# CS 181 Artificial Intelligence (Fall 2023), Midterm Exam

### Instructions

- Time: 10:15–11:55am (100 minutes)
- This exam is closed-book, but you may bring one A4-size cheat sheet. Put all the study materials and electronic devices into your bag and put your bag in the front, back, or sides of the classroom.
- You can write your answers in either English or Chinese.
- Two blank pieces of paper are attached, which you can use as scratch paper. Raise your hand if you need more paper.
- For multiple choice questions:
  - □ means you should mark ALL choices that apply;
  - ○ means you should mark exactly ONE choice;
  - When marking a choice, please fill in the bubble or square COMPLETELY (e.g., ● and ■). Ambiguous answers will receive no points.
  - For each question with □ choices, you get half of the points for selecting a non-empty proper subset of the correct answers.

## 1 Multiple choice (10 pt)

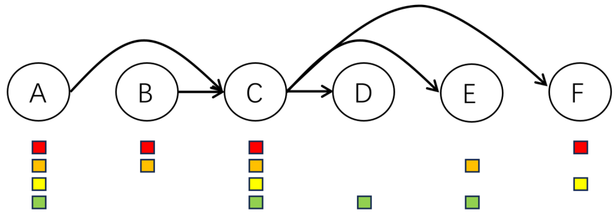
Each question has one or more correct answers. Select all the correct answer(s). For each question, you get 0 point if you select one or more wrong answers, but you get 0.5 point if you select a non-empty proper subset of the correct answers. Fill your answers in the table below.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| | | | | |

| 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|
| | | | | |

1. Which of the following statements is/are true?
   A. For a search tree, the fringe of BFS is a FIFO (First In First Out) queue and it takes $O(bs)$ space, where $b$ is the branching factor and $s$ is the depth of the shallowest solution.
   B. For a search tree, the fringe of DFS is a LIFO (Last In First Out) stack and it takes $O(bm)$ space, where $b$ is the branching factor and $m$ is the maximum depth.
   C. UCS is complete no matter whether the minimum arc cost is positive or not.
   D. In a 3D maze path-finding problem, Euclidean distance is a consistent heuristic function.
   E. None of the above.

2. In class we've talked about an algorithm for tree-structured CSPs. We provided an example here. Each pair of nodes connected by an edge should be assigned with different colors. The domain of each node is given below. Which of the following statements is/are true when solving this specific tree-structured CSP?




A. This CSP can be solved in $O(nd^2)$ time, where $n$ is the number of nodes and $d$ is the domain size.

B. The consistency of edge $\langle$A,C$\rangle$ will be checked before edge $\langle$C,F$\rangle$.

C. After making all edges consistent, the domain of node $C$ will be {red, yellow}.

D. Node $A$ and $F$ can be assigned with different colors in a final solution.

3. In the context of game and adversarial search, which of the following statements is/are correct?

A. In zero-sum games, agents have independent utilities.

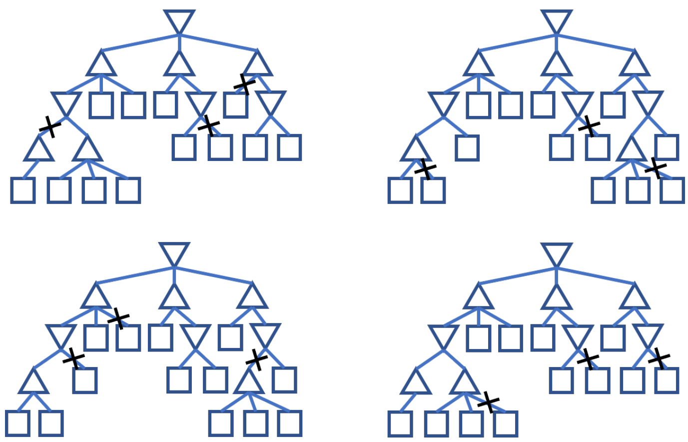
B. The computational complexity of minimax is the same as that of DFS.

