Computer Science and Engineering 415
Introduction to Artificial Intelligence

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Sample Final Examination

(The real final will be on Thursday, June 13.)

This is a "closed-book" examination; do not use any books or other recorded materials that you may have brought with you. Do both Part I and Part II.

Part I. Multiple Choice Put all your answers for this part on the multiple-choice answer sheet. Use only standard number 2 pencils for this part.

In each question, the answer number for each alternative is indicated in square brackets, e.g., [E]. For each question, choose the best answer. Mark only one answer per question. (A correct answer is worth 5, and an incorrect answer is worth 0). If you feel that a question is flawed, inconsistent or overly ambiguous, give a clear explanation of your objection on the written-answer portion of the exam.

There are 28 questions in this part, each worth 5 points, making the total possible for Part I equal to 140.

1. Of the following, how many evaluate to NIL?

```
()                              (rest '(x))
(null nil)                      (append nil nil)
(numberp nil)                   (- 5 5)
```

   Choose one of: [A] none, [B] one or two, [C] three, [D] four or five, or [E] all six.

2. Which of the following evaluates to the list (A B C)?

   Choose one of:
   [A] (list (second '(f a r))(first '(b a c k))),
   [B] (cons (second '(f a r))(rest '(z b c))),
   [C] (append (second '(f a r))(second '(b a c k)) '(c)),
   [D] (rest '(a b c)), or
   [E] ' '(a b c).

3. Which state-space search algorithm explores states in order of increasing distance from the start state, taking into account distances (given or computed) on each arc of the state space graph?

   Choose one of: [A] depth-first search, [B] best-first search, [C] uniform-cost search, [D] alpha-beta search, or [E] breadth-first search.

4. The A* algorithm is:

   Choose one of: [A] a fast way to compute most-general unifiers, [B] a method of applying Horn clauses, [C] a special case of best-first search, [D] a backward-chaining procedure, or [E] a parsing strategy.

5. Which of the following correctly expresses the statement, "Each integer has a unique additive inverse," assuming we use the predicates I(x) to mean that x is an integer, and A(x, y) to mean that y is an additive inverse of x?

   Choose one of: [A] $(\forall x)[I(x) \rightarrow (\exists y)[A(x,y) \wedge (\forall z A(x,z) \rightarrow y = z)]]$, [B] $I(x) \rightarrow A(x,y)$, [C] $\exists y[\forall x A(x,y)]$, [D] $[I(x) \wedge A(x,y)] \rightarrow \neg\exists z A(x,z)$, or [E] $\neg I(x) \vee \neg A(x,y) \vee \neg\exists z A(x,z)$.

6. Which of the following is a tautology?

   Choose one of: [A] $P \vee \neg Q$, [B] $P \wedge \neg Q$, [C] $\Box$, [D] P, or [E] $P \vee \neg P$.

7. Which of the following is a contradiction?

   Choose one of: [A] $P \vee \neg Q$, [B] $P \wedge \neg Q$, [C] $\Box$, [D] P, or [E] $P \vee \neg P$.

8. Which of the following is not expressed as a clause?

   Choose one of: [A] $P \vee \neg Q$, [B] $P \wedge \neg Q$, [C] $\Box$, [D] P, or [E] $P \vee \neg P$.

9. Which of the following is NOT a subsitution instance of $Q(x, y, f(z))$?

   Choose one of: [A] $Q(a,b,c)$, [B] $Q(x,a,f(z))$, [C] $Q(g(w),g(w),f(z))$, [D] $Q(g(a),h(b),f(c))$, or [E] $Q(y,y,f(y))$.

10. The subsitution $\{a/x, b/y\}$ is a unifier for which pair of literals?

    Choose one of: [A] $P(x,a), P(y,b)$, [B] $P(x,a), P(b,y)$, [C] $P(y,x), P(b,a)$, [D] $P(x,y), Q(a,b)$, or [E] $P(a,b), P(b,a)$.

11. Which of the following is a most general unifier for $P(x,y,z)$ and $P(f(w),a,g(b))$? Here w, x, y, and z are variables, f and g are function symbols, and a and b are constants.

    Choose one of: [A] $\{f(w)/x, a/y, g(b)/z\}$, [B] $\{x/x, y/y, z/z\}$, [C] $\{f(a)/x, a/y, g(b)/z\}$, [D] $\{g(b)/x, g(f(w))/y, g(f(a))/z\}$, or [E] $\{a/x, a/y, a/z\}$.

