CS-171, Intro to A.I. — Final Exam — Fall Quarter, 2017

A few errors and improvements, noticed during the exam, have been corrected or revised below.

YOUR NAME: ______________________________

YOUR ID: __________ ID TO RIGHT: __________ ROW: ________ SEAT: ________

The exam will begin on the next page. Please, do not turn the page until told.

When you are told to begin the exam, please check first to make sure that you have all 14 pages, as numbered 1-14 in the bottom-right corner of each page (including scratch paper at the end). We wish to avoid copy problems. We will supply a new exam for any copy problems.

The exam is closed-notes, closed-book. No calculators, cell phones, electronics.

Please turn off all cell phones now. No electronics are allowed at any point of the exam.

Please clear your desk entirely, except for pen, pencil, eraser, and an optional water bottle. Scratch paper is not needed because it is provided at the end of the Exam.

This page summarizes the points for each question, so that you may plan your time.

1. (12 pts total, 2 pts each) Predictive Error vs. Model Complexity.

2. (8 pts total, 1 pts each) FOPL and English correspondences.

3. (10 pts total, -1 pt each wrong answer, but not negative) Search Properties.

4. (10 pts total, 2 pts each) Propositional Logic.

5. (14 pts total, 2 pts each) Probability Formulas.

6. (4 pts total, -1 pt for each error, but not negative) Mini-Max Search in Game Trees.

7. (8 pts total, -1 for each error, but not negative) Alpha-Beta Pruning.

8. (8 pts total, 1 pt each) Constraint Satisfaction Problem (CSP) Concepts.

9. (4 pts total, 2 pts each) Bayesian Networks.

10. (10 pts total, 2 pts each) English to FOL Conversion.

11. (7 pts total, -1 pt for each edit step from your answer to the correct answer, but not negative) The Knowledge Engineering process.

12. (5 pts total, 1 pt each) Probability.

<u>The Exam is printed on both sides to save trees! Work both sides of each page!</u>

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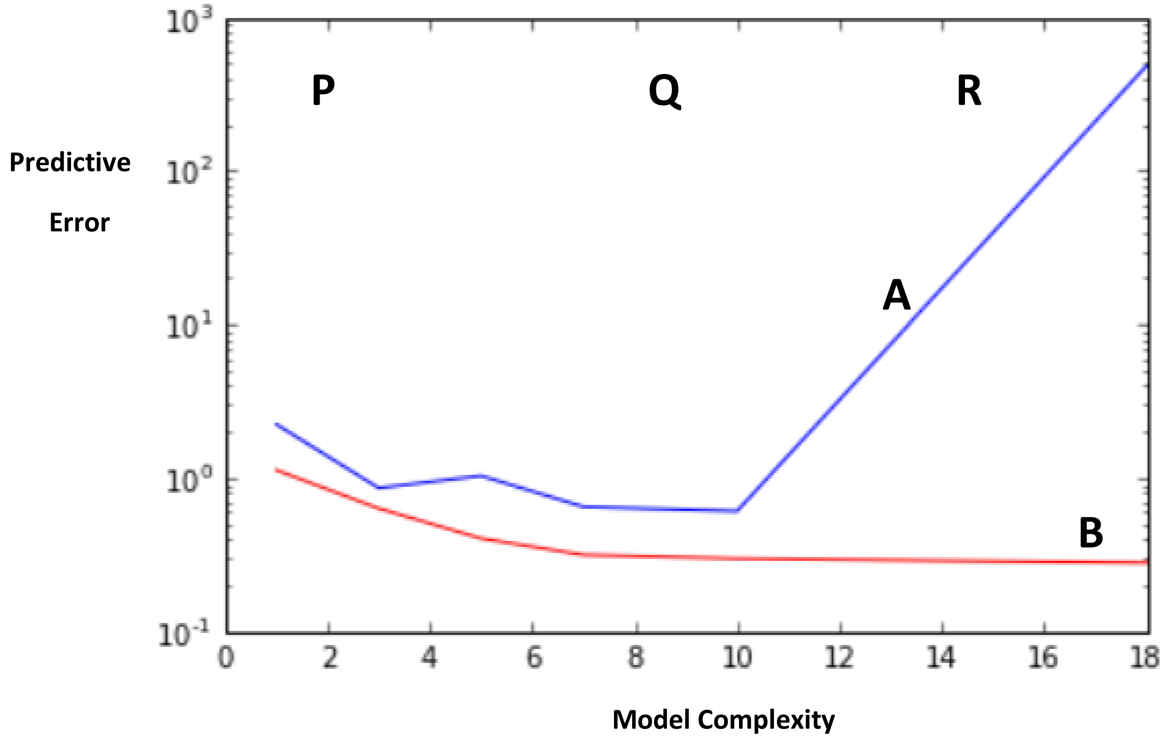
1. (12 pts total, 2 pts each) Predictive Error vs. Model Complexity. Below is a graph of Predictive Error (y-axis) vs. Model Complexity (x-axis), and how Error on Test/Training Data varies as Model Complexity varies.