C. The assumption behind minimax is that your opponent is rational and smart.

D. The effectiveness of $\alpha - \beta$ pruning is independent of the ordering of child nodes.

E. None of the above.

4. Assume we run $\alpha - \beta$ pruning, expanding successors from left to right, on the game trees shown below. On how many of the four game trees are all three pruning operations possible? (We say a pruning operation is possible on a game tree if there exists a utility assignment to the terminal nodes of the tree such that the pruning will occur if we follow the $\alpha - \beta$ pruning algorithm.)



A. 0.

B. 1.

C. 2.

D. 3.

E. 4.

5. Which of the following statements about propositional logic is/are correct?

   A. In order to show $KB \models \alpha$, we can prove $KB \vee \neg\alpha$ is unsatisfiable.
   B. Truth table enumeration is sound and complete for propositional logic.
   C. $\neg A \vee \neg B \vee \neg(\neg C) \vee D$ is a valid horn clause.
   D. $(A \vee B) \wedge (\neg A \vee C) \equiv (B \vee C)$.
   E. None of the above.

6. Which of the following statements about first-order logic is/are correct?

   A. Forward chaining is sound and complete for first-order horn clauses.
   B. Backward chaining is data-driven, so it avoids working on repeated subgoals.
   C. $\forall x P(x) \equiv \neg(\neg\exists x P(x))$.
   D. $> (\text{Height}(\text{Zhongli}), \text{Height}(\text{Hutao}))$ is a complex sentence in first-order logic.
   E. None of the above.

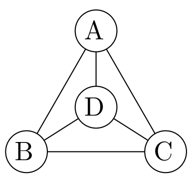
7. Which of the following statements about FOL expression is/are correct?

   A. "Everybody loves someone." can be translated to the following FOL expression:
   $\forall x \forall y\ \text{Loves}(x, y)$.
   B. "Every student at ShanghaiTech is smart." can be translated to the following FOL expression:
   $\forall x\ \text{Student}(x) \wedge \text{At}(x, \text{ShanghaiTech}) \Rightarrow \text{Smart}(x)$.
   C. "Anyone who has a dog doesn't feel lonely." can be translated to the following FOL expression:
   $\forall x \forall y\ \neg\text{Dog}(y) \vee \neg\text{Have}(x, y) \vee \neg\text{Lonely}(x)$.
   D. "There is someone who eats everything." can be translated to the following FOL expression:
   $\forall y \exists x\ \text{Eat}(x, y)$.
   E. None of the above.

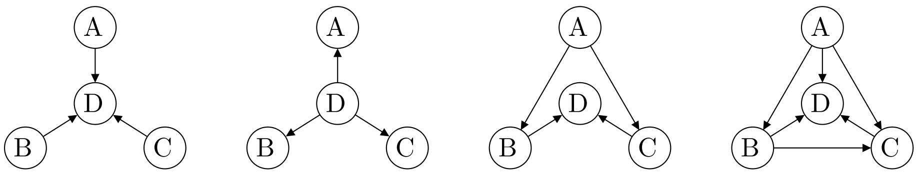
8. Given the factors $P(A|B)$, $P(C|A, B)$ and $P(B)$, which factor will be created after joining on B and summing out B?

   A. $P(A)$
   B. $P(C|A)$
   C. $P(A, C)$
   D. $P(A, B, C)$
   E. None of the above.

9. Suppose A, B, C and D are 4 random variables. Given a Markov network below,



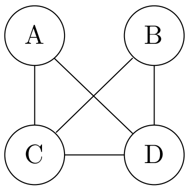

which of the following Bayes networks can always encode the same distribution as the Markov network?




