LE/EECS 4401/5326 3.0 Artificial Intelligence — Dept. of Electrical Eng. & Computer Sci.
GS/EECS 5326 3.0 Topics in Artificial Intelligence — York University — Winter 2020

Assignment 2

Total marks: 80

Out: March 22
Due: April 6 at 23:59

Note: Your report for this assignment should be the result of your own individual work. Take care to avoid plagiarism ("copying"). You may discuss the problems with other students, but do not take written notes during these discussions, and do not share your written solutions.

1. [20 points] Consider the following assertions:

   (i) *Canadians are typically not francophones.*

   (ii) *All Québecois are Canadians.*

   (iii) *Québecois are typically francophones.*

   (iv) *Robert is a Québecois.*

   In this case, it seems plausible to conclude by default that Robert is francophone.

   a) Represent these assertions in first-order logic using two abnormality predicates, one for Canadians and one for Québecois, and argue that as it stands, minimizing abnormality would *not* be sufficient to conclude that Robert is francophone.

   b) Show that minimizing abnormality will work if we add the assertion

   All Québecois are abnormal Canadians,

   but will not work if we only add

   Québecois are typically abnormal Canadians.

   c) Now represent this example in default logic. Represent assertions (i) to (iv) as two facts and two normal default rules, and show that the resulting default logic theory has two extensions. You may use a variable-free version of the problem where the letters q, c, and f stand for the propositions that Robert is a Québecois, Canadian, and francophone respectively, and where the defaults are considered only with respect to Robert.

   d) Modify your default logic theory in c) to ensure that there is only one extension by using a nonnormal default rule.

2. [20 points] Consider the following example:

   Aching elbows and aching hands may be the result of arthritis. Arthritis is also a possible cause of tennis elbow, which in turn may cause aching elbows. Dishpan hands may also cause aching hands.

   a) Represent these facts in a belief network. Let ar stand for "arthritis," ah for "aching hands," ae for "aching elbow," te for "tennis elbow," and dh for "dishpan hands."

   b) Give an example of an independence assumption that is implicit in this network.

   c) Write the formula for the full joint probability distribution over all five variables (given the network).

   d) Suppose that the following probabilities are given:

$$
\begin{aligned}
&\mathbf{Pr}(ah|ar, dh) = \mathbf{Pr}(ae|ar, te) = 0.1\\
&\mathbf{Pr}(ah|ar, \neg dh) = \mathbf{Pr}(ae|ar, \neg te) = 0.99\\
&\mathbf{Pr}(ah|\neg ar, dh) = \mathbf{Pr}(ae|\neg ar, te) = 0.99\\
&\mathbf{Pr}(ah|\neg ar, \neg dh) = \mathbf{Pr}(ae|\neg ar, \neg te) = 0.00001\\
&\mathbf{Pr}(te|ar) = 0.0001\\
&\mathbf{Pr}(te|\neg ar) = 0.01\\
&\mathbf{Pr}(ar) = 0.001\\
&\mathbf{Pr}(dh) = 0.01
\end{aligned}
$$

   Assume that we are interested in determining whether it is more likely that a patient has arthritis, tennis elbow, or dishpan hands.

   (a) With no observations at all, which of the three is most likely a priori?

   (b) If we observe that the patient has aching elbows, which is now most likely?

   (c) If we observe that the patient has both aching hands and elbows, which is the most likely?

   (d) How would your rankings change if there were no causal connection between tennis elbow and arthritis, where, for example, $\mathbf{Pr}(te|ar) = \mathbf{Pr}(te|\neg ar) = 0.00999$ (instead of the two values given earlier).

   Show the calculations justifying your answers.

3. [20 points] Imagine that we have a collection of blocks on a table and a robot arm capable of picking up blocks and putting them elsewhere, as shown in Figure 1.

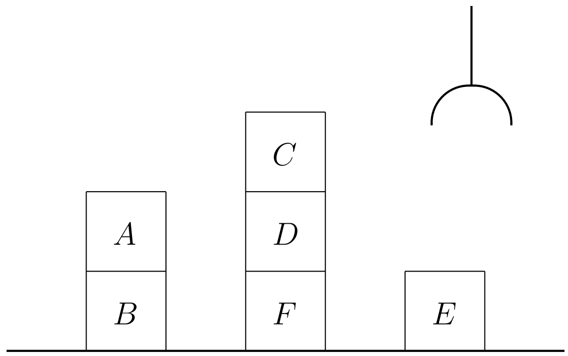

Figure 1: The Blocks World

We assume that the robot arm can hold at most one block at a time. We also assume that the robot can only pick up a block if there is no other block on top of it. Finally, we assume that a block can only support or be supported by at most one other block, but that the table surface is large enough that all blocks can be directly on the table. There are only two actions available: $puton(x, y)$, which picks up block x and moves it onto block y, and $putonTable(x)$, which moves block x onto the table. Similarly, we have only two fluents: $On(x, y)$, which holds when block x is (directly) on block y, and $OnTable(x)$, which holds when block x is (directly) on the table.

a) Write the precondition axioms for the actions in the situation calculus.

b) Write the effect axioms for the actions in the situation calculus.

c) Show how successor state axioms for the fluents would be derived from these effect axioms.

d) Argue that the successor state axioms are not logically entailed by the effect axioms by briefly describing an interpretation where the effect axioms are satisfied but the successor state axioms are not.

e) Show how frame axioms are logically entailed by the successor state axioms.

4. [20 points] This question is a follow up from the previous one. We consider a planning problem involving an initial situation and a goal in the Blocks world. Suppose that in the initial situation, the blocks are arranged as in Figure 1 and that the goal is to get them arranged as in Figure 2.

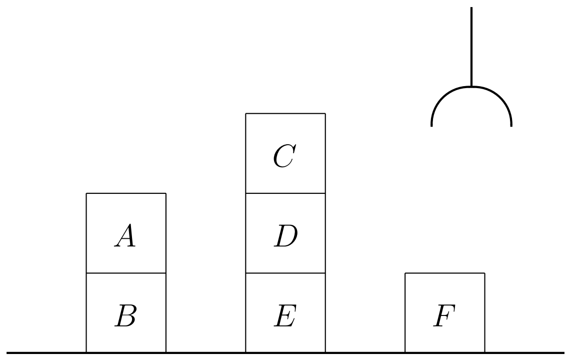

Figure 2: The Blocks World Goal

a) Write a sentence in the situation calculus of the form $\exists s.\alpha$ that asserts the existence of the final goal situation.

b) Write a situation term e (that is, a term that is either S_0 or of the form $do(a, e')$ where a is a ground action term and e' is itself a ground situation term) such that e denotes the desired goal situation.

c) Suppose that we wantt to fomalize the problem using a STRIPS representation. Decide what the operators should be and then write the precondition, add list, and delete list for each operator. You may change the language as necessary.

d) Consider the database corresponding to the initial state of the problem. For each STRIPS operator and each binding of its variables such that the precondition is satisfied, state what the database progressed through this operator would be.