B.Sc. Engg. / HD 6th Semester

29 October 2018

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
Department of Computer Science and Engineering (CSE)

SEMESTER FINAL EXAMINATION
SUMMER SEMESTER, 2017-2018

DURATION: 3 Hours
FULL MARKS: 150

CSE 4617: Artificial Intelligence

Programmable calculators are not allowed. Do not write anything on the question paper.

There are **8 (eight)** questions. Answer any **6 (six)** of them.

Figures in the right margin indicate marks.

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1. a) Suppose we must solve planning problems for cleaning a house. Various rooms can be dusted (making the room dust-free) or swept (making the room have a clean floor), but the robot can only sweep or dust a room if it is in that room. Sweeping causes a room to become dusty (i.e., not dust-free). The robot can only dust a room if the dustcloth is clean; but dusting rooms that are extra-dusty, like the garage, cause the dustcloth to become dirty. The robot can move directly from any room to any other room.
Assume there are only two rooms, the garage – which, if it is dusty, it is extra-dusty – and the living room – which is not extra-dusty.
Assume the following features:

- Lr dusty is true when the living room is dusty.
- Gar dusty is true when the garage is dusty.
- Lr dirty floor is true when the living room floor is dirty.
- Gar dirty floor is true when the garage floor is dirty.
- Dustcloth clean is true when the dust cloth is clean.
- Rob loc is the location of the robot.

- Suppose the robot can do one of the following actions at any time:
- move: move to the other room,
- dust lr: dust the living room (if the robot is in the living room and the living room is dusty),
- dust gar: dust the garage (if the robot is in the garage and the garage is dusty),
- sweep lr: sweep the living room floor (if the robot is in the living room), or
- sweep gar: sweep the garage floor (if the robot is in the garage).

Answer the following questions:

i. Give the STRIPS representation for dust gar. 3

ii. Suppose that the initial state is that the robot is in garage, both rooms are dusty but have clean floors and the goal is to have both rooms not dusty. Draw the first two level (with two actions, so the root has children and grandchildren) of a forward planner showing the actions (but you don't have to show the states) 6

iii. Draw the CSP for a planning horizon of 2. Describe each constraint (you don't need to give the table, but need to explicitly say what values are (in)consistent.) 9

b) Given the knowledge base (KB) containing the clauses: 3+4

$a \leftarrow b \land c.$
$b \leftarrow d.$
$b \leftarrow e.$
$c.$
$d \leftarrow h.$
$e.$
$f \leftarrow g \land b.$

Figure 1: Knowledge Base

Answer the following questions:

i. Show the bottom up proof for this KB.

ii. 'a' is a logical consequence of KB. Explain what this means. Give a top-down derivation for the query: ?a.

2. a) How would the implementation of a BFS and DFS differ if you were to extend the generic search algorithm to implement both. 4

b) Suppose you have a Bayesian network that has the following conditional probabilities after applying the chain rule and compensating for conditional independence [i.e. discarding information about other variables given parents] : P(A), P(B | A), P(C | B), P(D | A, C), P(E | B), P(F | E)

i. Draw the belief network that has these conditional probabilities. 5

ii. Suppose you want to compute P(D). What variables can be pruned? 2

iii. In the belief network, each variable is Boolean (that is, has domain {true, false}). A = true is written as a and A = false is written as ¬a, and similarly for the other variables. You have the following conditional probabilities: 8+6

P (a) = 0.8	P (d | a ∧ c) = 0.5	P (e | ¬b) = 0.4
P (b|a) = 0.8	P (d | a ∧ ¬c) = 0.6	P (f | e) = 0.3
P (b|¬a) = 0.8	P (d | ¬a ∧ c) = 0.7	P (f | ¬e) = 0.8
P (c | b) = 0.9	P (d | ¬a ∧ ¬c) = 0.2	
P (c | ¬b) = 0.3	P (e | b) = 0.9	

Table 1: Conditional probabilities

(a) Now, imagine you want to compute P(d) and are going to eliminate A first. What is the resulting factor after eliminating A? You need to show the variables that this is a factor on and you must show the first three elements of the factor numerically, but don't simplify them (e.g., you should write them as 0.1 ∗ 0.2 + 0.3 ∗ 0.4 + 0.5). Show the remaining factors that are created in computing P(d). For each variable eliminated you need to show what variable was eliminated, show which factors were removed to create the factor, and show the new factor (including which variables the new factor depends on). You do not need to give the numerical values of the factors created, just what variables they depend on.