(a) (b) (c) (d)

A. (a).
B. (b).
C. (c).
D. (d).
E. None of the above.

10. Consider the Markov network below, which of the following statements is/are correct?




| | | | $\phi(A,C,D)$ |
|---|---|---|---|
| $+a$ | $+c$ | $+d$ | 10 |
| $+a$ | $+c$ | $-d$ | 20 |
| $+a$ | $-c$ | $+d$ | 30 |
| $+a$ | $-c$ | $-d$ | 40 |
| $-a$ | $+c$ | $+d$ | 40 |
| $-a$ | $+c$ | $-d$ | 30 |
| $-a$ | $-c$ | $+d$ | 20 |
| $-a$ | $-c$ | $-d$ | 10 |

| | | | $\phi(B,C,D)$ |
|---|---|---|---|
| $+b$ | $+c$ | $+d$ | 40 |
| $+b$ | $+c$ | $-d$ | 30 |
| $+b$ | $-c$ | $+d$ | 20 |
| $+b$ | $-c$ | $-d$ | 10 |
| $-b$ | $+c$ | $+d$ | 10 |
| $-b$ | $+c$ | $-d$ | 20 |
| $-b$ | $-c$ | $+d$ | 30 |
| $-b$ | $-c$ | $-d$ | 40 |

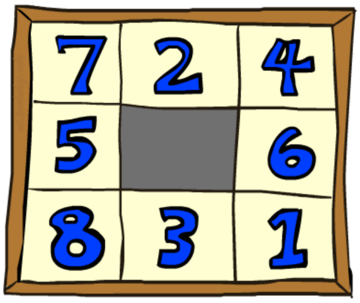
A. $A, C, D$ forms a maximal clique.
B. $A \perp\!\!\!\perp B | C, D$
C. $P(+a, +b, +c, +d) = 0.04$.
D. The Markov blanket of $A$ is $C, D$.
E. None of the above.

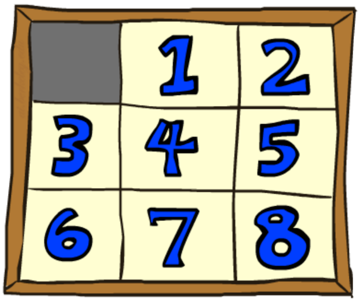
**Solution**:

1. BD
2. AD
3. BC
4. B
5. B
6. A
7. BC
8. C
9. D
10. ABCD

## 2 Search & CSP (10 pt)

### 2.1 Search (5 pt)






The 8 puzzle is a sliding puzzle which has 8 square tiles numbered 1 to 8 in a $3 \times 3$ frame, with one unoccupied position. Tiles adjacent to the open position can be moved by sliding them horizontally or vertically. The goal of the puzzle is to place the tiles in numerical order (from left to right, top to bottom).

(a) **State Space.** What is the size of the state space (including all the states, regardless of whether they can be reached from the start state or not)? (1 pt)

○ 8 ○ 32 ○ $4^9$ ○ 9! ○ $8^9$

**Solution**:

9!

(b) **Branching Factor.** What is the branching factor (i.e., the maximal number of children) of the search tree? (1 pt)

○ 1 ○ 2 ○ 3 ○ 4 ○ 9

**Solution**:

4

(c) **Heuristic Function.** Determine the properties of the following three heuristic functions. Place a checkmark (✓) in the cell if the heuristic function has the corresponding property. (3 pt)

$h_1(s)$ = Total number of tiles misplaced.

$h_2(s)$ = Total manhattan distance to the goal state.

$h_3(s)$ = Total inversion count of the current state.

(Explanation for $h_3(s)$: For each tile, we calculate the inversion count, which is the number of tiles that are ahead of it (i.e., to its right in the same row, or in a row below it) and have a smaller number. We get $h_3(s)$ by summing all inversion counts.)

**Solution**:

| | not admissible | admissible | not consistent | consistent |
|---|---|---|---|---|
| $h_1(s)$ | | | | |
| $h_2(s)$ | | | | |
| $h_3(s)$ | | | | |

| | not admissible | admissible | not consistent | consistent |
|---|---|---|---|---|
| $h_1(s)$ | | ✓ | | ✓ |
| $h_2(s)$ | | ✓ | | ✓ |
| $h_3(s)$ | ✓ | | ✓ | |

## 2.2 CSP (5 pt)

Course arrangement is a real-world CSP. For simplicity, suppose we need to schedule 6 courses: CS280 **(C)**, SI251 **(S)**, POLI2004 **(P)**, FORE2018 **(F)**, GEPE1001 **(G)**, and BIO1001 **(B)** into the time table shown below. We use index 1–10 to denote each time slot. Each course shall be assigned to only one time slot.

