CS 161 – Winter 2023 – Final Exam (Sample)
Fundamentals of Artificial Intelligence

Instructor: Prof. Quanquan Gu

2023/03/22: 3:00 PM - 6:00 PM

Name: ______________________ **Student Number**: ______________________

This exam contains 8 pages (including this cover page) and 7 questions. Total of points is 36.
Good luck!

Distribution of Marks

Question:	1	2	3	4	5	6	7	Total
Points:	22	3	2	2	3	2	2	36
Score:								

1. You are given a search tree with one node **A** labeled as a start state and another node **F** labeled as a goal state. List the nodes in the tree according to the order in which they will be **expanded**. The goal test is applied when the node is expanded. When the order of expansion is arbitrary, assume that nodes are expanded from left to right.

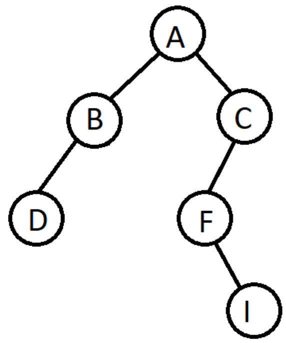

Figure 1: The search tree

(a) (10 points) **Breadth-First Search**

1	2	3	4	5	6	7	8	9	10
A									

Answer: (start from 1) ABCDF

(b) (12 points) **Iterative Deepening Search**: For example, we first limit the search depth to 1, which means the 1st node expanded is A; done. Then we limit the search depth to 2, again the first node expanded is A, and the nodes at depth 2 shall be expanded later. You are required to fill the rest of the expansion sequence, until the algorithm reaches the goal.

1	2	3	4	5	6	7	8	9	10	11	12
A	A										

Answer: (start from 1) AABCABDCF

2. True or False

   (a) (1 point) $\Pr(\alpha \vee \beta) = \Pr(\alpha) + \Pr(\alpha \wedge \beta)$ for any events α and β

      A. True

      B. False

   Answer: B

   (b) (1 point) $(X \wedge Y) \vee (\neg X \wedge \neg Y)$ is a disjunctive normal form (X, Y are variables).

      A. True

      B. False

   Answer: A

   (c) (1 point) $\forall x \exists y$ Likes(x, y) is equivalent to $\forall y \exists x$ Likes(y, x)

      A. True

      B. False

   Answer: A

3. Single Choice Questions

   (a) (1 point) The following two sentences

$$\forall x\ g(x) \Rightarrow (\exists t\ f(t) \wedge h(x,t))$$
$$\exists t\ f(t) \wedge (\forall x\ g(x) \Rightarrow h(x,t))$$

   are

      A. Equivalent

      B. The first implied the second

      C. The second implied the first

      D. None of the others

   Answer: C

   (b) (1 point) The result of dropping quantifiers from $\forall x \exists y f(x, y)$ during the process of converting to Conjunctive Normal Form (CNF), gives (A is the Skolemization constant, F is the Skolemization function)

      A. $f(x, F(x))$

      B. $f(F(x), y)$

      C. $f(x, F(y))$

      D. $f(x, A)$

      E. None of the others

   Answer: A

4. Suppose the probability of a patient having cancer is 0.2. A test will produce a positive result with probability 0.9 if a patient has cancer, and will produce a negative result with probability 0.7 if a patient does not have cancer.

   (a) (1 point) Which of the following is the closest to the probability of a patient having cancer given a positive test result?

   A. 0.2
   B. 0.4
   C. 0.6
   D. 0.8

   Answer: B, $(0.2 \times 0.9)/(0.2 \times 0.9 + 0.8 \times 0.3) = 3/7$, closest to 0.4.

   (b) (1 point) Which of the following is the closest to the probability of a patient having cancer given two positive test results? Suppose the tests results are independent given whether the patient has cancer or not.

   A. 0.3
   B. 0.5
   C. 0.7
   D. 0.9

   Answer: C, $(0.2 \times 0.9 \times 0.9)/(0.2 \times 0.9 \times 0.9 + 0.8 \times 0.3 \times 0.3) = 9/13$, closest to 0.7.

5. Answer the following 3 questions based on the Bayesian network given in Figure 2.

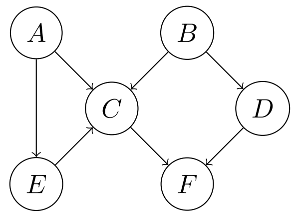

Figure 2: Bayesian network.

(a) (1 point) The conditional probability $\Pr(D|A)$ can be expressed in terms of $\Pr(B)$ and $\Pr(D|B)$. True or false?

A. True

B. False

Answer: A. $\Pr(D|A) = \frac{\Pr(D,A)}{\Pr(A)} = \frac{\sum_b \Pr(D,A,b)}{P(A)} = \frac{\sum_b \Pr(D|b)\Pr(b)\Pr(A)}{\Pr(A)} = \sum_b \Pr(D|b)\Pr(b)$.

(b) (1 point) E is conditionally independent with F given A. True or false?

A. True

B. False

Answer: B. F is a descendant of E.

