FALL 1998
COMPUTER SCIENCES DEPARTMENT
UNIVERSITY OF WISCONSIN – MADISON
PH.D. QUALIFYING EXAMINATION

Artificial Intelligence

September 14, 1998
3:00 – 7:00 PM
119 Noland

GENERAL INSTRUCTIONS:

1. Answer each question in a separate book.
2. Indicate on the cover of *each* book the area of the exam, your code number, and the question answered in that book. On *one* of your books, list the numbers of *all* the questions answered. *Do not write your name on any answer book.*
3. Return all answer books in the folder provided. Additional answer books are available if needed.

SPECIFIC INSTRUCTIONS:
Answer:

- either one (1) of the questions G540-1 or G540-2, *and*
- both (2) questions in the section labeled B760, B766, or B780 corresponding to your chosen focus area, *and*
- any two (2) additional question in the sections B760, B766, and B780, where these two questions need *not* come from the same section, *and*
- both (2) questions in the section labeled A76x that corresponds to your focus area.

Hence, you are to answer a total of *seven* (7) questions.

POLICY ON MISPRINTS AND AMBIGUITIES:
The Exam Committee tries to proofread the exam as carefully as possible. Nevertheless, the exam sometimes contains misprints and ambiguities. If you are convinced that a problem has been stated incorrectly, mention this to the proctor. If necessary, the proctor can contact a representative of the area to resolve problems during the *first hour* of the exam. In any case, you should indicate your interpretation of the problem in your written answer. Your interpretation should be such that the problem is nontrivial.

Answer either one (1) of the questions G540-1 or G540-2.

G540 – Introduction to AI Questions

G540-1. In the *Four-Queens Problem* the goal is to place four queens on a 4 x 4 chess board so that none can capture any other. (That is, only one queen can be on any row, column or diagonal of the board.)

a. Formulate this problem as a search problem by giving the initial state, goal test, and operators needed.
b. Give an admissible heuristic for this problem.
c. Use your heuristic function in an A* search to a goal node. Draw at most the first eight (8) nodes of the search graph produced by the search and label each node by (i) the ordinal number of when the node was generated, (ii) its g value, and (iii) its heuristic function value.

G540-2. Assuming that the statements below are true, *formally prove* that R logically follows. Justify each deductive step by stating which inference rule you used.

(1) $A \wedge B \wedge C$
(2) $A \wedge B \Rightarrow D$
(3) $A \vee D \Rightarrow E \vee F$
(4) $E \vee G \Rightarrow R$
(5) $F \wedge C \Rightarrow R$
(6) $E \wedge F \Rightarrow R$

Answer both (2) of the questions in the section labeled B76x that corresponds to your chosen focus area. Also answer any two (2) additional questions in any of the other sections (these two questions need NOT occur in the same section).

B760 – Machine Learning Basic Questions

B760-1. Imagine you need to learn a Boolean concept, but only have positive examples. Discuss how this could be done with each of the following algorithms, or explain why trying to do so would be inappropriate.

a. k-nearest neighbors

b. Naive Bayes

c. Quinlan's C4.5

d. feedforward neural networks trained with backpropagation

B760-2. Consider the approach of using Q-learning to address the task of *reinforcement learning*.

a. Briefly explain the Q function and how it is refined.

b. Discuss one (1) strength and one (1) weakness of representing a Q function as a table versus representing it using a feedforward neural network.

c. Discuss one (1) strength and one (1) weakness of using an internal model of the environment versus directly acting on the environment.

B766 – Computer Vision Basic Questions

B766-1. A *stereo* system has been built with the following characteristics. Two CCD cameras are used containing 512 x 512 pixels corresponding to a 10 cm x 10 cm sensor array. The focal length of the lens is 16 cm and is focused at infinity, meaning that the image plane is 16 cm from the optical center of the lens. For all conjugate pairs of corresponding points, (x1, y1) in the left image and (x2, y2) in the right image, y1 = y2. The optical axes of the two cameras are parallel to each other, and perpendicular to the image planes. The baseline between the two cameras is 1 meter.

a. Give a formula specifying how the disparity of a pair of corresponding points is related to the baseline, focal length, and depth.

b. If the nearest depth to be measured is 16 meters, what is the largest disparity that will occur (in pixels)?

c. What depth corresponds to a disparity of 1 pixel? Explain what this result means in terms of the limits of this stereo system.

B766-2. Suppose you are given a binary image and want to use the *Generalized Hough Transform* to detect upright right triangles with side length 5 pixels, where the right angle is oriented in the lower-left corner.

a. How many dimensions are there in the Hough parameter space for this problem?

b. What are they?

c. Assuming the reference point for the triangle is the right-angle corner point, a "1" in the input image at coordinates (8,7) will "vote for" what points in the parameter space? Give your answer as a figure showing the coordinates of the points.

d. How would your solution be generalized if you wanted to detect upright right triangles in a range of sizes from side length 3 to side length 10?

B780 – Robot Motion Planning Basic Questions

B780-1. A mobile robot knows its own and its goal coordinates at all times; it uses its vision sensor to sense surrounding obstacles. Consider the following sensor-based motion planning algorithm: go toward the goal; when encountering obstacles, pass every odd obstacle on your left and every even obstacle on your right; whenever possible, go straight toward the goal. Does the algorithm converge? If your answer is "yes", prove it. If your answer is "no", give a counterexample.

B780-2. Consider a three-dimensional 3-link PPP arm manipulator (P="prismatic" - a so-called Cartesian arm). Does the inverse kinematics for this arm always have a unique solution? If not, what is the maximum number of solutions possible? Draw a sketch; explain your answer in detail.

Answer both (2) of the questions in the section labeled A76x that corresponds to your chosen focus area.

A780 – Robot Motion Planning Advanced Questions

A780-1. For a two-link revolute-revolute arm, with each link of length L, a straight line path is desired between two positions, (0 deg., 90 deg.), and (0 deg., 45 deg). Evaluate the minimum number of knots on the line that are necessary to make the actual trajectory deviate from the line by no more than $L/5$? Draw a sketch; explain why yours is the minimum number of knots.

A780-2. Draw the internal Voronoi diagram for a triangle with sides 3, 4, and 5. List the elements of the diagram; explain your construct.