| | Mon. | Tue. | Wed. | Thu. | Fri. |
|---|---|---|---|---|---|
| A.M. | 1 | 3 | 5 | 7 | 9 |
| P.M. | 2 | 4 | 6 | 8 | 10 |

Here are the constraints:

i) **C** in Wed. P.M. or Fri. P.M.

ii) **S** in A.M.

iii) **P** in Tue. P.M. or Wed. P.M.

iv) **F** in Tue.

v) **G** in P.M.

vi) **B** in Mon. A.M. or Wed A.M.

vii) No time conflict between any two courses

viii) **S** is scheduled before **C**

ix) **F** is scheduled before **P**

x) **B** is scheduled before **G**

(a) **Unary Constraints.** Update the domain of each course by removing time slots that violate **unary constraints**. Fill the **updated** domain in the table below. We have filled **C** as an example. (1 pt)

| **C** | **S** | **P** |
|---|---|---|
| 6,10 | | |
| **F** | **G** | **B** |
| | | |

**Solution**:

| **C** | **S** | **P** |
|---|---|---|
| 6,10 | 1,3,5,7,9 | 4,6 |
| **F** | **G** | **B** |
| 3,4 | 2,4,6,8,10 | 1,5 |

(b) **MRV & LCV.** (3 pt)

(1) Assume we have assigned **C**=10. Suppose we are using arc consistency as our filtering strategy. By applying the Minimum Remaining Values (MRV) strategy, which variable or variables should we choose next? (1.5 pt)

☐ S ☐ P ☐ F ☐ G ☐ B

**Solution**:
P,F,B

(2) Assume we have assigned **C**=10. Suppose we are using arc consistency as our filtering strategy. If we choose **P** as the next variable to be assigned. By applying the Least Constraining Values (LCV) strategy, which value should we choose to assign? (1.5 pt)

○ 1 ○ 2 ○ 3 ○ 4 ○ 5
○ 6 ○ 7 ○ 8 ○ 9 ○ 10

**Solution**:
6

(c) **Iterative Improving.** Instead of running backtracking search, you decide to start over and run iterative improvement with the min-conflicts heuristic for value selection. Starting with the following assignment:

**C**:6, **S**:8, **P**:2, **F**:3, **G**:4, **B**:5

For each variable, write down how many constraints it violates in the table below. It helps us reassign variable values to minimize conflicts. (1 pt)

| **C** | **S** | **P** |
|---|---|---|
| | | |
| **F** | **G** | **B** |
| | | |

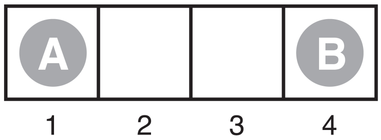
**Solution**:

| **C** | **S** | **P** |
|---|---|---|
| 1 | 2 | 2 |
| **F** | **G** | **B** |
| 1 | 1 | 1 |

# 3 Game. (10pt)

## 3.1 Chess Game (4 pt)

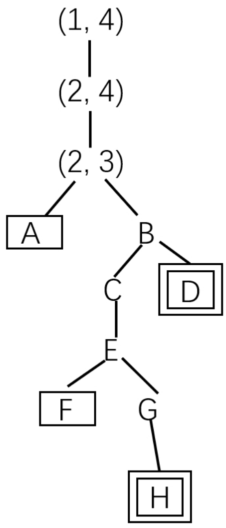
Consider the following two-player chess game. The figure below represents the starting state.




Player A moves first and the two players then take turns. Each player must move his token to an open adjacent space in either direction. If the opponent occupies an adjacent space, then a player may jump over the opponent to the next open space if any. For example, if A is on 3 and B is on 2, then A may move back to 1. The game ends when one player reaches the opposite end of the board. If player A reaches space 4 first, then the value of the game to A is +1; if player B reaches space 1 first, then the value of the game to A is −1.

Alice constructed the game tree below with the following notations.

- Each state is represented by a tuple $(S_A, S_B)$, indicating the locations of the two tokens.
- The terminal state is put in a square box.
- Loop states (states that already appear on the path to the root) are put in double square boxes.