1.a. (2 pts) Which curve is the Error on Training Data **(write A or B):** ____________

1.b. (2 pts) Which curve is Error on Test Data **(write A or B):** ________________

1.c. (2 pts) If I get more Training Data, how would my Error on Test Data change?

Mark "X" in exactly one blank line:

______ Error decreases. ______ Error stays the same. ______ Error increases.

1.d. (2 pts) Which part of the x-axis corresponds to Overfitting? **(write P, Q, or R)** ___________

1.e. (2 pts) Which part of the x-axis corresponds to Underfitting? **(write P, Q, or R)** __________

1.f. (2 pts) Which part of the x-axis corresponds to Ideal Model Complexity? **(write P, Q, or R)** ____________

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2. (8 pts total, 1 pts each) FOPL and English correspondences. Fill in each blank below with Y (Yes) or N (No) based on whether the First Order Predicate Logic expression is equivalent to the English sentence.

2.a. (1 pt) _______ All cats are mammals.

$\forall x \, Cat(x) \Rightarrow Mammal(x)$

2.b. (1 pt) _______ For everyone, there is someone whom they love.

$\forall x \, \exists y \, Loves(x, y)$

2.c. (1 pt) _______ There is someone whom everyone loves.

$\forall x \, \exists y \, Loves(x, y)$

2.d. (1 pt) _______ Everyone likes ice cream.

$\neg \exists x \, \neg Likes(x, IceCream)$

For questions 2.b,c,d, special instructions were issued during the test: Assume that the only objects in the world are persons! I.e., assume

$\forall$x Person(x)

This fix was necessary because the guard predicate "Person(x) $\Rightarrow$ …" was omitted.

2.e. (1 pt) _______ Jacky has a brother who is Rick's classmate.

$\forall x \, Brother(x, Jacky) \Rightarrow ClassMate(x, Rick)$

2.f. (1 pt) _______ Everyone has a favorite food.

$\forall x \exists y \, Person(x) \Rightarrow [Food(y) \wedge Favorite(y, x)]$

2.g. (1 pt) _______ Every person at UCI is smart.

$\neg \exists x \; Person(x) \; \wedge At(x, UCI) \wedge \; \neg Smart(x)$

2.h. (1 pt) _______ There is someone at UCI who is smart.

$\exists x \; Person(x) \; \wedge At(x, UCI) \; \Rightarrow Smart(x)$

3. (10 pts total, -1 pt each wrong answer, but not negative) Search Properties.
Fill in the values of the four evaluation criteria for each search strategy shown. Assume a tree search where b is the finite branching factor; d is the depth to the shallowest goal node; m is the maximum depth of the search tree; C* is the cost of the optimal solution; step costs are identical and equal to some positive ε; and in Bidirectional search both directions use breadth-first search.

Note that these conditions satisfy all of the footnotes of Fig. 3.21 in your book.

Criterion	Complete?	Time complexity	Space complexity	Optimal?
Breadth-First				
Uniform-Cost				
Depth-First				
Iterative Deepening				
Bidirectional (if applicable)				

4. (10 pts total, 2 pts each) Propositional Logic. Consider an internet packet that can be present in multiple devices simultaneously (e.g., router can cache the packet even if it is already delivered to a computer). We use propositional logic to represent the packet location. The packet, router, computer in this question are unique.

Ontology:

R: The packet is at the router.
C: The packet is at the computer.
S: The packet is oversized.

Translate the following two English sentences into propositional logic CNF, using the given ontology. Note that these statements are independent. The first is done for you, as an example.

