CS-271, Intro to A.I. — Final Exam — Spring Quarter, 2010

1. (2 pts) NAME AND EMAIL ADDRESS: _________________________________

YOUR ID: _______  ID TO RIGHT:_______  ROW:____  NO. FROM RIGHT:____

The exam will begin on the next page.

This page summarizes the points available for each question so you can plan your time.

1. (2 pts) Name and email address.

2. (14 pts total, 2 pts each) English to first-order logic translation.

3. (16 points total, 2 pts each) Logical equivalences.

4. (7 points total, 1 pt each) Resolution proof.

5. (15 pts total, 1 pt each) Logical definitions.

6. (10 pts total, -1 for each error, but not negative) Alpha-beta pruning.

7. (15 pts total, -1 for each wrong answer, but not negative) Search Strategy Evaluation.

8. (6 pts total, 1 pt each) Linearly Separable Classifiers.

9. (15 pts total, 1 pt each) Constraint Satisfaction Problems.
2. (14 pts total, 2 pts each) Fill in each blank below with Y (= Yes) or N (= No) depending on whether the logic expression correctly expresses the English.

2a. \( \neg \)  
\[
\forall x \text{ Man}(x) \land \text{Mortal}(x)
\]

2b. \( \text{Y} \)  
\[
\exists x \text{ Brother}(x, \text{Fido}) \land \text{Dog}(x)
\]

2c. \( \text{Y} \)  
\[
\forall q \exists s \text{ Quiz}(q) \implies \left[ \text{Student}(s) \land \text{Got100}(s, q) \right]
\]

2d. \( \neg \)  
\[
\forall s \exists q \text{ Student}(s) \implies \left[ \text{Quiz}(q) \land \neg \text{Got100}(s, q) \right]
\]

(Question 2d was discarded as ambiguous. Everyone gets it right.)

2e. \( \neg \)  
\[
\forall s \exists q \text{ Student}(s) \implies \left[ \text{Quiz}(q) \land \text{Got100}(s, q) \right]
\]

2f. \( \text{Y} \)  
\[
\forall x \exists y \text{ Person}(x) \implies \left[ \text{Food}(y) \land \text{Favorite}(y, x) \right]
\]

2g. \( \neg \)  
\[
\exists x \left[ \text{Person}(x) \land \text{At}(x, \text{UCI}) \right] \implies \text{Smart}(x)
\]

3. (16 points total, 2 pt each) Label the following statements as T (= true) or F (= false). Recall that “X is equivalent to Y” means that X and Y have the same truth table. Recall that “X entails Y” means that whenever X is true, Y is also true. Use rewrite rules.

3a. \( \text{T} \)  
\[
(A \implies B) \text{ is equivalent to } (\neg A \lor B).
\]

3b. \( \text{F} \)  
\[
[ (A \implies B) \land (\neg A) ] \text{ entails } (\neg B).
\]

3c. \( \text{T} \)  
\[
[ (A \implies B) \land (\neg B) ] \text{ entails } (\neg A).
\]

3d. \( \text{T} \)  
\[
[ (A \implies B) \land (\neg A \implies C) \land (\neg C) ] \text{ entails } B.
\]

3e. \( \text{T} \)  
\[
[ (A \implies B) \implies (\neg (A \implies \neg B)) ] \text{ is equivalent to } A.
\]

3f. \( \text{T} \)  
\[
(A \lor (B \land C)) \text{ is equivalent to } (A \lor B) \land (A \lor C).
\]

3g. \( \text{T} \)  
\[
(A \iff B) \text{ is equivalent to } (\neg A \iff \neg B).
\]


3h. \( (A \Leftrightarrow B) \) is equivalent to \( (\neg A \Rightarrow \neg B) \land (\neg B \Rightarrow \neg A) \).

4. (7 points total, 1 pt each) Complete the resolution proof below that Jill is Sue's niece. For ease in naming the statements in the KB, they are labeled KB1, KB2, KB3, KB4, ... Write each unifier as \{ var1/val1, var2/val2, ... \}, i.e., a list of variable/value substitutions.

KB1: Daughter(Jill, Mary)
KB2: Sister(Mary, Sue)
KB3: \((\neg \text{Daughter}(x, y) \lor \neg \text{Sister}(y, z) \lor \text{Niece}(x, z))\)

Goal: Niece(Jill, Sue)

4a. The negated goal is KB4: \(\neg \text{Niece}(Jill, Sue)\).