(1). Write down the tuple notation (i.e., $(S_A, S_B)$) of the following states of the game tree above. (2pt)

| A | D | E | H |
|---|---|---|---|
| | | | |

(2). Dose the standard minimax algorithm work for this problem? (1pt)

○Yes. ○No.

(3). According to the game tree, $A$ has a strategy to win the game no matter how $B$ moves. If we change the game from 4 squares to 5 squares, with all the rules unchanged, does $A$ still have a strategy to win the game no matter how $B$ moves? (2pt)

○Yes. ○No.

**Solution:**

| A | D | E | H |
|---|---|---|---|
| (4,3) | (1,4) | (3,2) | (2,4) |

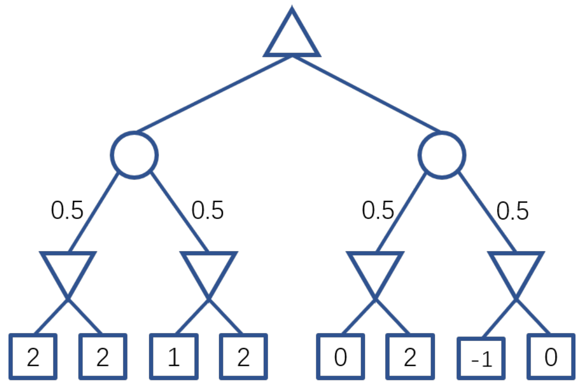
(1)

(2) Yes. / No.

(3) No.

## 3.2 Game Tree with Chance Node (6 pt)

We use a circle to represent a chance node, in which an agent makes its decision according to the probabilities marked on the edges to the child nodes. The figure below shows the complete game tree for a trivial game. Assume that the leaf nodes are to be evaluated in a left-to-right order, and that before a leaf node is evaluated, we know nothing about its value, i.e., the range of possible values is $-\infty$ to $\infty$.




(1). Based on this game tree, which is the best move from the root node? (2pt)

○Left. ○Right.

(2). Given the values of the first six leaves, do we need to evaluate the seventh and eighth leaves? (1pt)

○Yes. ○No.

(3). Given the values of the first seven leaves, do we need to evaluate the eighth leaf? (1pt)

○Yes. ○No.

(4). Suppose the leaf node values are known to lie between $-2$ and 2 inclusive. After the first two leaves are evaluated, what is the value range for the chance node on the left? (1pt)

Answer: ____________________________

(5). How many leaf nodes are there that need *not* be evaluated under the assumption in (4)? (1pt)

Answer: ________________

**Solution**:

(1) Left.

(2) Yes.

(3) No.

(4) $[0, 2]$.

(5) 3.

# 4 Logic (10 pt)

Hey, Travelers! Welcome to Fontaine, the country of Justice!

Fontaine is ruled by Furina, the Hydro Archon and God of Justice. All people in Fontaine worship Furina. Despite her power, Furina is troubled by some tricky problems these days.

You are invited to Fontaine by an anonymous letter to help Furina deal with her trouble. Now, the first problem is how to get in touch with Furina. Luckily, you find two helpful natives in Fontaine, Lyney and Lynette. They are willing to share some information about Furina with you.

*Lyney (Lynette's brother)*

Hi, traveler! It seems that you are searching for something.

*Paimon (Your Companion)*

Yes! We have to find Lady Furina, but we are not familiar with Fontaine...

*Lynette (Lyney's sister)*

Oh, Furina and her assistant BigWei usually stays at the court. To be more specific, at least one of Furina and BigWei will stay at the court for judgement.

*Lyney (Lynette's brother)*

Yes. I remember that several days ago, BigWei said he would be absent from judgement for a month.

*Paimon (Your Companion)*

Does it mean we may find Furina at the court?

*Lyney (Lynette's brother)*

You may not. As far as I am concerned, if Furina stays at the court happily, or both of Furina and BigWei are at the court, then she will meet you.

*Lynette (Lyney's sister)*

I am sure that Furina is happy as I saw her eating a lot of puff and pudding yesterday. She loves dessert.

*You (The Traveler)*

That's great! We can definitely meet Furina today, because ...