3. a) In a nuclear research submarine, a sensor measures the temperature of the reactor core. An alarm is triggered (A = true) if the sensor reading is abnormally high (S = true), indicating an overheating of the core (C = true). The alarm and/or the sensor can be defective (A ok = false, S ok = false) which can cause them to malfunction. The alarm system can be modelled by the following belief network (all variables are Boolean): 6+6

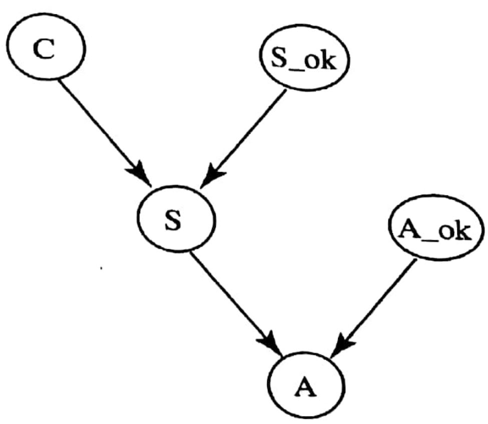

Figure 2: Corresponding belief network

Answer the following questions:

i. Suppose we add a second, identical sensor to the system and trigger the alarm when either of the sensors reads a high temperature. The two sensors break and fail independently. Give the extended belief network. (Draw the graph and specify any new conditional probabilities).

ii. When an alarm is observed, a decision is made whether to shut down the reactor. Shutting down the reactor has a cost cs associated with it (independent of whether the core was overheating), while not shutting down an overheated core incurs a cost cm much higher than cs. Draw the decision network modelling this decision problem for the original system (i.e., only one sensor). Specify any new tables that need to be defined (you should use the parameters cs and cm where appropriate in the tables). You can assume that the utility is the negative of cost.

b) Consider the following search problem: 4+9

- the set of states $S = \{s_0, s_1, s_2, s_3, s_4, s_5\}$
- successors of s_0 are $\{s_0, s_1, s_2\}$
- successors of s_1 are $\{s_1, s_2, s_3\}$
- successors of s_2 are $\{s_2, s_3\}$
- successors of s_3 are $\{s_0, s_3, s_4\}$
- successors of s_4 are $\{s_4, s_5\}$
- successors of s_5 are $\{s_2, s_3, s_5\}$
- objective function f is as follows: $f(s_0) = 0$, $f(s_1) = 3$, $f(s_2) = 2$, $f(s_3) = 4$, $f(s_4) = 1$, and $f(s_5) = 5$

Answer the following questions:

i. Which (if any) states are local maxima and global maxima?

ii. Trace hill climbing search starting in state s_0 (indicate which state is considered at each iteration, and which solution is returned when the search terminates). Does it return the optimal solution?

4. a) You have been hired by the organizers of the Tour de France to enforce anti-doping measures for all cyclists and teams. We have been instructed to suspend any team that has a member with a doping violation. A cyclist is considered to have a violation if he has tested positive for EPO or tested positive for synthetic testosterone. We consider a test result to be positive if both the first sample and second sample return positive. A cyclist will also receive a violation if they miss a test. 15

Write a short set of axioms to define the problem as described in the preceding paragraph. You can add any information in the KB that lets you test the predicates. You should only use the following predicates, where [x] tells you how many parameters the predicate requires:

- suspendTeam[1]
- hasMember[2]
- hasViolation[1]
- testPositive[2]
- firstPositive[2]
- secondPositive[2]
- missedTest[1]

b) Prove that Bottom-up proof procedure is sound. What is a minimal model? 8+2

5. a) Consider the case where the arc consistency algorithm terminates and some domains have multiple values. Is there guaranteed to be a solution? Defend your answer with an example. 6

b) Suppose that in a decision network, the decision variable Run has parents Look and See. Suppose that we are using variable elimination to find the optimal policy. Suppose that after eliminating all of the other variables, we have the factor 6+6

Look	See	Run	Utility
True	True	Yes	23
True	True	No	8
True	False	Yes	37
True	False	No	56
False	True	Yes	28
False	True	No	12
False	False	Yes	18
False	False	No	22

Table 2: Utility for various combinations of Look, See and Run

i. What is the resulting factor after eliminating the decision variable Run?
ii. What is the optimal decision function for Run?

c) Consider a scheduling problem, where there are eight variables A, B, C, D, E, F, G, H each with domain {1, 2, 3, 4}. Suppose the constraints are: $A > G$, $A \leq H$, $|F - B| = 1$, $G < H$, $|G - C| = 1$, $H - C$ is even, H != D, D > G, D != C, E !=C, E < D − 1, E !=H − 2, G !=F, H !=F, C != F, D !=F, $|E - F|$ is odd. 7
Draw the Arc-consistency network for this scenario.