4.example. The packet is at the router and at the computer.

$R \land C$

4.a. (2 pts) The packet is at the router or at the computer.

____

4.b. (2 pts) If the packet is oversized, then it is not at the computer.

____

For problems 4.c,d, some students were confused between the use of R and C as Boolean propositional symbols in the rest of the problem, and the use of R and C to indicate location in problems 4.c,d. Any future offering of this problem will ask students to mark "X" in the proper blank.

4.c. (2 pts) Using only statements 4.a and 4.b, what is the location of the packet? (No explanation needed.)

Write R (= Router), C (= Computer), or N (= Not able to determine) __________________

4.d. (2 pts) You now are told that the packet is oversized (i.e., S = True). Using only this new fact plus statements 4.a and 4.b, what is the location of the packet? (No explanation needed.)

Write R (= Router), C (= Computer), or N (= Not able to determine) __________________

4.e. (2 pts) What is the correct conversion of the propositional logic statement below into CNF?

$$\neg [((R \lor \neg C) \Rightarrow S) \Rightarrow (R \land C)]$$

Write A, B, C, D, or E ____________

A. $(R \lor \neg S) \land (C \lor \neg S) \land (R \lor \neg C)$

B. $(R \land \neg S) \lor (C \land S) \lor (\neg R \land \neg C)$

C. $(\neg R \lor S) \land (C \lor S) \land (\neg R \lor \neg C)$

D. $(\neg R \lor S) \land (\neg C \lor \neg S) \land (R \lor C)$

E. None of above

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5. (14 pts total, 2 pts each) Probability Formulas. Write out the following probability formulas. Below, "in terms of X" means X should appear in your answer. All answers should be formulas, not text.

5.a. (2 pts) Write the formula for $P(A \wedge B)$ in terms of $P(A \vee B)$ and possibly other terms.

$P(A \wedge B)$ =

5.b. (2 pts) Write the formula for the conditional probability $P(A \mid B)$.

$P(A \mid B)$ =

5.c. (2 pts) Factor $P(A \wedge B \wedge C)$ completely using the Product Rule (or Chain Rule). You may use any variable ordering you wish.

$P(A \wedge B \wedge C)$ =

5.d. (2 pts) Given a joint probability distribution $P(A \wedge B \wedge C)$, use the Sum Rule (or Law of Total Probability) to write the marginal probability of $P(A)$.

$P(A)$ =

5.e. (2 pts) Write Bayes' Rule (or Bayes' Theorem).

$P(A \mid B)$ =

5.f. (2 pts) Assume that A and B are independent. Write $P(A \wedge B)$ in terms of $P(A)$ and $P(B)$ and possibly other terms.

$P(A \wedge B)$ =

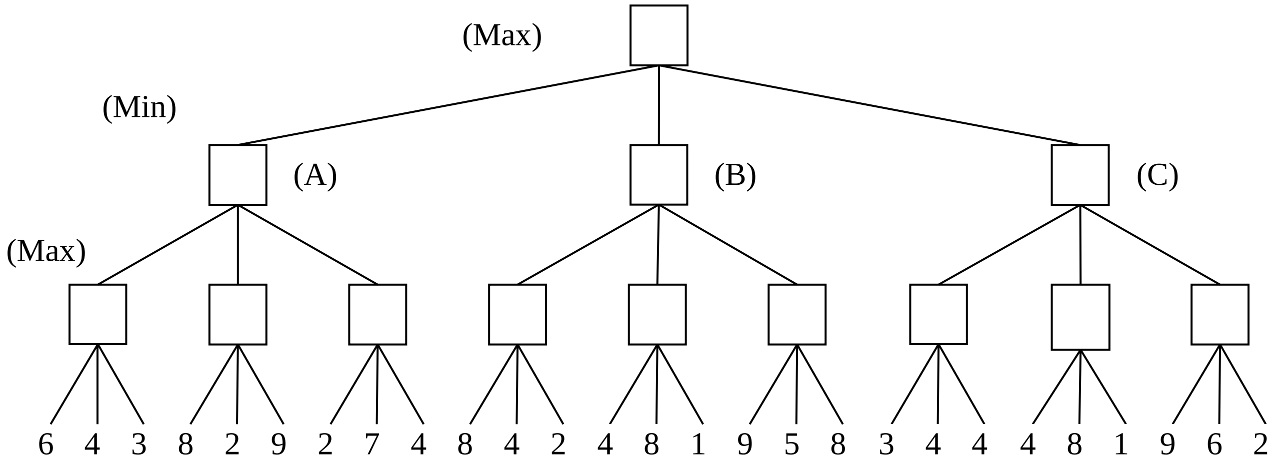
5.g. (2 pts) Assume that A and B are conditionally independent given C. Write $P(A \wedge B \mid C)$ in terms of $P(A \mid C)$ and $P(B \mid C)$ and possibly other terms.

