP VB NNP Prep

Booking.com hired Brianna Bayer as an accountant

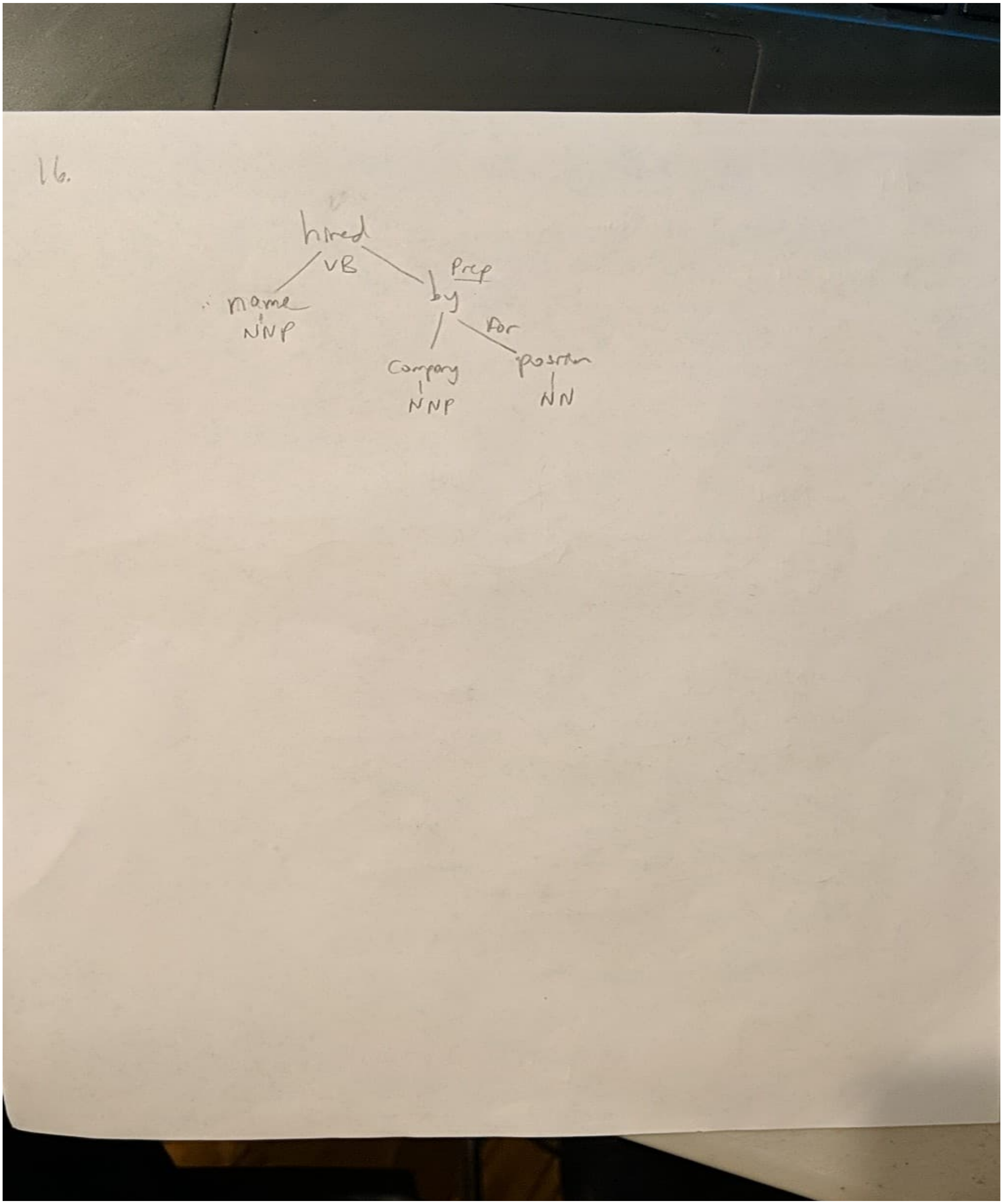
hiring subject of NN

NNP VB Prep Extra NN NNP

Comcast hired as their new CEO Catherine Bayer

hiring Subject of

16. (5 points) Define informally a pattern over dependency structures that allows you to extract the relevant information from all the example sentences for the database table.



17. (4 points) Hiring information may be expressed in many different ways in natural language. Below is a list of general problems in natural language processing. Give an example sentence that contains relevant hiring information for out database that demonstrates why each of these problems poses a challenge for our simple extraction patterns.

- Synonymy
  Alice was picked up by Apple to be a Developer.

- Hypernymy
  John was hired at the phone company Verizon.

- Co-reference
  John said he would want to start as a Developer at Apple.

- Semantic inference
  Alice started coding for the Health Division.