4b. The most general unifier of KB3 and KB4 is: \{ \(x/Jill, z/Sue\) \}.

4c. The result of resolving KB3 and KB4 is KB5: \(\neg \text{Daughter}(Jill, y) \lor \neg \text{Sister}(y, Sue)\).

4d. The most general unifier of KB2 and KB5 is: \{ \(y/Mary\) \}.

4e. The result of resolving KB2 and KB5 is KB6: \(\neg \text{Daughter}(Jill, Mary)\).

4f. The most general unifier of KB1 and KB6 is: \{ \}.

4g. The result of resolving KB1 and KB6 is KB7: \{ \} (or false, or contradiction, etc.).

5. (15 pts total, 1 pt each) 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. The first one is done for you as an example.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent</td>
<td>Syntax</td>
<td>Semantics</td>
<td>Entailment</td>
<td>Sound</td>
<td>Complete</td>
<td>Complex sentences</td>
<td>Valid</td>
<td>Satisfiable</td>
<td>Unsatisfiable</td>
<td>Proof</td>
<td>Horn clause</td>
<td>Conjunctive Normal Form</td>
<td>Frame problem</td>
<td>Interpretation</td>
<td>Term</td>
</tr>
<tr>
<td><strong>A</strong></td>
<td><strong>B</strong></td>
<td><strong>C</strong></td>
<td><strong>D</strong></td>
<td><strong>E</strong></td>
<td><strong>F</strong></td>
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<td><strong>H</strong></td>
<td><strong>I</strong></td>
<td><strong>J</strong></td>
<td><strong>K</strong></td>
<td><strong>L</strong></td>
<td><strong>M</strong></td>
<td><strong>N</strong></td>
<td><strong>O</strong></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td>Perceives environment by sensors, acts by actuators.</td>
<td>Chain of inference rule conclusions leading to a desired sentence.</td>
<td>Constructed from simpler sentences, parentheses, and connectors.</td>
<td>Describes a sentence that is true in all models.</td>
<td>A first-order logic expression that refers to an object.</td>
<td>Represented as a canonical conjunction of disjunctions.</td>
<td>The need to assert what remains unchanged after an action.</td>
<td>Describes a sentence that is false in all models.</td>
<td>Defines truth of each sentence with respect to each possible world.</td>
<td>An inference procedure that derives only entailed sentences.</td>
<td>An inference procedure that derives all entailed sentences.</td>
<td>Associates symbols with world objects, relations, and functions.</td>
<td>Describes a sentence that is true in some model.</td>
<td>Disjunction of literals, at most one of which is positive.</td>
<td>The idea that a sentence follows logically from another sentence.</td>
<td>Specifies all the sentences in a language that are well formed.</td>
</tr>
</tbody>
</table>
6. (10 pts total, -1 for each error, but not negative) ALPHA-BETA PRUNING. Cross out each leaf node that will not be examined because it is pruned by alpha-beta pruning. Traverse the tree left-to-right.

7. (15 pts total, -1 for each wrong answer, but not negative) Search Strategy Evaluation. 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 finite depth to the shallowest goal node;
   m is the finite maximum depth of the search tree;
   l is the finite depth limit;
   C* is the true cost to the least-cost goal node;
   step costs are identical and equal to some positive ε;
   and in Bidirectional search both directions use breadth-first search.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Complete?</th>
<th>Time complexity</th>
<th>Space complexity</th>
<th>Optimal?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadth-First</td>
<td>Yes</td>
<td>O(b^d)</td>
<td>O(b^d)</td>
<td>Yes</td>
</tr>
<tr>
<td>Uniform-Cost</td>
<td>Yes</td>
<td>O(b^(1+floor(C*/ε)))</td>
<td>O(b^(1+floor(C*/ε)))</td>
<td>Yes</td>
</tr>
<tr>
<td>Depth-First</td>
<td>No</td>
<td>O(b^m)</td>
<td>O(bm)</td>
<td>No</td>
</tr>
<tr>
<td>Depth-Limited</td>
<td>No</td>
<td>O(b^l)</td>
<td>O(bl)</td>
<td>No</td>
</tr>
<tr>
<td>Iterative Deepening</td>
<td>Yes</td>
<td>O(b^d)</td>
<td>O(bd)</td>
<td>Yes</td>
</tr>
<tr>
<td>Bidirectional (if applicable)</td>
<td>Yes</td>
<td>O(b^(d/2))</td>
<td>O(b^(d/2))</td>
<td>Yes</td>
</tr>
</tbody>
</table>
8. (6 pts total, 1 pt each) Label the following as Y (= yes) or N (= no) depending on whether a perceptron with a “hard” decision boundary (step transfer function) can correctly classify the examples shown. If your answer is Y (= yes), fill in a set of weights that correctly classifies them. Use $w_0$ as the threshold and $w_i$ as the weight for input $x_i$. All perceptrons have three Boolean inputs, $x_1$, $x_2$, and $x_3$, and a “dummy” input, $x_0$, which is always equal to one. They all compute the decision function $\sum w_ix_i > 0$. You may not transform the input space, i.e., they operate on the stated inputs.