$P(A \wedge B \mid C)$ =

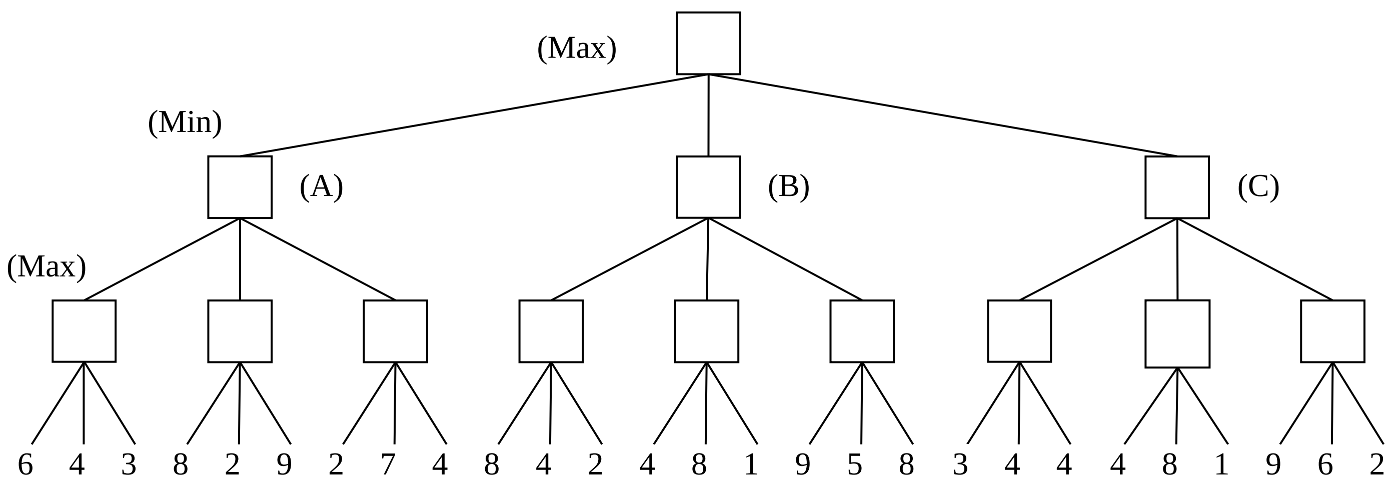
6. (4 pts total, -1 pt for each error, but not negative) Mini-Max Search in Game Trees.

6.a. The game tree below illustrates a position reached in the game. It is **Max**'s turn to move. Inside each leaf node is the estimated score of that resulting position returned by the heuristic static evaluator.
FILL IN EACH BLANK SQUARE WITH THE PROPER MINI-MAX SEARCH VALUE.

6.b. What is the best move for Max? (write A, B, or C) _____________



7. (8 pts total, -1 for each error, but not negative) Alpha-Beta Pruning. Process the tree left-to-right. This is the same tree as above (6.a). You do not need to indicate the branch node values again.
CROSS OUT EACH LEAF NODE THAT WILL BE PRUNED BY ALPHA-BETA PRUNING.



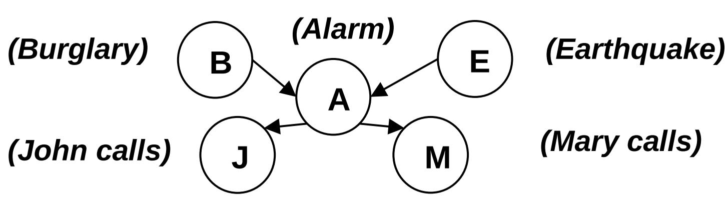
8. (8 pts total, 1 pt each) Constraint Satisfaction Problem (CSP) Concepts.