(**Start of this problem**)

## 4.1 Translate to propositional logic (1pt)

You want to explain why you are confident of meeting Furina. Propositional logic is quite helpful in such circumstances, so you continue saying that:

You (The Traveler)

We can define
A to represent *BigWei is at the court,*
B to represent *Furina is at the court,*
C to represent *Furina is happy,*
D to represent *Furina will meet us.*

Then we can translate each sentence into a propositional clause:

*"at least one of Furina and BigWei will stay at the court."* A∨B

*"BigWei is absent from judgement."* ¬A

*"Furina is happy."* C

*"If Furina stays at the court happily, or both of Furina and BigWei are at the court, then she will meet us."* ??

**Instruction**: Please select the correct statement to replace the above ?? from the candidates below by filling up the circle like ●, not ✓:

○ $(B \wedge C) \vee (A \wedge B) \Rightarrow D$

○ $(B \vee C) \vee (A \wedge B) \Rightarrow D$

○ $(B \vee C) \wedge (A \vee B) \Rightarrow D$

**Solution**:

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

## 4.2 Convert to Conjunctive Normal Form (2pt)

Now you can convert and combine these clauses into **Conjunctive Normal Form** (CNF). The first three clauses $A \vee B$, $\neg A$, $C$ are quite simple and we can just use $\wedge$ to combine them. The last clause which you selected in 4.1 is more complicated, please try to convert it by yourself.

**Instruction**: To fill in the blank $(A \vee B) \wedge (\neg A) \wedge C \wedge$ ______(conversion of the clause you choose in 4.1), please select the proper conversion from the candidates below by filling up the circle like ●, not ✓:

○ $(\neg B \vee \neg C \vee D) \wedge (\neg A \vee \neg C \vee D) \wedge (\neg B \vee \neg D) \wedge (\neg B \vee \neg A \vee D)$

○ $(\neg B \vee \neg C \vee D) \wedge (\neg A \vee \neg B \vee D)$

○ $(\neg B \vee \neg C \vee D) \wedge (\neg A \vee \neg C \vee D) \wedge (\neg A \vee \neg B \vee D)$

○ None of the above.

**Solution**:

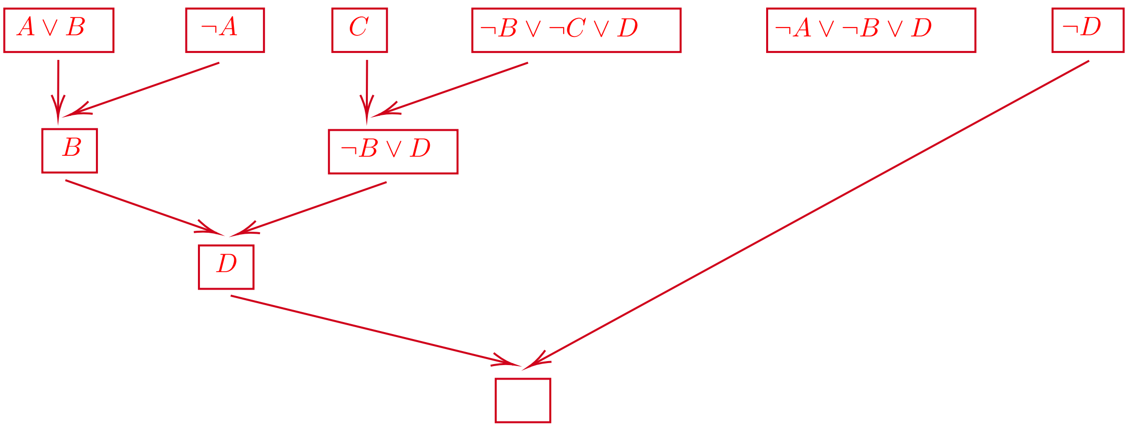
$(\neg B \vee \neg C \vee D) \wedge (\neg A \vee \neg B \vee D)$

### 4.3 Resolution (2pt)

Finally, we have a clause in CNF. We only need to use resolution to prove the conclusion that 'Furina will meet us'.