6. a) Consider the grid world in the following figure:

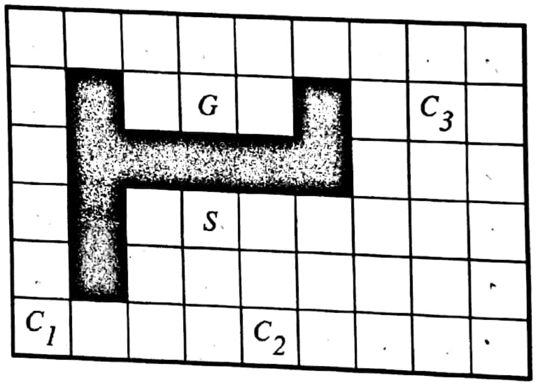

Figure 3: Grid World

Assume that a robot can be in any of the white squares, and can do one step up, down, left, or right at each time. It cannot step into one of the black squares or outside of the boundary. The cost of a path is the number of steps in the path. At the squares marked with C_i are coffee shops where, if the robot goes to the square, it will be given coffee. Suppose the robot starts at the square marked as S, without coffee, and must end up at the square marked G carrying coffee. Represent the grid world as a state-space search problem.

i. What is a state for this problem?
ii. How many states are there?
iii. What is the start state?
iv. Draw the first two levels of the search space. [Root is considered level-1] 2
v. Define two non-trivial admissible heuristics functions for this problem. Your first heuristic, h_1, should not take into account the locations of the coffee shops or the blocked squares. The second heuristic, h_2, should take into account the locations of the coffee shops, but not locations of the blocked squares. 2 2 5 4
Hint: a useful concept is the Manhattan distance between two points (x1, y1) and (x2, y2) which is $|x1 - x2| + |y1 - y2|$.

b) Give an overview of the simulated annealing search algorithm. With the help of the h(n) - h(n)' graph show how the probability of selecting a non-improving node changes. The graph should have separate curves for various temprature values. 10

a) Both A* and Branch and Bound (B&B) find the optimal solution. When would you use A* over B&B and when will you use B&B over A*? Give one example of each. 8

b) Consider the following Bayesian Network: 5

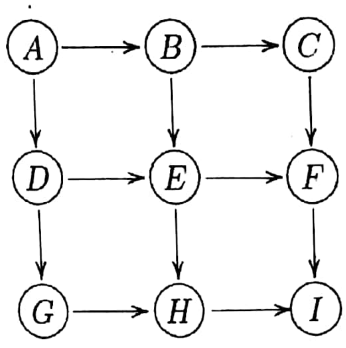

Figure 4: Bayesian Network

Which nodes could you prune before running variable elimination to compute P (A | D = t, E = t, F = t)? Explain why you can prune these nodes and no others.

c) Consider the following formula for P(Q): 12

$$P(Q) = \sum_{K,L,M,N,O} f_0(K) \times f_1(L) \times f_2(K,L,M) \times f_3(M,N) \times f_4(K,O) X f_5(L,N,O,Q)$$

i. Simplify this formula by summing out variable O, just as you would do in a single step of variable elimination. Explicitly state all the substeps you need to perform to sum out O. For each substep, state which operation you perform on which factors, and which variables the factor resulting from the operation is dened over. Give the simplied formula for P(Q) after summing out O.

ii. Now sum out K from the simplified formula that you acquired from the previous question. Do the same steps you did for summing out O.

8. a) Bill has noticed that his morning newspaper delivery has been sporadic. There are several relevant variables relating to whether or not the paper is delivered. Delivery is dependent on the paper having been successfully printed the previous night. Possible explanations for a paper not having been printed are a malfunction at the printing press, or the end of civilization as we know it. 15

The prior probability of a printer malfunction is 0.05. Bill has been noticing some ominous signs of the apocalypse and so expects the end of civilization with a relatively high probability of 0.001. If the end of civilization is here, then the paper not be printed for sure. If there is a printing malfunction and no end of civilization, there is a probability of 0.05 that the paper will be printed (this is non-zero because the malfunction might be fixed in time). If there is no malfunction and no end of civilization, there is a probability of 0.99 that the paper will be printed. If the paper is not printed it will not be delivered. If it is printed, there is a probability of 0.9 that it will be delivered. The fact that this probability is not 1 suggests that there are other possible causes for the paper not being delivered that we should eventually add to our belief network (e.g. the paperboy being sick).

Draw the belief network and build the the truth tables according to the probabilities above.

b) How to you evaluate Stochastic Local Search. Using 4-Queens problem as an example show how local search might not work and might need random walk or random restarts. 5+5