(c) (1 point) Suppose all variables be either 0 or 1, and we are given the following probabilities:

$$
\begin{aligned}
&\Pr(A=1) = 0.4, \\
&\Pr(E=1|A=1) = 0.2, \quad \Pr(E=1|A=0) = 0.3 \\
&\Pr(C=1|A=1,B=1,E=1) = 0.8, \quad \Pr(C=1|A=1,B=1,E=0) = 0.7, \\
&\Pr(C=1|A=0,B=1,E=1) = 0.5, \quad \Pr(C=1|A=0,B=1,E=0) = 0.6.
\end{aligned}
$$

Which of the following is the conditional probability $\Pr(C=1|B=1)$?

A. 0.064

B. 0.154

C. 0.630

D. Cannot be calculated based on the given data

E. None of the above

Answer: C. We have

$$
\begin{aligned}
&\Pr(C=1|B=1) = \frac{\Pr(C=1,B=1)}{\Pr(B=1)} = \frac{\sum_a \sum_e \Pr(a,B=1,C=1,e)}{\Pr(B=1)} \\
&= \frac{\sum_a \sum_e \Pr(a)\Pr(e|a)\Pr(B=1)\Pr(C=1|a,e,B=1)}{\Pr(B=1)} \\
&= \sum_a \sum_e \Pr(a)\Pr(e|a)\Pr(C=1|a,e,B=1) \\
&= 0.63.
\end{aligned}
$$

6. Consider the following constraint satisfaction problem. We have 4 variables $\{A, B, C, D\}$. The domain of each variable is $\{1, 2, 3, 4\}$. The constraints, as shown in the graph, require any connected variables must not have the same value.

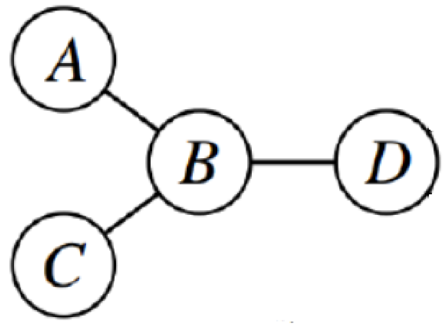

Figure 3: Constraint satisfaction problem

(a) (1 point) According to the Degree Heuristic (choose the variable with the most constraints on remaining variables). Which of the variable we should choose first? (choose all that applies)

A. A
B. B
C. C
D. D

Answer: B. Node A, C, D only have one constraint with the node B and node B has three constraints with node A, C, D.

(b) (1 point) Suppose we assigned $A = 1$ and performed forward checking. Suppose by some criterion, we decide to first explore the variable D. According to the Least Constraining Value strategy, which value to D should we choose first?

A. 1
B. 2
C. 3
D. 4

Answer: A. If we assign value $2, 3, 4$ to node D, then node B only has two possible value remaining. If we assign value 1 to node D, then node B still has three possible value (2,3,4).

7. Given the following search tree, suppose we are using alpha-beta pruning to help with the search.

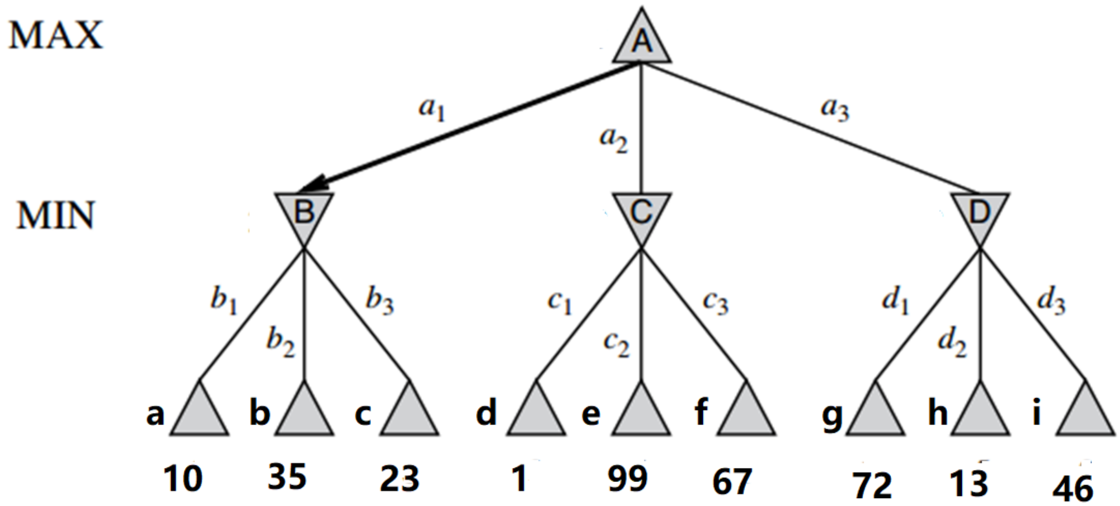

Figure 4: Constraint satisfaction problem

(a) (1 point) What is the value of node A?

A. 1
B. 67
C. 13
D. 99

Answer: C. After taking a minimum of leaf nodes, the value of nodes (B, C, D) are $(10, 1, 13)$. Therefore, the value of node A is $\max(10, 1, 13) = 13$

(b) (1 point) How many nodes will be pruned by alpha-beta pruning?

A. 0
B. 1
C. 2
D. 3

Answer: C. After calculating the value of node $B(10)$, the value of (max) node A is no less than 10. Thus, alpha-beta search will prune the nodes e, f, after searching the node d and finding that the value of node C is no more than 1.

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