**Instruction**: Use **resolution** to prove that $(A \vee B) \wedge (\neg A) \wedge C \wedge$ ______ $\models D$ (the blank represents the clause you choose in 4.2). Complete the remaining steps of the proof below. Feel free to add any clause blocks according to your needs.


**Solution**:



Paimon (Your Companion)

How smart you are, traveler! Now we can go to the court to meet Furina!

At the court

Furina (God of Justice)

Hi, traveler and Paimon! Have you received my letter? My assistant, BigWei, has been absent for several days.

Paimon (Your Companion)

What happened to him?

Furina (God of Justice)

I guess he might have become unconscious at home, because recently I found that he owned some Sinthe. Sinthe is a kind of toxic drinks. If anyone drinks any toxic drinks, he will become unconscious. All native people in Fontaine will drink any attractive drinks they own. BigWei is also native in Fontaine.

## 4.4 Translate to first-order logic (3pt)

Paimon (Your Companion)

Oh, I'm a little confused. Dear traveler, could you please organize the information?

You (The Traveler)

All right! I've recorded all that Furina has said. I will organize it and show you later.

Now you want to organize the information with first-order logic. First, you define several symbols:

- Fontaine(x): Predicate representing x is a native person in Fontaine.
- Unconscious(x): Predicate representing person x is unconscious.
- Toxic(x): Predicate representing x is a kind of toxic drinks.
- Attractive(x): Predicate representing x is a kind of attractive drinks.
- Own(x,y): Predicate representing person x owns y.
- Drink(x,y): Predicate representing person x drinks y.

- BigWei: Constant representing person's name.
- Sinthe: Constant representing a kind of drinks.

Then you convert what you have recorded into first-order logic clauses.

**Instruction**: Fill in the right blank with the correct FOL translation of the left sentence.

| **Record** | **First-order Logic** |
|---|---|
| Sinthe is a kind of toxic drinks. | Toxic(Sinthe) |
| BigWei is native in Fontaine. | |
| Bigwei owns Sinthe. | Own(BigWei, Sinthe) |
| If anyone drinks any toxic drinks, he will become unconscious. | $\forall x \forall y$ Drink$(x, y) \land$ Toxic$(y) \Rightarrow$ Unconscious$(x)$ |
| All native people in Fontaine will drink any attractive drinks they own. | |

Paimon (Your Companion)

Emm... I think we are still not sure whether BigWei is unconscious or not.

You (The Traveler)

I think ...

**Solution**:

1. Fontaine(BigWei)]
2. $\forall x \forall y$ Fontaine$(x) \land$ Own$(x, y) \land$ Attractive$(y) \Rightarrow$ Drink$(x, y)$
   or $\forall x$ Fontaine$(x) \Rightarrow (\forall y$ Own$(x, y) \land$ Attractive$(y) \Rightarrow$ Drink$(x, y))$
   or $\forall x \forall y\ \neg$Fontaine$(x) \lor \neg$Own$(x, y) \lor \neg$Attractive$(y) \lor$ Drink$(x, y)$
   or any other FOL sentence with the same meaning

### 4.5 Is Paimon Right? (2pt)

**Instruction**: Please select the proper response from the candidates below by filling up the circle like ●, not ✓:

○ Paimon is right. Current information is not enough for us to decide whether BigWei is unconscious or not.

○ Paimon is wrong. We can use forward chaining/backward chaining to prove that BigWei is unconscious.

**Solution**:

Paimon is right.

(**End of this problem**)

Furina (God of Justice)

I have to stay at the court for judgement, so I hope you can go to his house to find out how's it going with him. Are you prepared?

Paimon (Your Companion)

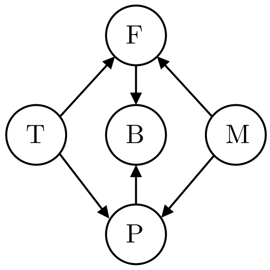
Yes! Let's go, traveler!

You (The Traveler)

Let's go!

# 5 Graphic Models (10 pt)

Suppose B, F, M, P, T are 5 boolean random variables. Consider the Bayes net shown in the figure below.