For each of the following terms on the left, write in the letter corresponding to the best answer or the correct definition on the right.

	Minimum Remaining Values Heuristic	A	Specifies the allowable combinations of variable values
	Solution to a CSP	B	The values assigned to variables do not violate any constraints
	Least Constraining Value Heuristic	C	Set of allowed values for some variable
	Domain	D	Every variable is associated with a value
	Constraint	E	Nodes correspond to variables, links connect variables that participate in a constraint
	Consistent Assignment	F	Chooses the next variable to expand to have the fewest legal values in its domain
	Complete Assignment	G	A complete and consistent assignment
	Constraint Graph	H	Prefers to search next the value that rules out the fewest choices for the neighboring variables in the constraint graph

9. (4 pts total, 2 pts each) Bayesian Networks. Below is the network from the Burglar Alarm problem.
Write down an expression that will evaluate to P(J=f ∧ M=t ∧ A=t ∧ B = t ∧ E = f).
<u>First line (1):</u> Write the joint probability as a symbolic factored conditional probability using the network.
<u>Second line (2):</u> Substitute probabilities from the tables to yield numbers separated by multiplication symbols.
Remember that the tables show the probability that each variable is True, e.g., P(C) means P(C=t).
You do not need to do the multiplications to produce a number (the probability).

P(J | A) P(M | A) P(A | B, E) P(B) P(E).



P(E)
.002

A	P(M)
t	.70
f	.01

B	E	P(A)
t	t	.95
t	f	.94
f	t	.29
f	f	.001

P(B)
.001

A	P(J)
t	.90
f	.05

P(J=f ∧ M=t ∧ A=t ∧ B = t ∧ E = f)

(1) =

(2) =

Full credit for (2) if your answer is right for the formula you gave in (1), even if (1) was wrong. Trivial answers to (1) are excluded.

10. (10 pts total, 2 pts each) English to FOL Conversion. For each English sentence below, write the FOL sentence that best expresses its intended meaning. Use the predicates Cat(x) for “x is a cat,” Mouse(x) for “x is a mouse,” and Chases(x, y) for “x chases y.” <u>The first one is done for you as an example.</u>

10.example. “Every cat chases every mouse.”

$$\forall x\ \forall y\ [\ Cat(x) \wedge Mouse(y)\ ] \Rightarrow Chases(x, y)$$

10.a. (2 pts) “For every cat, there is some mouse such that the cat chases that mouse.”

10.b. (2 pts) “There is a cat and that cat chases every mouse.”

10.c. (2 pts) “Some cat chases some mouse.”

10.d. (2 pts) “There is a mouse that every cat chases.”

10.e. (2 pts) “For every mouse, there is a cat who chases that mouse.”

11. (7 pts total, -1 pt for each edit step from your answer to the correct answer, but not negative)
The Knowledge Engineering process.
Your book identifies seven sequential steps in the knowledge engineering process, which steps are below. Unfortunately, the order of the steps has been scrambled. Please, straighten them out.

A. Encode a description of the specific problem instance
B. Assemble the relevant knowledge
C. Pose queries to the inference procedure and get answers
D. Encode general knowledge about the domain
E. Debug the knowledge base
F. Identify the task
G. Decide on a vocabulary of predicates, functions, and constants

Fill in the blanks with the letters A, B, C, D, E, F, and G, all in the proper sequence.

________ ________ ________ ________ ________ ________ ________.

12. (5 pts total, 1 pt each) Probability. Consider this full joint distribution for Boolean variables A, B, C:

A	B	C	P(a,b,c)
t	t	t	0.08
t	t	f	0.12
t	f	t	0.24
t	f	f	0.36
f	t	t	0.04
f	t	f	0.06
f	f	t	0.04
f	f	f	0.06

Calculate the following probabilities (write a number from the interval [0,1]). <u>SHOW YOUR WORK.</u>

12.a. (1 pt) P(A = f) =

12.b. (1 pt) P(B = t) =

12.c. (1 pt) P(B = t, C = t) =

12.d. (1 pt) P(A = f, C = t) =

12.e. (1 pt) P(A = t | B = t) =

****** THIS IS THE END OF THE FINAL EXAM. HAPPY HOLIDAYS!! ******

SCRATCH PAPER

SCRATCH PAPER

SCRATCH PAPER

SCRATCH PAPER