12. Which of the following is a most general unifier for $P(x,y,f(z))$ and $P(w,y,f(a))$?

    Choose one of: [A] $\{a/x, a/y, a/z, a/w\}$, [B] $\{w/x, w/y, a/z\}$, [C] $\{a/x, b/y, a/z, a/w\}$, [D] $\{b/x, c/y, a/z, b/w\}$, or [E] $\{x/w, a/z\}$.

13. Which is an appropriate result of calling a unification procedure on the literals $Q(a,x)$ and $Q(y,f(x))$?

    Choose one of: [A] $\{x/y, a/f(x)\}$, [B] $\{a/x, y/f(x)\}$, [C] $\{a/x, f(x)/y\}$, [D] $\{a/y, f(x)/x\}$, or [E] "not unifiable".

14. Consider the domain $D = \{a, b, c, d, e\}$, and let I assign the relation $\{(a, b), (b, a), (a, c), (c, a)\}$ the predicate $P(x, y)$. Then D and I comprise a model for ...

    Choose one of: [A] $\exists x P(x, x)$, [B] $\forall x \forall y (P(x, y) \rightarrow P(y, x))$, [C] $\forall x \exists y P(x, y)$, [D] $\forall x \forall y (P(x, y) \wedge P(y, x))$, or [E] $\exists x \forall y P(x, y)$.

15. The most important use of the Roberts Cross operator is which of the following?

    Choose one of: [A] contrast enhancement, [B] detecting edges, [C] labelling connected components, [D] binarizing an image, or [E] removing noise.

16. The Roberts Cross operator can be defined as follows:

$$R[i, j] = \sqrt{(A[i, j] - A[i + 1, j + 1])^2 + (A[i + 1, j] - A[i, j + 1])^2}$$

    Consider the image A below. Here i is the row index, and j is the column index; they both range from 0 to 3.

1	1	8	8
1	8	8	1
1	8	1	1
1	1	1	1

    What is the value of $R[0, 0]$?

    Choose one of: [A] $\sqrt{85}$, [B] $\sqrt{65}$, [C] $\sqrt{63}$, [D] 0, or [E] 7.

17. Consider the binary image of Figure 1. How many 4-connected components of 1s are there?

    Choose one of: [A] 1, [B] 2, [C] 3, [D] 4, or [E] 5.

```
1 1 0 0 0 0 0 0
1 1 0 0 0 0 0 0
0 0 1 0 0 0 0 0
0 0 0 1 1 1 1 1
0 0 0 1 0 0 0 1
0 0 0 1 0 1 0 1
0 0 0 1 0 0 0 1
0 0 0 1 1 1 1 1
```

Figure 1: A binary image.

18. Again, consider the binary image of Figure 1. How many 8-connected components of 1s are there?

    Choose one of: [A] 1, [B] 2, [C] 3, [D] 4, or [E] 5.

19. Once again, consider the binary image of Figure 1. How many 4-connected components of 0s are there?

    Choose one of: [A] 1, [B] 2, [C] 3, [D] 4, or [E] 5.

20. Again, consider the binary image of Figure 1. How many 8-connected components of 0s are there?

    Choose one of: [A] 1, [B] 2, [C] 3, [D] 4, or [E] 5.

21. For one final time, consider the binary image of Figure 1. What is the minimum total number of connected components we could have at one time, counting both components of 0s and of 1s, subject to the constraint that connected objects do not pass through each other?

    Choose one of: [A] 3, [B] 4, [C] 5, [D] 6, or [E] 7.

22. Using the Hough transform for line detection (with polar representation of lines), each element of the parameter space array represents what?

    Choose one of: [A] the value of ρ corresponding to a given value of θ, [B] the value of θ corresponding to a given value of ρ, [C] the strength of a line in the image space, [D] the quantization error for a parameter pair (θ, ρ), or [E] The number of lines in the image passing through a point (x, y).

23. The main advantage of using the Hough transform for line detection (over techniques like analyzing chain codes of groups of pixels selected via edge detection) is what?

    Choose one of: [A] computational speed, [B] insensitivity to noise, [C] compensation for digitization errors, [D] ability to generalize to geometric figures of higher dimensionality, or [E] ability to "hallucinate" lines not represented in the image at all.

