

## Homework #3: Chapters 9 and 10

The following exercises are due at the beginning of class on Wednesday, March 23.

You must use SWI-Prolog to answer part (a) of exercise 4. SWI-Prolog is free software and can be downloaded from <http://www.swi-prolog.org/>. Both Linux and Windows versions are available. Get the most recent stable version and install it in your Lehigh home directory or on a personal computer. In either case, you will need approximately 5 megabytes of free disk space to install the software.

1. [12 points, 3 points each] For each pair of atomic sentences, give the most general unifier if it exists. Assume that  $x$ ,  $y$ , and  $z$  are variables, while other symbols are either predicates, constants, or functions as required by their use in the sentences.
  - a)  $P(A,B,B)$ ,  $P(x,y,z)$
  - b)  $Q(y,G(A,B))$ ,  $Q(G(x,x),y)$
  - c)  $\text{Older}(\text{Father}(y),y)$ ,  $\text{Older}(\text{Father}(x),\text{John})$ .
  - d)  $\text{Knows}(\text{Father}(y),y)$ ,  $\text{Knows}(x,x)$ .
  
2. [38 points total] Consider the first-order logic sentences defined below.

$\forall x,y P(x,y) \wedge Q(y,x) \Rightarrow R(x,y)$   
 $\forall x,y S(x,\text{Bob}) \wedge S(y,x) \Rightarrow P(x,y)$   
 $\forall x,y S(x,y) \Rightarrow Q(y,x)$   
 $\forall x,y T(x,y,x) \Rightarrow Q(x,y)$   
 $\forall x,y T(x,x,y) \Rightarrow Q(x,y)$   
 $T(\text{Alice},\text{Dawn},\text{Alice})$   
 $T(\text{Bob},\text{Bob},\text{Carl})$   
 $T(\text{Alice},\text{Bob},\text{Dawn})$   
 $T(\text{Carl},\text{Alice},\text{Carl})$   
 $S(\text{Bob},\text{Alice})$   
 $S(\text{Dawn},\text{Bob})$   
 $S(\text{Dawn},\text{Carl})$   
 $S(\text{Carl},\text{Dawn})$   
 $S(\text{Alice},\text{Dawn})$   
 $S(\text{Carl},\text{Eve})$

Use backward chaining to find **ALL** answers for the following queries. When matching rules, proceed from top to bottom, and evaluate subgoals from left to right. You must show your search tree using the same form I did in class (that is, each node should contain a list of subgoals remaining to be proven, and each child is a subsequent recursive call). Note, the form of the proof tree shown in Fig. 9.7 of the book (p. 288) is unacceptable, because it does not show when backtracking occurs.

- a) [14 points]  $\exists x Q(x,\text{Carl})$
- b) [24 points]  $\exists x,y R(x,y)$ .

(continued on reverse)

3. [15 points, 3 points each] Translate the following first-order logic sentences into Prolog. Note, some sentences may require more than one Prolog statement.

- a)  $\text{SubOrg}(\text{CSE}, \text{Lehigh})$
- b)  $\forall x, y \text{ HeadOf}(x, y) \wedge \text{Department}(y) \Rightarrow \text{Chair}(x, y)$
- c)  $\forall x, y, z \text{ Member}(x, y) \wedge \text{SubOrg}(y, z) \Rightarrow \text{Member}(x, z)$
- d)  $\forall x \text{ Faculty}(x) \vee \text{Staff}(x) \Rightarrow \text{Employee}(x)$
- e)  $\forall x \text{ Dean}(x) \Rightarrow \text{Faculty}(x) \wedge \text{Administrator}(x)$

4. [35 points total] Consider the following knowledge about animals. All Animals breathe oxygen. There are three types of Animal: Bird, Fish and Mammal. Birds are covered in feathers, have two legs, and move by flying. There are two kinds of Birds: Robins and Hawks. Robins eat worms and Hawks eat rodents. Fish are covered in scales and move by swimming. Mammals are covered in fur and move by walking. There are three kinds of Mammals: Apes, Cows, and Lions. Apes have two legs. Cows have four legs and eat grass. Lions have four legs and eat meat. Nemo is a Fish, Lee is a Hawk, Rob is a Robin, Kong is an Ape, Elsa is a Lion, and Bessie is a Cow.

- a) [20 points] Create a Prolog program to reason with the knowledge provided above. Only include facts and rules that correspond to the information given here, do not encode any additional knowledge of animals that you may have. Hint: The Prolog program will be easier to write if you use unary predicates to represent categories.

Test your Prolog program by asking it the following questions (of course, you will have to phrase each question as one or more Prolog goals):

- Is Nemo covered in scales?
- How many legs does Elsa have?
- How does Bessie move?
- Does Lee breathe oxygen?
- Do Bessie and Elsa eat the same thing?
- Do Kong and Rob have the same number of legs?
- Who are all of the individual mammals? (not what are the kinds of mammals)

Attach a printout of the program (you do not need to submit it electronically) to your submission. Also, include a printout that shows your queries and the program's responses (you may simply copy this from SWI-Prolog's main window and paste it into a file for printing).

- b) [15 points] Draw a semantic network that represents the same knowledge. See Figure 10.9 on page 351 of the book for an example.