Given the following CPTs:

| $P(+t)$ |
|---|
| 0.6 |

| $P(+m)$ |
|---|
| 0.1 |

| | | $P(+f \vert T, M)$ | $P(+p \vert T, M)$ |
|---|---|---|---|
| $+t$ | $+m$ | 0.4 | 0.8 |
| $+t$ | $-m$ | 0.1 | 0.9 |
| $-t$ | $+m$ | 0.8 | 0.2 |
| $-t$ | $-m$ | 0.6 | 0.1 |

| | | $P(+b \vert F, P)$ |
|---|---|---|
| $+f$ | $+p$ | 0.9 |
| $+f$ | $-p$ | 0.1 |
| $-f$ | $+p$ | 0.0 |
| $-f$ | $-p$ | 0.0 |

Paimon (Your Companion)

Well... let me guess:
B: Bonus. Obtain a bonus item while making a wish.
P: Probability. The probability of obtaining a bonus item is high while making a wish.
F: Adequate amount of Acquaint Fate. Making a wish consumes certain amount of Acquaint Fate.
M: Spend money to purchase Acquaint Fate.
T: Have already made a lot of wishes. The more wishes you make, the more likely you will get a bonus item.

Lyney (Lynette's brother)

Don't talk like a nut! In our world, purchase will not affect the probability of getting a bonus item.

## 5.1 Exact Inference (6 pt)

### 5.1.1 Probabilities (2 pt)

Which of the following are asserted by the network structure? Choose "yes" if the statement is asserted by the network structure, and "no" otherwise.

1. $P(T, F, M) = P(T)P(F)P(M)$ ○ yes ○ no
2. $P(T|B) = P(T|B, M)$ ○ yes ○ no
3. $P(F|T, M) = P(F|T, M, P)$ ○ yes ○ no

Paimon (Your Companion)

Paimon would like to remind you that
P(A)=P(A|B) if and only if A is independent of B.

**Solution**:

no, no, yes

### 5.1.2 Polytree (1 pt)

Is the network a polytree? Choose “yes” if the network is a polytree, and “no” otherwise.

○ yes ○ no

**Solution**:

no

### 5.1.3 Chance to Get a Bonus (2 pt)

What is $P(+b|+t, -m, -p)$?

Paimon (Your Companion)

Eh? Paimon doesn't understand why the chance to get a bonus item is so low when not making a purchase...

**Solution**:

0.01

### 5.1.4 Ordering of Variable Elimination (1 pt)

Suppose you would like to find $P(+b)$. For each ordering $\alpha$ of variable elimination, we denote $S_\alpha$ to be the size of the largest factor that is generated during the variable elimination process following ordering $\alpha$. Among the 4 orderings below, select the ordering(s) $\alpha$ with the largest $S_\alpha$:

☐ $P, T, F, M$ ☐ $M, P, T, F$ ☐ $T, M, P, F$ ☐ $F, P, M, T$

Paimon (Your Companion)

Paimon remembers that the size of the largest factor is the number of rows in the corresponding CPT.

**Solution:**

AD

## 5.2 Approximate Inference (4 pt)

Suppose you would like to find $P(+b|+m)$. Consider the sample $(+t, +m, +f, +p, +b)$.

### 5.2.1 Rejection Sampling (1 pt)

Will this sample be rejected by rejection sampling? Choose "yes" if the sample will be rejected, and "no" otherwise.

○ yes ○ no

**Solution:**

no

### 5.2.2 Likelihood Weighting (1 pt)

What is the weight of this sample in likelihood weighting?

- ○ 0.09
- ○ 0.1
- ○ 0.1728
- ○ 0.192
- ○ 0.9

**Solution:**

0.1

### 5.2.3 Gibbs Sampling (2 pt)

Suppose we initialize the sample to $(+t, +m, +f, +p, +b)$, and choose to re-sample $T$ first. What is the probability that $T$ will still be re-sampled to $+t$?

*Paimon (Your Companion)*

Paimon thinks it should be somehow related to the markov blanket of T... Oh, things are really getting complicated when it comes to probabilities. Paimon only want the bonus item!

**Solution:**

0.75