24. In the Hough transform formulation,

$$H[\theta, \rho] = \sum_{x=0}^{n-1} \sum_{y=0}^{n-1} F[x, y]\mathrm{hit}(x, y, \theta, \rho)$$

    which of the following is an appropriate description of the function $\mathrm{hit}(x, y, \theta, \rho)$? of lines), each element of the parameter space array represents what?

    Choose one of: [A] 1 if $|x \cos\theta + y \sin\theta - \rho| < \epsilon$; 0, otherwise,
    [B] $(x - \theta)^2 + (y - \rho)^2$,
    [C] $1/(x^2 + y^2 - \theta^2 - \rho^2)$,
    [D] 1 if $x = y$ or $\theta = \rho$; 0, otherwise, or
    [E] $\rho \tan(\theta + \arctan(y/x))$.

25. Consider the set of rules below and the initial set of assertions $\{A, B, C, D, E, F\}$. Assuming the rules are attempted in the order given, show the order in which *forward chaining* establishes new assertions.

```
If A and B Then J
If C and D Then K
If E and F Then L
If J and K Then M
```

Choose one of: [A] M, L, K, J;
[B] L, K, J, M;
[C] M, J, K, L;
[D] K, L, J, M;
[E] J, K, L, M.

26. Now (considering the same rules and assertions as in the previous problem), suppose M is to be proved using *backward chaining*. Show the order in which subgoals are identified.

    Choose one of: [A] J, A, B, K, C, D, L, E, F;
    [B] J, K, A, B, C, D;
    [C] A, B, C, D, E, F;
    [D] K, J, D, C, F, E;
    [E] A, B, J, C, D, K, E, F, L.

27. Consider the following "expert system" rule:

```
If (AND (headache       (? cf1))
        (fever          (? cf2))
        (exposed-to-flu (? cf3)) )
THEN flu
WITH-CERTAINTY (0.8 * (AND-INDEP (? cf1)(? cf2)(? cf3)))
```

    The function AND-INDEP computes a certainty factor for the conjunction of the three subconditions, assuming that they are independent.

    If CF1 is 0.9, CF2 is 0.8, and CF3 is 0.8, what then will be the certainty associated with FLU as computed by this rule?

    Choose one of: [A] 0.64, [B] 0.4608, [C] 0.72, [D] 0.512, or [E] 0.9.

28. Which of the following is not a significant advantage of Common Lisp for implementing AI programs?

    Choose one of: [A] automatic garbage collection, [B] support for manipulating symbolic expressions, [C] speed of execution, [D] interactive debugging environment, or [E] a unified representation for both programs and data.

Part II. Written Answers

Do not use the multiple-choice answer sheet for this part. Rather, either use some blank paper or write on your test paper. Put your name on whatever you are going to turn in.

1. (10 points) Write a Common Lisp function definition for a recursive function ADD-NUMS which takes a list as its argument. The list may contain numbers and symbols. The function ignores the symbols and returns the sum of the numbers. You may assume that the list does not contain any embedded sublists.

   For example, the call (ADD-NUMS '(HERE 4 EXAMPLE 2 DO THE SUM WE IGNORE 8 SYMBOLS)) should return 14.

2. (30 points) Suppose you have been giving the task of designing a computer program whose job it will be to take a set of student course requests for a given 3-quarter academic year and a set of course offerings with times (days and hours of the week) and course (room) capacities, and to compute a set of schedules for each student that accommodate as many students requests as possible.

   You decide to use a form of state space search for this problem. Explain how you would structure the state space and specify the search algorithm. Be sure to describe your state representation, the operators for getting new states, a test of goal states, and a heuristic evaluation function.

3. (10 points) Choose one of the following three topics. Explain the major steps or components in the method. Your answer to this question should be approximately 100-200 words in length. Do not choose a technique if you have already described in in the previous problem.

   (a) Case-based problem solving.

   (b) A* search.

   (c) Genetic search.

4. (10 points) If a program that plays Tic-Tac-Toe uses minimax search of the game tree, and it uses the static evaluation function given below, what should be the backed-up value at the starting board position given that the program is to search to a depth of one ply? Draw the tree, compute the values of each node, and write them down next to their nodes.

   Static value $= 100A + 10B + C - (100D + 10E + F)$ where A is the number of lines of three X's, B is the number of unblocked lines with a pair of X's, and C is the number of unblocked lines with a single X. Similarly D, E, and F give numbers of lines of O's in various configurations.