*Where the answer is Y, other weights are OK iff the decision function is correct.*

8a. “At least two inputs are 1.”
Correctly classifiable? ______ Y ______
If yes, weights are $w_0 = -1.5$ ______; $w_1 = 1$ ______; $w_2 = 1$ ______; $w_3 = 1$ ______.

8b. “Exactly two inputs are 1.”
Correctly classifiable? ______ N ______
If yes, weights are $w_0 =$ ______; $w_1 =$ ______; $w_2 =$ ______; $w_3 =$ ______.

8c. “At most two inputs are 1.”
Correctly classifiable? ______ Y ______
If yes, weights are $w_0 = 2.5$ ______; $w_1 = -1$ ______; $w_2 = -1$ ______; $w_3 = -1$ ______.

8d. “Input $x_1 = 1$, input $x_2 = 0$, input $x_3 =$anything.”
Correctly classifiable? ______ Y ______
If yes, weights are $w_0 = -0.5$ ______; $w_1 = 1$ ______; $w_2 = -1$ ______; $w_3 = 0$ ______.

8e. “IF input $x_1 = 1$ THEN input $x_2 = 0$ ELSE input $x_2 = 1$.”
Correctly classifiable? ______ N ______
If yes, weights are $w_0 =$ ______; $w_1 =$ ______; $w_2 =$ ______; $w_3 =$ ______.

8f. “Input $x_1 =$ input $x_2$.”
Correctly classifiable? ______ N ______
If yes, weights are $w_0 =$ ______; $w_1 =$ ______; $w_2 =$ ______; $w_3 =$ ______.
9. (15 pts total, 1 pt each) Constraint Satisfaction Problems. Label the following statements as T (true) or F (false).

9a. ______ T ______ A constraint satisfaction problem (CSP) consists of a set of variables, a set of domains (one for each variable), and a set of constraints that specify allowable combinations of values.

9b. ______ F ______ A consistent assignment is one in which every variable is assigned.

9c. ______ F ______ A complete assignment is one that does not violate any constraints.

9d. ______ F ______ A partial assignment is one that violates only some of the constraints.

9e. ______ T ______ The nodes of a constraint graph correspond to variables of the problem, and a link connects any two variables that participate in a constraint.

9f. ______ T ______ A constraint consists of a pair <scope, rel>, where scope is a tuple of variables that participate and rel defines the values those variables can take on.

9g. ______ Perform constraint propagation creates a new constraint between two variables that did not previously participate in a constraint together. (Question 9g was discarded as ambiguous. Everyone gets it right.)

9h. ______ T ______ A variable in a CSP is arc-consistent iff, for each value in its domain and each of its binary constraints, that constraint is satisfied by that domain value together with some value in the domain of the other variable in that constraint.

9i. ______ F ______ Constraint satisfaction problems are semi-decidable because they may never terminate if the problem has no legal solution.

9j. ______ T ______ The minimum-remaining-values (MRV) heuristic chooses the variable with the fewest remaining legal values to assign next.

9k. ______ F ______ The degree heuristic is used to set the temperature in methods for solving CSPs based on Simulated Annealing.

9l. ______ T ______ The least-constraining-value heuristic prefers the value that rules out the fewest choices for the neighboring variables in the constraint graph.

9m. ______ T ______ The min-conflicts heuristic for local search prefers the value that results in the minimum number of conflicts with other variables.

9n. ______ F ______ The min-conflicts heuristic is rarely used because it is only effective when the constraint graph is a tree.

9o. ______ T ______ Any tree-structured CSP can be solved in time linear in the number of variables.