CSE 3521

Homework 2 - Logical Agents

Due 9/27 at 10:55am

Learning Goals What I want to evaluate with this assignment is:

- Understanding of logic-based agents and the considerations that go into designing a knowledge-based agent for real-world problems
- Ability to apply the logical inference methods learned in class to new examples
- Ability to formulate real statements and constraints as logical sentences

Submission Instructions You can either bring answers on paper to class on 9/27 or submit electronic answers to these questions (in PDF form) via Carmen.

1. Describe at least 2 differences between the search agents from the first part of the course and the knowledge-based logic agents we've been learning about. (1-2 sentences)

2. A propositional knowledge base is shown below (on the left), along with its equivalent in Conjunctive Normal Form, or CNF (on the right).

$$\begin{aligned} A \wedge C &\Rightarrow G \\ B & \\ \neg F &\Rightarrow \neg B \\ \neg B \vee D & \\ D &\Rightarrow (\neg F \vee C) \\ \neg A \vee E &\Rightarrow \neg F \end{aligned} \quad \equiv \quad \begin{aligned} &\neg A \vee \neg C \vee G \\ &B \\ &F \vee \neg B \\ &\neg B \vee D \\ &\neg D \vee \neg F \vee C \\ &\neg F \vee A \\ &\neg E \vee \neg F \end{aligned}$$

   The process of *resolution* that we discussed in class can be distilled into a single rule when using a KB in Conjunctive Normal Form: if clauses $\ell_1 \vee \cdots \vee \ell_k$ and $m_1 \vee \cdots \vee m_n$ contain complementary literals (e.g., B and $\neg B$), then we can add a new sentence to the KB that is the disjunction of ℓ and m without the complementary literals.

   For example, given clauses $\neg A \vee B$ and $\neg C \vee A$, we can cancel out the A and $\neg A$ to add the sentence $\neg C \vee B$ to the KB. (Note that if a literal shows up twice, you can just ignore the second occurrence: e.g., $\neg C \vee \neg C \vee B$ is equivalent to $\neg C \vee B$.)

   Using this rule for resolution and the CNF knowledge base given on the right above, prove that G is entailed. Show your work.

3. For this question, use the knowledge base given in implicative Horn clause format below:

$$
\begin{aligned}
T &\Rightarrow R \\
P \wedge Q &\Rightarrow R \\
S \wedge A \wedge C &\Rightarrow P \\
A &\Rightarrow B \\
D \wedge F &\Rightarrow C \\
B \wedge D &\Rightarrow T \\
A \wedge D \wedge T &\Rightarrow E \\
E \wedge B &\Rightarrow S \\
F &\Rightarrow Q \\
A & \\
D &
\end{aligned}
$$

   (a) Apply forward chaining to this KB. What atomic symbols are **not** entailed by this knowledge base? Show your work.

   (b) What atomic statement(s) could be added to the KB so that it entails every atomic symbol it can? Justify your answer.

4. For this question, use the new KB given in implicative Horn clause format below:

$$
\begin{aligned}
P &\Rightarrow Q \\
B &\Rightarrow C \\
O &\Rightarrow N \\
Q \wedge D \wedge M &\Rightarrow J \\
D \wedge F \wedge A &\Rightarrow P \\
A \wedge C &\Rightarrow F \\
P \wedge L &\Rightarrow M \\
L \wedge C &\Rightarrow D \\
F \wedge B &\Rightarrow L \\
M \wedge N &\Rightarrow X \\
A & \\
B &
\end{aligned}
$$

   Use backward chaining to attempt to prove each of the following atomic statements: Q, X, and J. (Show your work.) If a statement is not entailed, explain why not (i.e., what information is missing that breaks the chain of inference?)

5. Rewrite the following English sentences as first-order logic sentences. Keep the following things in mind:

   - Remember that FOL uses *objects* (which can have *variables* stand in for them); these have no properties in and of themselves, but are just concrete things in the world.
   - You can use whatever *relations* and *functions* you need, but try to make them simple.
   - Please write variables in lower case and relation/function names in CamelCase.
   - Note that one English sentence may correspond to multiple FOL sentences!

   (a) At least one rabbit is deadly.

   (b) African swallows can carry coconuts; European swallows cannot.

   (c) There is a king who will not repress you if you are a peasant.

   (d) If any parrot is dead and its feet have been nailed to its perch, then it wouldn't voom if you put 4,000 volts through it.
   (Hint: you may need a nested implication for this!)

6. You have been tasked with designing knowledge-based expert agents for two robots. For each robot's task, describe

   - What kinds of objects in the world the robot will need to be aware of
   - How these objects can be organized into an ontology (a short description or sketch of a taxonomic tree will suffice)
   - What kinds of events in the world the robot needs to model to achieve its goals

   (a) **Street crossing guard**

   Goal: Get all pedestrians across the street safely, without them getting hit by vehicles (but without stopping traffic entirely).

   Sensors: The robot is aware of objects at either end of the crosswalk and objects that are about to enter the intersection from any direction.

   (b) **Warehouse fetching**

   Goal: Given an Amazon order assigned by a dispatcher, fetch all items in the order as quickly as possible and return to the dispatcher for the next order. Also, the robot should notify dispatch if an item runs out. This is a multi-agent warehouse; there are other robots around. (However, you don't have to say anything about the dispatcher.)

   Sensors: The robot is aware of its current position, the items currently in its basket, the item currently in front of it, and any other robots nearby. It also has a map of the warehouse in its head, so it knows where every item is.